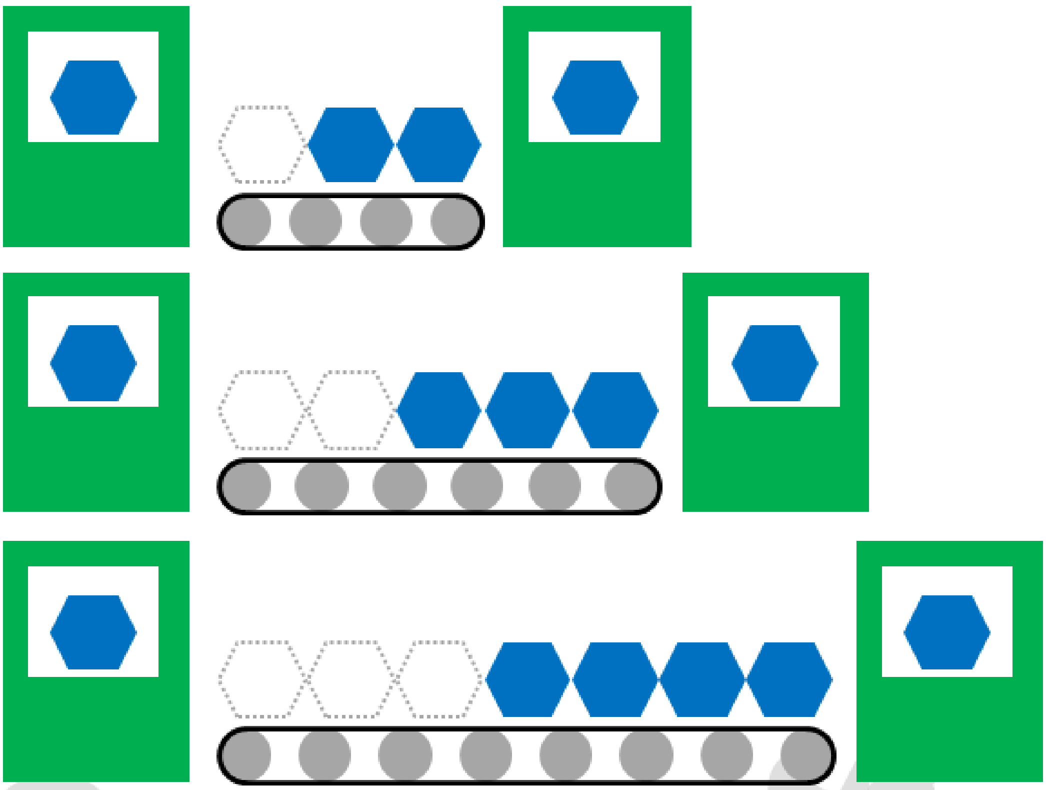
# Collected Blog Posts of AllAboutLean.com

# 2014

Christoph Roser



# Collected Blog Posts of AllAboutLean.com 2014

**Christoph Roser**

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## Other Books by Christoph Roser

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

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

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

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

**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

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

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

**Collected Blog Posts of AllAboutLean.com 2019**, AllAboutLean Publishing, 2020. ISBN 978-3-96382-025-0

## Preface to the 2013–2019 Collection of Blog Posts

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

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

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

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

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

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

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

# Table of Content

# 1 Japanese Standard Pointing and Calling (Video)

*Christoph Roser, January 05, 2014 Original at*
*https://www.allaboutlean.com/vsm-start-at-customer/*

*Figure 1: I see you! (Image Roser)*

During my last trip to Japan, I finally took **videos capturing the Japanese Pointing-and-Calling** standard. Pointing and calling is a safety standard that started with Japanese train operators but now is widely used in industry. The idea is that whenever you confirm something, you not only look at it, but also point at it and call out your observation.

## 1.1 The Technique


*Figure 2: Locations of Pointing and Calling in Video (Image Roser)*

Pointing and calling **combines looking at something, pointing at it, calling out the observation, and listening to your own voice**. For example, when a speed limit starts in 500 meters, the train driver points at the sign and says, "*Limit 75 Distance 500.*" When leaving the station, the driver points at the timetable and says, *"Three o' clock 12 minutes 15 seconds depart Shibuya station.*" The conductor points at the doors after closing and states, "*Good Closure,*" then points at the monitors and states, "*Good monitors for departure.*" There are dozens of examples of places where this technique is used. The following video shows a few of them, with different train operators using the pointing-and-calling standard, plus one employee at Toyota headquarters using this standard while crossing the road.

## 1.2 Video of Examples of Pointing and Calling in Japan

*The Video by AllAboutLean.com is available on YouTube as "Pointing and Calling Japanese Safety Standard at Railway Companies & Toyota (HD)" at https://youtu.be/9W6tHOmWyLQ*

In Japanese, these techniques are known by different terms; for example, *Shisa kanko (指差喚呼); Shisa kakunin kanko (指差確認喚呼); Yubisashi koshō (指差呼称); and Shisa koshō (指差呼称).* In English also sometimes called the "*yosh check*", after the Japanese sound (not a proper word) "*yoshi*" which means something like "all right".

## 1.3 The Value of Pointing and Calling

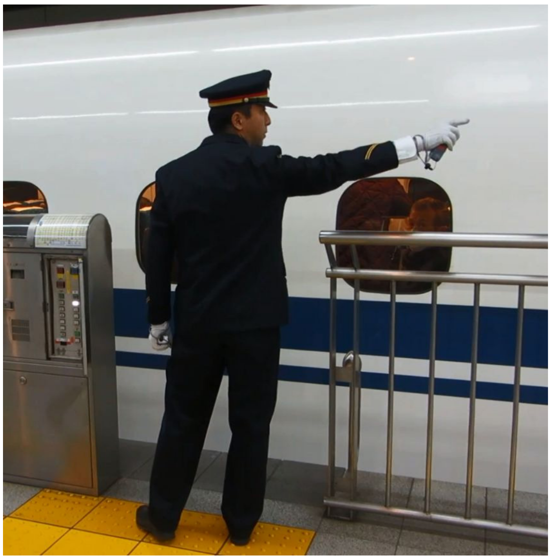

*Figure 3: I see you, too! (Image Roser)*

Pointing and Calling gives **co-action and co-reaction among the operator's brain, eyes, hands, mouth, and ears**. Not only looking but also pointing and sometimes stating the observation avoids sloppiness and helps keep focus and attention. For simple tasks (and most of these tasks are reasonably simple), this technique **reduces errors by almost 85%**. Some companies use only pointing, or only calling, but the technique is most effective when combined.

Additionally, pointing and calling allows for **easy process confirmation**. A supervisor observing the employee can easily verify that the signal has been seen and that the timetable has been checked. Hence, it is much easier to train operators and correct mistakes.

Furthermore, this technique **reduced accidents at Japanese railway companies by 30%**, helping them make train travel in Japan the most reliable and safest train travel in the world (although not necessarily the cheapest).

## 1.4 Examples for Point and Call

*Figure 4: I also see you! (Image Roser)*

With Japanese railroads, anything that has to be looked at is usually confirmed using point and call. First and foremost, this is for **observing railroad signals** that indicate whether the train is allowed to proceed, whether there are speed restrictions, or whether the train needs to stop.

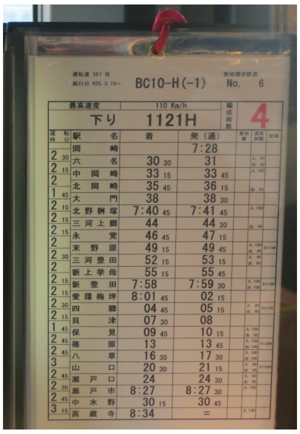


*Figure 5: Every second counts! (Image Roser)*

The technique is also used to **verify the timetable**. At every stop, the driver points to the corresponding line in the timetable to verify the target arrival and departure times. Naturally, the **look at the watch** also includes pointing at the watch. (By the way, in Japan the internal timetables are by the second!) Furthermore, Japanese train operators are not allowed to carry mobile phones, since texting while driving a train is as dangerous as with texting while driving a car.

When the train stops, the **speed is verified** by pointing at the speedometer. Platform attendants and conductors also **point along the platform to check if the train is clear**, often also pointing at additional surveillance monitors for this purpose.

## 1.5 Usage Outside Japanese Railway Companies

*Figure 6: And I also see you, too! (Image Roser)*

The technique started with Japanese railway companies around 1900, and it is now widespread throughout Japan. Over the years, I have observed dozens of operators of many different railway companies in many different locations. Every time, it has been a beauty to watch this magnificent standard in action.

The standard has also spread outside Japanese railway companies. The Japanese Industrial Safety and Health Association has included this pointing-and-calling standard in its trainings since around 1980, helping the spread of this method.

For example, some companies require their employees to look and point when **crossing the road**. In my observation, however, there is less diligence here. Only about 5% of the people I observed at Toyota Headquarters followed this standard. Some bus companies in Japan have also introduced this standard.

This standard is also often **used in industry for visual confirmation**. I have also seen this during the **quality check of printed products**. The operator points with his finger at every spot he is supposed to check (unfortunately, I was not taking a video of this at the time). Electricians point at the wires they work on and call "*Beware of electric shock. Okay!"* This standard is also used for inspection of the workplace before maintenance, pointing and calling, "*Motor stop. Okay!*" When opening or closing valves, the operator points and calls, "G*ood valve closed*" or "G*ood valve open.*" There are many more examples in industry, albeit not all companies use this technique. Some construction companies have also adapted this approach.

The technique is also used in the New York subway system, albeit to a much lesser extent, and on some trains in Korea and Taiwan, and by construction companies in Hong Kong. Other than that, there are very few instances where this standard is used in the rest of the world.

## 1.6 Acceptance Problems

*Figure 7: You want me to point where?!?! (Image Gabrie under the CC-BY-SA 3.0 license)*

There is one problem with this standard: many people are reluctant to do this. Pointing, or even pointing and calling, may look strange to outsiders. I believe if you ask the average Western employee to point his finger at a sign every time, **you may get a completely different finger in your direction** (even if only in the operators mind).

Initially, Japanese employees were also reluctant to use this technique, and it took some effort to get over this feeling of embarrassment. Nowadays, however, it is part of everyday life.

## 1.7 Editorial Notes

All operators and employees observed were asked for permission beforehand. There was no difference visible in their use of the standard before and after I indicated my desire to videotape them. The video above is provided via YouTube.

**PS**: Fellow author and blogger James Albright also covered this topic from a pilots point of view.

# 2 Consistency at Toyota – The Board of Directors of the Toyota Motor Company

*Christoph Roser, January 12, 2014 Original at*
[https://www.allaboutlean.com/consistency-at-toyota/](https://www.allaboutlean.com/consistency-at-toyota/)

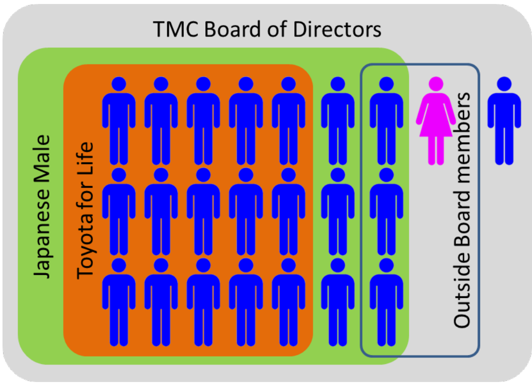


*Figure 8: TMC Board members 2014 (Image Roser)*

The Toyota Motor Company (TMC) is one of the most well-managed firms in the world. Among multinational corporations, it is probably the most famous one. Since its founding in 1937, TMC has continuously improved. The question is, how did Toyota do that? What does Toyota do differently from other companies, who stumble from one problem into the next? I believe the corporate culture and style start with the behavior at the top. Hence, in this post I will look at the board of directors of TMC in more detail.

## 2.1 The Highly Uniform Toyota Men's Club

The Toyota Board of Directors (as of 2013) includes 23 individuals. Looking at their biographies in more detail shows a high degree of uniformity.

### 2.1.1 Nationality and Gender

Unsurprisingly, all but one of the members of the board are Japanese. The only exception is Mark T. Hogan, a former director and vice president of General Motors. Hence, the board is 96% Japanese. Similarly, all but one are male. The only female is Yoko Wake, a professor at the prestigious Keio University who also serves as one of the three outside members of the board. Again, this makes the board 96% male, and the lone woman is merely an *outside member*. I believe the lack of females on the board may be a weakness, as is the lack of international members. However, I did a very similar analysis ten years ago, when there was no woman and no foreigner at all; hence, overall it is an improvement, albeit a rather slow one.

### 2.1.2 Typical Resume of a Board Member

The typical resume of a Toyota board member goes like this: graduated from university, joined Toyota the month after graduation at age 24, stayed with Toyota forever. Excluding the outside members, 15 of the 19 board members joined Toyota directly after graduation at an average age of 24 and then stayed at Toyota for 38 years. Their average age is 62 years.

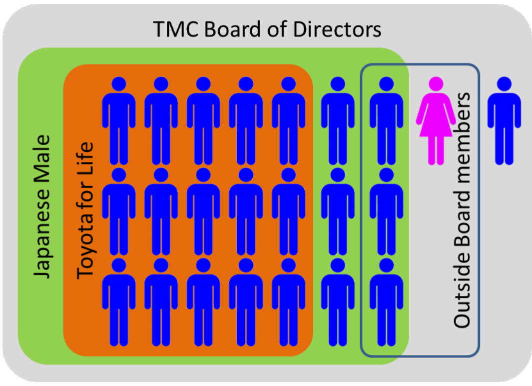


*Figure 9: TMC Board members 2014 (Image Roser)*

There are only four exceptions: Nobuyori Kodaira and Haruhiko Kato, who were both previous high-ranking government officials in the Ministry of Trade and Industry (MITI) and the Ministry of Finance respectively. Of the remaining two, Ikuo Uno was formerly president and chairman of the Nippon Life Insurance Company, and Mark T. Hogan was at GM as mentioned above. It is curious to see that there is only one industry insider, Mark T. Hogan, whereas everybody else who joined from outside is from the government or an insurance company. It probably is good to have political connections in Japan too. But I find it more amazing that almost 80% of the board of directors know only Toyota, but then know Toyota very well.

## 2.2 Benefit for Toyota

### 2.2.1 Toyota Managers Training

The typical rise through the ranks at Toyota starts with six months of working on the assembly line – regardless whether you are an an engineer, business manager, physicist, or anything else. Everybody gets to know the basics. From then onward, the typical Toyota manager is put on a journey through all areas of the company, from purchasing to sales, from manufacturing to human resources. This journey also encompasses other companies of the Toyota group. In the end, the manager knows all aspects of the business. I believe this allows Toyota managers to make better decisions when compared to Western managers, whose resumes jump between completely different industries and who often lack knowledge about the undesired side effects and consequences of their decisions.

### 2.2.2 "Toyotaness" of the Toyota Managers

The average board member is with Toyota for 38 years. Such a long tenure is nowadays rare in the Western world, especially among high-ranking managers. I believe the adherence and identification with the company benefits from such a long experience at the company. In the West, I get the feeling that for some managers it is "*just another job,*" whereas at Toyota the company is everything. Not only do they know more about the undesired consequences of decisions, but they also care more about their company.

## 2.3 Historic Developments

I did a similar analysis to this ten years ago. Back then, all but one were home-bred Toyota insiders. Only one joined the board from a high-ranking government position. Of course, all were Japanese males. With currently four members coming from outside of Toyota, there is a very slow trend toward outside members, albeit with such a small number this may also be coincidence. The non-Japanese aspect, however, is almost certainly not a coincidence. A foreigner doesn't just pop up on the board by accident. Hence this must be by design, probably following a lengthy internal discussion process.

## 2.4 Recommendations

I think it is highly beneficial for Toyota to have board members with such an extreme experience working at Toyota. Continuing this would probably help Toyota (albeit some recent changes create another risk, see Internal Threat to the Toyota Production System Due to New Hiring Practices).

However, Toyota could also benefit from more non-Japanese or female members to give different perspective.

## 2.5 Sources

The main source for this data was the Toyota Annual Report 2012. The members are listed below, with some notable information highlighted.

Top Members

- Chairman Takeshi Uchiyamada, born 1946, joined Toyota in 1969
- President Akio Toyoda, born 1956, joined Toyota in 1984, from the founding family

Executive Vice Presidents, members of the board

- Satoshi Ozawa, born 1945, joined Toyota in 1974
- Mitsuhisa Kato, born 1953, joined Toyota in 1975
- Yasumori Ihara, born 1951, joined Toyota in 1975
- Nobuyori Kodaira, born 1949, joined Toyota in **2008** – working for MITI beforehand
- Masamoto Maekawa, born 1949, joined Toyota in 1973
- Seiichi Sudo, born 1951, joined Toyota in 1974

Directors

- Mamoru Furuhashi, born 1950, joined Toyota in 1973
- Koei Saga, born 1951, joined Toyota in 1977
- Yoshimasa Ishii, born 1953, joined Toyota in 1976
- Haruhiko Kato, born 1952, joined Toyota in **2011**, working for Ministry of Finance beforehand
- Kiyotaka Ise, born 1955, joined Toyota in 1980
- Shigeki Terashi, born 1955, joined Toyota in 1980
- Ikuo Uno, born 1935, joined Toyota in **2013**, working for Nippon Life Insurance before, oldest board member
- **Mark T. Hogan**, born 1953, joined Toyota in **2010**, working for GM beforehand

Audit and Supervisory Board Members

- Yoichiro Ichimaru, born 1948, joined Toyota in 1971
- Masahiro Kato, born 1952, joined Toyota in 1975
- Masaki Nakatsugawa, born 1955, joined Toyota in 1976

Outside Audit & Supervisory Board Member

- Akishige Okada, joined Toyota board in 2006, Sumitomo Mitsui Bank Executive
- Yoko Wake, joined Toyota board in 2011, **only female**, Professor at Keio University
- Yoichi Morishita, joined Toyota board in 2006, from Panasonic Kunihiro Matsuo, joined Toyota board in 2007, Attorney General

# 3 Lean is Zero Defects? – I don't think so!

*Christoph Roser, January 19, 2014 Original at* *https://www.allaboutlean.com/zero-defects/*


*Figure 10: Zero Defects? (Image Roser)*

If you work in manufacturing, sooner or later you will find someone who claims that lean manufacturing is all about *Zero Defects*. Or *Zero Inventory*. Or *Zero Lead Time*. Or *Zero Whatever*. **This is bollocks! Zero Defects was a management fad from the 1960s** that pops up regularly every now and then again. In this post we will look at what *Zeros* there really are in lean manufacturing – if any.

In my view, most of the *Zero Whatever* claims stem from the uncertainty and insecurity of the people issuing them. If they are unsure about what they are doing, then it gives them false security to claim things that cannot be achieved. Hence, they are setting themselves up to fail. For some reason, some people work more relaxed if they know that that it will fail anyway. Rather than working on improvement, they can already plan an exit strategy if things won't work out. They can look for reasons why it failed – which, of course, never has anything to do with them but only with others. In these cases, lean manufacturing is more of a religion than the common-sense manufacturing approach it should be.

## 3.1 Zero Defects

**Zero Defects** is probably the most common claim associated with the Toyota production system. The goal – supposedly – is to have no failures or defects of any kind, ever. Skeptics sometimes ask me, "*If Toyota is Zero Defects, then why did all the* problems with the brakes *happen in 2011?*"

Well, first of all, in most cases the problem was not with the car, but between the steering wheel and the driver's seat. In most if not all cases, the driver simply mixed up the pedals, resulting in what the National Highway Traffic Safety Administration called "*pedal misapplication.*" Additionally, the US government probably wanted to boost its own US car industry by putting a damper on foreign imports – regardless of how Toyota cars sold in the US actually have a higher domestic content than many traditional US car makers. Hence, they leaned on Toyota much more harshly than they did, for example, during the Firestone and Ford tire controversy.

But let's get back to *Zero Defects*. This is actually a misquote. The full quote is in reality **Zero Defects Accepted!** The idea is that no defect that is found should be passed on to the next station in the progress. This means not only to pass no defect knowingly to the consumer, but to pass no defect knowingly to anybody downstream. In a Toyota assembly line, the entire line is stopped rather than a detected problem being passed on to the next person in line. Contrast this with most Western car manufacturers, where a special group often exists at the end of the line to fix all the problems and the detected defects are simply handed down since they are somebody else's responsibility.

Overall, this **Zero Defects Accepted** approach at Toyota has improved their quality much more than any **Zero Defect** approach anywhere else. W. Edwards Deming – the guy that actually taught Toyota how to improve quality –made a very clear statement about this. Point 10 of his 14 key principles states to *Eliminate slogans, exhortations, and targets for the work force asking for* **zero defects** *and new levels of productivity*.

Deming even takes it one step further. For him there are acceptable defects. Depending on the product you make, the type of defect, and the impact of the defect, it may be more cost effective to accept the defect. While major problems must be corrected, there may be minor defects that the customer is willing to accept rather than pay more for a non-defective product.

In sum, **Zero Defects** is bollocks. At best, you may have **Zero Defects Accepted**. Or, after careful consideration of the defects, you may even **accept some defects**.

## 3.2 Zero Inventory

The next big misunderstanding is **Zero Inventory**. Sometimes Toyota is even called the **Zero Inventory Company**. Clearly, Zero Inventory is impossible. Inventory also serves as an often-necessary buffer against fluctuations in demand or supply. Taiichi Ohno, the brain behind the Toyota Production System, clearly stated that *Reducing inventories to zero is nonsense* and *In no way is the Toyota production system a zero-inventory system* (Ohno, Taiichi, and Setsuo Mito. *Just-In-Time for Today and Tomorrow*. Productivity Press, 1988).

While it is true that Toyota aims to reduce inventory, they do understand its need and its function in manufacturing. In many Western companies, there is the drive to reduce inventory, regardless of what the manufacturing system allows or needs, resulting in even more waste through chaos on the shop floor. Toyota did indeed drastically reduce its inventory, but in some cases it may intentionally raise inventory to cover for demand and supply fluctuations and to allow a smoother production. It is also a well-known secret among lean experts that sometimes you need to raise inventory to stabilize the production system before you can address the issues that allow you to reduce inventory again.

## 3.3 Zero Set-Up Time

Yet another of those wannabe Zeros is **Zero Set-up Time**. The idea is that you should reduce all your set-up times to zero. Yet again, it is a question of the cost of the reduction compared to the benefit. In general, Toyota accepts about 5% to 10% of the time as set-up time, with the goal to reduce lot sizes. This brings us next to Zero Lot Size.

## 3.4 Zero Lot Size

Even the creators of **Zero Lot Size** have figured out that a lot size of zero makes no sense whatsoever, and they usually talk about a **Zero Excess Lot Size**. The idea of reducing lot size is basically sound, but as with everything, it has to be seen in perspective with other aspects of the production system. Just setting Zero Lot Size as a target on its own is highly risky.

## 3.5 Other Zeros

There are a whole bunch of other Zeros floating around in literature.

- Zero Price
- Zero Cost
- Zero Lead Time
- Zero Downtime or Zero Breakdowns
- Zero Handling Time
- Zero Surging (Changes in Quantity or Mix)

All of them are pretty much impossible to achieve (except maybe Zero Price, but that would be difficult to sustain). While it would be nice to have any of them, you can't focus on all of them at the same time. Often these Zero goals are conflicting. In most cases, it may be more economical to set a goal other than zero, which would lead to a better overall and long-term profitability for your industry. Where this goal is depends heavily on your business. This ideal point is also changing over time. Finding these sweet spots and setting correct targets are difficult management tasks, but please, **do not set targets to zero**. **The ultimate consequence of zero inventory is zero output.** Since you surely don't want zero output, you should not want zero inventory. Now go out and improve your industry!

# 4 Evolution of Toyota Assembly Line Layout – A Visit to the Motomachi Plant

*Christoph Roser, January 26, 2014 Original at [https://www.allaboutlean.com/toyota-line-layout/](https://www.allaboutlean.com/toyota-line-layout/)*

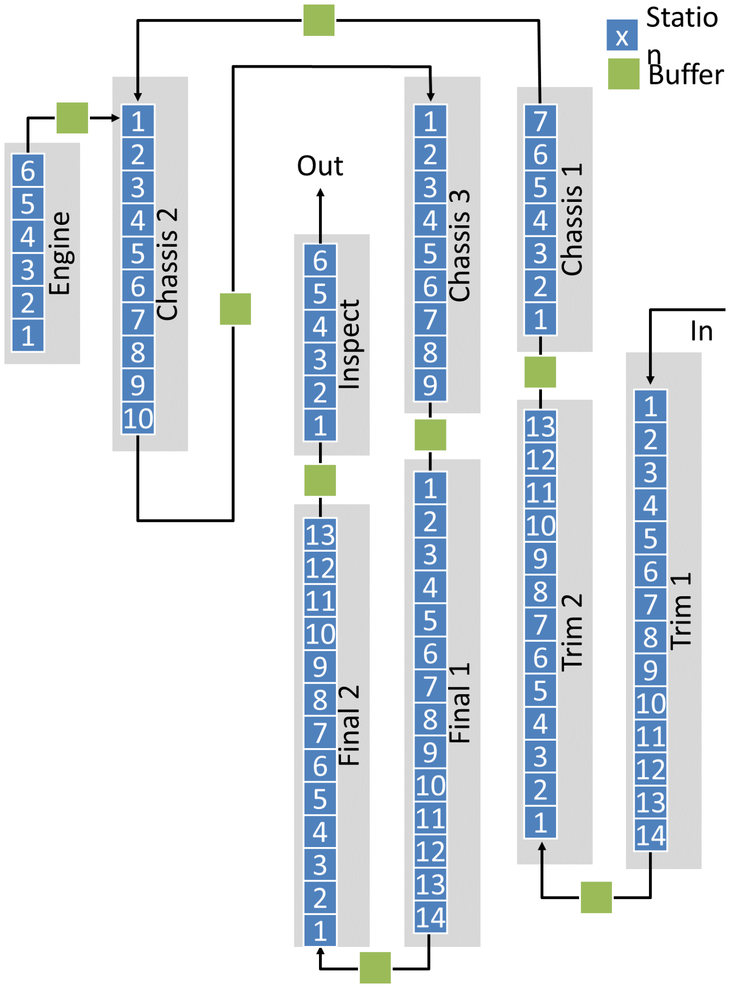


*Figure 11: Current Layout of Toyota Motomachi Plant 2014 (Image Roser)*

Toyota is a company that is constantly evolving, aiming to reduce waste. Over the last few years, I have heard about changes to the Toyota assembly lines to improve efficiency. During a recent trip to Japan, I was able to observe the assembly line at the Motomachi plant. In this post I will show the evolution of line layouts at Toyota.

## 4.1 Old Standard Layout for Toyota Plants

Traditionally, Toyota assembly lines consisted of three to four sub-lines, each about 300 meters in length. The trim line is for the installation of electrical parts. In the chassis line, the drive train, motor, exhaust, etc., are added. During the final line, bumpers, window glass, wheels, etc., are attached.

## 4.2 Layout Experiments at the Kyushu Plant 1992

For the new Kyushu plant constructed in 1992, this division was increased significantly. The line was split into a total of eleven self-contained subsections. Each section is about 100 meters long.

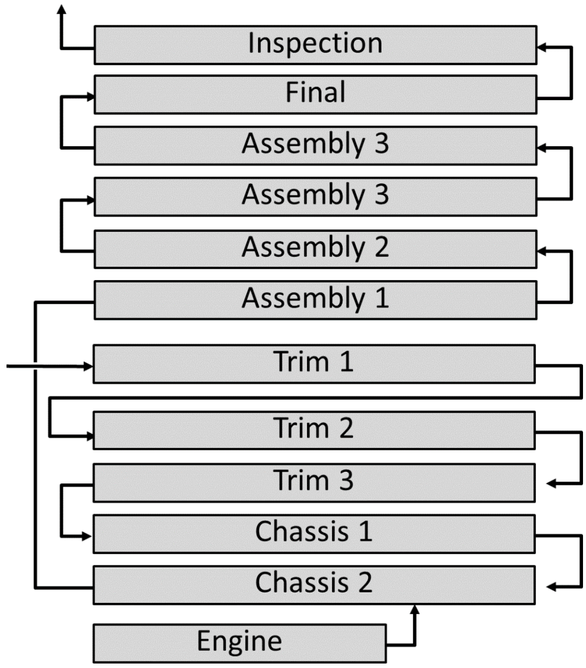


*Figure 12: Layout of Toyota Kyushu Plant 1992 (according to Monden, Image recreated by Roser)*

## 4.3 Changes in the Motomachi Plant 1994

In 1994, the Motomachi line was also renovated. While not as radical as in Kyushu, some of the longer segments were split into smaller parts (one trim, two chassis, two final). Below is the 1994 layout of the Motomachi line:

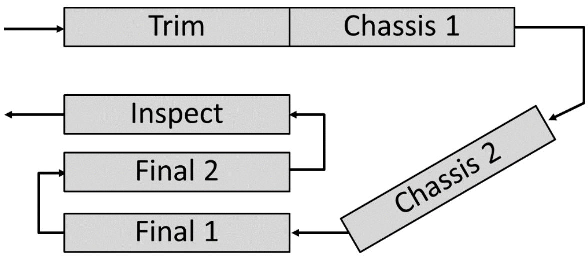


*Figure 13: Old Layout of Toyota Motomachi Plant(according to Monden, Image recreated by Roser)*

## 4.4 New Layout Motomachi Plant

Below is the current (2014) layout of the Motomachi plant. Compared to the previous layout from 1994, this one contains many more individual segments divided by small buffer stocks (green boxes). With eight line segments, the plant still has less than Kyushu in 1992 (eleven segments), but more than in the 1994 renovation (six segments) and much more than before 1994 (three to four segments). Each small blue box below represents one station along the line or, in most cases, approximately one worker (not counting team and group leaders).

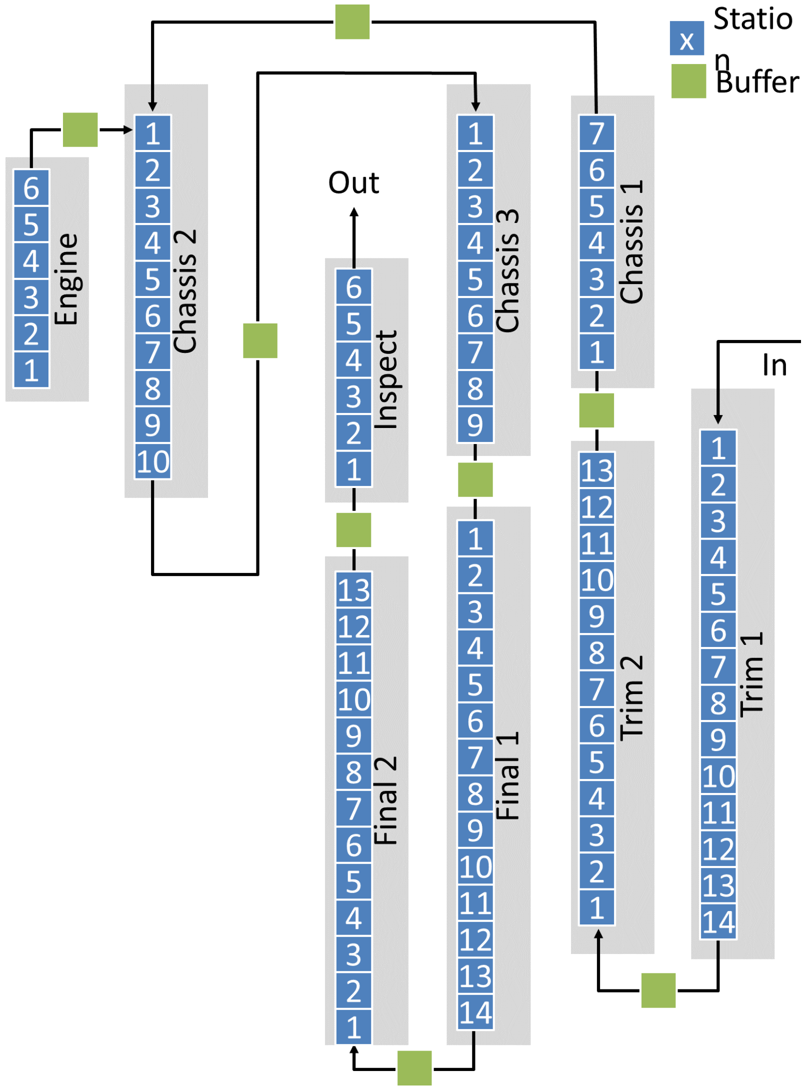


*Figure 14: Current Layout of Toyota Motomachi Plant (Image Roser)*

The exact number of people in the line depends also on the customer demand. One of the methods to adjust the output of the line is by adding or removing workers. When I observed the line, I measured a cycle time of 2:20 minutes per vehicle. The highly automated welding line was much faster, being able to produce one chassis in just over one minute. Interestingly, rather than cramming the line full with chassis (the Western way), Toyota used a pull system. New chassis were released only at the speed at which the assembly line could take them, hence there were always idle stations without any chassis in the welding line.

## 4.5 Advantages of the New Layout

There are different advantages for splitting the line. One major reason was worker motivation. At Toyota, every worker not only has the ability to stop the line, but must do so if there is a problem he cannot solve within one cycle time. However, in a long line, this means inconveniencing many other workers, not all of whom the worker has a social relation with. Hence, there is a feeling of guilt due to interrupting other people's work, and hence a hesitation to stop the line.

With a shorter line, only about fourteen workers are involved in a line stop. Only problems longer than four or five cycle times affect other line segments; everything else is decoupled through the buffer stock between the lines. Hence, most line stops affect only a small social group of workers. Furthermore, the workers can temporarily increase speed and build up a small buffer of cars, and then use the time gained for a short five minute meeting to discuss current issues.

The second advantage is improved productivity. A problem does not stop the entire line, but only a segment. Hence, the risk of disruptions is spread and the productivity of the line is increased.

One question that popped in my mind: Why did Toyota wait until 1994 before they started to experiment with breaking the line into smaller segments. Supposedly Taiichi Ohno, the key force behind the Toyota Production System, was quite against that idea. Only after his death in 1990 did they dare to change things. After all, Ohno had quite a forceful personality. In any case, Toyota will continue to experiment with different approaches for assembly and other processes in order to reduce waste.

# 5 Shigeo Shingo and the Art of Self Promotion

*Christoph Roser,February 02, 2014 Original at* [*https://www.allaboutlean.com/shigeo-shingo/*](https://www.allaboutlean.com/shigeo-shingo/)


*Figure 15: Shigeo Shingo (Image Roser)*

Shigeo Shingo is a name that everyone in the United States lean community knows. He is considered "*the world's leading expert on manufacturing practices and the Toyota Production System,*" an "*engineering genius,*" and the foremost guru of lean production. Some sources even claim he invented the Toyota Production System and taught Taiichi Ohno. Unfortunately, his achievements were much less stellar than this, but he was very skilled in the art of self-promotion.

## 5.1 The Beginnings

Born in Saga City, Japan, in 1909, he graduated from Yamanashi Technical College with a degree in mechanical engineering. Afterward, he worked as a railway technician in Taipei during the Japanese occupation of Taiwan during World War II. As the war ended, so did his Job in Taiwan. Shingo then became a consultant at the Japan Management Association (JMA) at age 34. In this position, he gathered experience at Mazda and Mitsubishi Heavy Industries.

## 5.2 Shingo and Toyota

In the 1950s, he was contracted by Toyota to update their Training within Industry (TWI) courses. TWI was a US program for training workers and improving quality. Highly successful, it was all but forgotten in the US after the war ended, but it made a successful revival in Japan. Shingo was contracted to update the "*Job Methods*" section of TWI (afterward called P-Course). He also taught classes on time motion, a well-known method originating with Taylor and Gilbreth in the US.

Between 1950 and 1970, Toyota developed a method to reduce changeover times. Many different employees at Toyota, including Taiichi Ohno, were involved in this. Shingo was not. Not until the very end, around 1970, was he contracted to do a class on quick changeover methods. This class helped improve the changeover of one of the last machines that were not yet improved. To repeat, he participated in only one quick changeover workshop at Toyota!

It was at this time that Shingo became more interested in the Toyota Production System. He learned what he could about it and constantly tried to schedule meetings with a more and more reluctant Taiichi Ohno. From Ohno's point of view, Shingo wanted to have academic discussions, whereas Ohno was only interested in practical applications.

In 1980, Shingo published a book on the Toyota Production System. This publication was without consent of Toyota, and he no longer did any trainings there afterwards. He did visit Toyota plants, and also worked for other companies in the Toyota group, but overall the relationships turned sour.

## 5.3 Shingo, the “Inventor” of the Toyota Production System

Afterward, Shingo moved to the United States. In 1980, the West was just starting to realize the power of the Japanese automotive industry, as it outperformed the US industry in both quality and price. There was much demand to understand what enabled this Japanese superior performance. Unfortunately, due to the language barrier there was little information about the secrets of the Toyota production System.

Shingo was one of the few sources in the United States–if not the only one–who knew about the Toyota methods. As such, he had a very fast rise to industry stardom. Shingo fueled this by an exceptional trip of self-promotion.

For example, he had his book translated into English. The Japanese title was “*The* **Toyota** *Production System.*” The English title, however, changed to “*The* **Shingo** *System.*” He wrote many more books, always giving himself a prominent position in the development of the Toyota Production System. For example, in one book he included a timeline of industry events. He placed himself on this timeline a whopping eleven times, claiming to have *developed the theory of flow layout, introduced scientific thinking, developed quick changeover, introduced pre-automation*, and *invented poka yoke and the non-stock production system*, to name just a few.

His fourteen books are still bestsellers in America, commanding staggering prices. A one-hundred-page pamphlet goes for $30, whereas a three-hundred-page medium-sized book costs a whopping $100. If you can read Japanese, the original Japanese books are much cheaper or even out of print due to low demand. Japanese lean experts who read his books considered them very low quality when compared to the literature available in Japanese and overall very poorly written. Wisely, Shingo did not claim that he invented the Toyota Production System in his Japanese books.

Outside these books, he claimed that he invented numerous things related to lean manufacturing as well as the Toyota Production System. This claim is based on a minor presentation for the Japanese Management Association in 1946. This presentation, conveniently, is now lost in history, and its content can no longer be verified.

During a project at Matsushita Electric, he installed conveyor belts for the transport of parts. He re-coined this as a new invention, the *Mikuni Method*. In reality, there was not much new about conveyor belts, and the method is now all but forgotten. Even most lean experts have never heard of the *Mikuni Method*.

## 5.4 The Legacy of Shigeo Shingo

Shigeo Shingo did not invent the Toyota Production System. He also did not invent the method of SMED. What he did was bring its knowledge to the United States and popularize it there. He provided first experiences in the Toyota Production System (he is less known in Europe). Thousands of people learned about Lean Manufacturing from him. He coined key terms used in lean manufacturing (for example, SMED for quick changeovers or Poka Yoke for mistake proofing). The *Shingo Prize for Excellence in Manufacturing* is one of the most prestigious awards in the industry, considered the Nobel Prize of manufacturing. For these achievements he is rightfully praised. However, he also seems to have claimed many more contributions to Lean than what he really did. For me this is unfortunate, since in my opinion there would have been no need for such additional self promotion. Being the first to bring the knowledge to the US would have been more than enough for his rise to stardom. In any case, the methods he taught are good, so please go out and use them to improve your industry.

## 5.5 Addendum

The question of Shigeo Shingo's contribution to TPS is a hot topic for discussion. Many US lean experts rush to defend the honor of Mr. Shingo. But also other US experts question his contributions. My main but not my only outside source is Art Smalley:

- Smalley, Art. "A Brief Investigation into the Origins of the Toyota Production System." *Art of Lean*, July 2006.
- Smalley, Art. "A Brief History of Set-Up Reduction: How the Work of Many People Improved Modern Manufacturing." *Art of Lean*, 2010.
- Isao, Kato. Shigeo Shingo's influence on TPS – An Interview with Mr. Isao Kato. Interview by Art Smalley, April 2006.

Please be aware that some of them have gone off-line since, but googling may provide copies in some odd corners of the web. In any case, Smalley's findings are consistent with my own experience in Japan and Europe, and also with my discussions with Toyota employees. There are some good overview discussions about the resulting conflict between supporters and critics:

- Kevin Meyer: Much Ado About Shingo and Ohno.
- Mark Graban: Is Shingo overrated?

## 5.6 Addendum 2

Since I wrote this post I have uncovered a few more bits of information. It seems that the main driver behind Shingo's rise to stardom was Norman Bodek. When re-publishing Shingo's book through Bodek's publishing house *Productivity Inc*. the title changed from the (Japanese) *Toyota Production System* to the (English) *Shingo System.* Bodek also (in his own words) "*started the Shingo prize and got him an honorary doctorate degree from Utah State University*".

Since then Bodek praised Shingo at every opportunity, calling him "absolutely brilliant, probably the greatest manufacturing genius of our time, able to solve every manufacturing problem presented to him". It seems that mainly through this successful promotion Shingo got the (in my view incorrect) reputation as the primary inventor of the Toyota production system.

# 6 Dress for Success in Lean Manufacturing

*Christoph Roser,February 09, 2014 Original at https://www.allaboutlean.com/dress-for-success/*

*Figure 16: Justin Timberlake (Image Gregxscene in public domain)*

Whenever you work with people, the impression you make on these people is important. Your **clothes and behavior have a great influence on this impression**. This post discusses strategies for your appearance to increase your chances of success on lean manufacturing projects.

## 6.1 In the Boardroom

*Figure 17: Suit and tie (Image Grondilu under the CC-BY-SA 3.0 license)*

Chances are, with lean manufacturing projects you are at the intersection between the shop floor and management. I find myself occasionally reporting to upper-level management or even the CEO on the status of the project. Naturally, I want to convey an impression of **professionalism and competence**. In the Western world, this means for men a **full dark suit, collared shirt, black belt and shoes, and a necktie**. In some companies, there is even an informal color standard for the suits. If you want to fit in, you need to adapt your outfit.

Furthermore, you also can adjust your behavior and phrasing. Fancy words do impress more in this environment. With respect to lean, Japanese words may help here. Rather than *continuous improvement,* it is *kaizen*. Instead of *leveling,* use *heijunka*. *Mistake proofing* becomes *poka yoke*, and so on. On a side note, professional titles (Ph.D., professorship, academic degrees, etc.) can help you with your impression.

## 6.2 On the Shop Floor

*Figure 18: Factory Workers (Image United States Department of Defense in public domain)*

Of course, on the shop floor, dress code is very different. On the shop floor, I also want to convey an impression of **professionalism and competence**. However, if you go to the shop floor in a full dark suit and tie, shove your academic degrees into everybody's face, and use a plethora of foreign-language buzzwords, you may as well go back to the boardroom. With this approach, you will not reach the people on the shop floor. **They will consider you an outsider, and they won't understand you, won't trust you, and will be reluctant to work with you.** Since the success of lean manufacturing projects is decided on the shop floor, this effectively means that **your project will most likely fail**.

On the other hand, dressing up in blue-collar work clothes will look weird. After all, you are most likely not a worker at this plant, and trying to adapt over-eagerly will also fail.

## 6.3 A Compromise

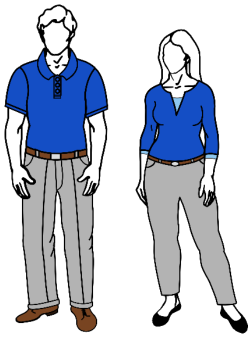

*Figure 19: Business casual (Image Elkagye, Themightyquill, and Nicoli Maege under the CC-BY-SA 3.0 license)*

As a compromise, I usually go for **black jeans or khaki pants and a dress shirt** (known as smart casual or business casual). This way I won't look too distant to the shop floor, but will also look somewhat respectable to management. If necessary, a tie and a jacket can be added quickly for management meetings. Hence it is acceptable on the shop floor and tolerable in boardrooms.

Naturally, I do not mention any of my titles and try to explain concepts in English on the shop floor. I also avoid any foreign-language or buzzwords. Most buzzwords have been around on the shop floor already, usually with less-than-stellar success. Hence shop floor workers are wary of such phrases. To have a successful project on the shop floor, you need to earn the workers' trust. Dressing accordingly is not everything, but it is one aspect of this.

## 6.4 The Easy Way Out

*Figure 20: Who's the boss? (Image Yorudun under the CC-BY-SA 3.0 license)*

In some cases, the dress problem is solved by the workplace requiring a certain style of clothing. These are usually to either protect the workers or the products. In this case, everybody regardless of hierarchy must dress up in this fashion. Common examples are clean rooms, environments with toxic gases or particles, eye protection in welding areas, reflective vests and helmets in warehouses, etc.

## 6.5 Summary

It is important to dress and behave in relation to the people you are working with. In lean manufacturing, this is frequently both the shop floor and management, hence you need to find a compromise. With this post I probably didn't reveal anything groundbreakingly new to you, but I wanted to remind you about this often-overlooked fact. For example, McKinsey is known for suits and tie. However, during my consulting days, my colleagues and I rarely wore suits on the shop floor. In some cases, I even went to work in jeans and T-shirt simply because everybody wore the same company T-shirt. I hope this reminder is helpful for you.

No go out and improve your Industry!

# 7 Poka Yoke Training – Simple Mistake Proofing Game

*Christoph Roser,February 16, 2014 Original at [https://www.allaboutlean.com/poka-yoke-training/](https://www.allaboutlean.com/poka-yoke-training/)*

*Figure 21: Poka yoke anyone? (Image Roser)*

Mistake proofing (or **Poka Yoke** in Japanese) is one important way to avoid waste in lean manufacturing. In this post, I will present a small game that can be used to teach the basics of poka yoke easily and quickly. The game is based on Kinder Surprise eggs made by Ferrero, also known as a **Kinder Egg**. These eggs are available almost anywhere – except in the US, in which case there are some alternatives.

## 7.1 The Basics of Poka Yoke

Poka yoke, also known as mistake proofing, is a basic technique to avoid mistakes. Initially it was known as idiot proofing or *baka yoke*, but Shigeo Shingo changed the term to the more friendly *mistake proofing*, lest an employee would feel addressed as *idiot*.

The underlying idea is that a product should be designed in a way that makes it impossible to assemble it incorrectly. For example, at the back of your computer, most plugs fit into only the corresponding matching socket. This way you can't mix up your speaker plugs with the monitor socket, reducing the likelihood of errors.

The technique can also be used in areas other than assembly and manufacturing. For example, in Germany, ATMs give you the cash only after you take back your bank card. This significantly reduces the risk of forgetting your card in the ATM (the money is rarely forgotten).

## 7.2 The Kinder Surprise Eggs

*Figure 22: Broken Kinder Egg (Image Roser)*

The poka yoke game is based on Kinder Surprise eggs. These eggs are widely available in Europe and Canada (For the US, see below). They contain a chocolate egg, which contains a small yellow capsule, which in turn contains a small toy.

These toys are the crucial part for our poka yoke game. Most of the toys require some assembly. These assembly steps can now be used to teach poka yoke.

## 7.3 The Toy Assembly

Assume, for example, you find a small toy for assembly in the egg as shown below. In this case, the toy is a blue dragon consisting of five components.

*Figure 23: Make me whole! (Image Roser)*

The egg also contains instructions and safety information (choking hazard unsuitable for children below age 3). Dispose of the instructions without reading. Rather, try to assemble the product without the instructions. In most cases, you will find this rather easy. Most toys are designed so that there are usually few or no possibilities to make mistakes. For example, the four attachments for the blue dragon body are designed so each attachment fits only the correct hole and also in the correct orientation.

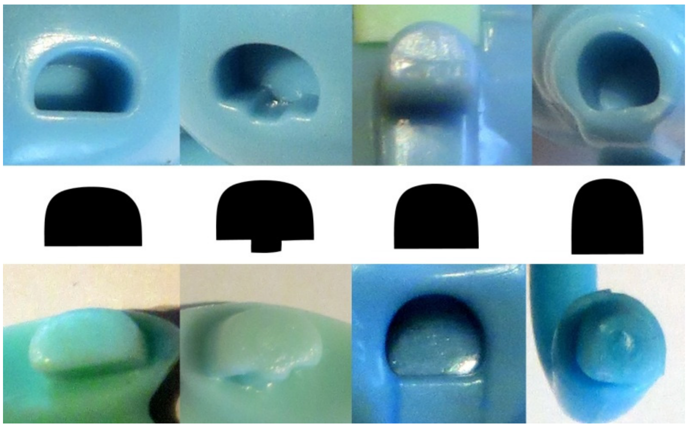

*Figure 24: Every pot has its lid, every hole has its peg … (Image Roser)*

The right wing will go only in the right hole. The left wing will fit only in the left hole. Similarly, the feet and the tail will fit only at the bottom and the back. All of them also can only be positioned in the right orientation (i.e., you cannot put the wings on backward even if you try). Hence, **the design of the attachments is mistake proof** or poka yoke.

However, some shapes are close enough to be initially confused, even though they do not fit. It would be a good discussion to **think about different shapes that can be used to make the blue dragon even more mistake proof**.

## 7.4 Assembly Options

Some toys can be assembled in more than one way. For example, the excavator below has four assembly options. In this case, it is interesting to **find out which way you can mess up the assembly and which way you can't**. The excavator leaves you four options for assembly, three of which are incorrect.

*Figure 25: One good excavator, three zombies … (Image Roser)*

Take for example the excavator above. Most of these mistakes are obvious. But each end fits in only one other part, and only the forward or backward orientation is ambiguous. An additional non-obvious mistake of putting the middle strut with the tool end into the machine is simply not possible. Only one end of the middle strut fits the engine, while the other end only fits the shovel. In this case, poka yoke does not allow this error. With exactly these thoughts, we pretty much arrived at the poka yoke game.

## 7.5 The Poka Yoke Game

The poka yoke game basically consists of handing out Kinder Surprise eggs to your trainees and having them dispose of the chocolate in a suitable way (I'm sure they will find a way they like). After opening the yellow containers in the eggs, tell them to ignore the paperwork and try to assemble the toys without the instructions. You then can **discuss the following three questions**:

- Can you assemble it correctly without instructions?
- Can you assemble it incorrectly?
- How would you design it to reduce errors even more?

### 7.5.1 Scale of the Game

The game is very well suited for **classroom** or **workshop teaching**. With smaller classes you can have an egg for every trainee or student. With larger classes you may use less eggs than students and have them work in groups. The game is surprisingly flexible, and the redundant chocolate will also improve the mood in the class.

Additionally, the game can be used for **open house events** and larger **exhibitions**. Anybody showing up gets an egg and has to assemble the product without instructions. This can be accompanied by a few posters explaining the theory. Trust me, it will be a popular booth in your open house. (Side note based on my experiences: If your booth is outside on a hot day, make sure your eggs are cooled. 😐)

### 7.5.2 Non-Assembly Collectibles

*Figure 26: Snap! No Assembly required … (Image Roser)*

Occasionally you will get a small toy that does not require assembly. In my experience, about one third of the eggs do not require assembly. For this case, I always keep a supply of toys for assembly at hand. The participant can keep the first toy and return the second toy after assembly.

*Figure 27: Part of my Collection. (Image Roser)*

Over the years I have collected quite a few eggs. For easier reference, I color code them according to their difficulty of assembly. *Green dots* are for easy eggs, *red dots* are for more difficult ones.

On a side note, I often find it more difficult to fit everything back in the egg afterward than I find it to assemble it in the first place.

## 7.6 Where to Get the Eggs?

In many countries in the world, these eggs are readily available in most supermarkets. Smaller quantities can be bought there easily. One egg costs around 1/2 Euro. For larger quantities (for example, if you need two thousand eggs for an open house), I recommend you contact your local Ferrero dealership directly and have a pallet shipped to you.

## 7.7 US Choking Hazard and Alternatives

As mentioned above, these eggs are **available almost anywhere except the US**. US laws prohibit any food with non-food items inside, to reduce the risk of choking. Hence these eggs are not available in the US. Some collectors do black market imports, but **I strongly advise against smuggling Kinder Surprise eggs into the US**. The penalties if caught are severe, and you leave yourself open for legal liability. Supposedly, about twenty-five thousand eggs are seized every year at the borders.

Recently, another company has found a loophole in the law and is selling similar Choco treasures, where the toy is not completely enclosed by chocolate. Unfortunately, these eggs usually have only completely assembled figurine inside, making them unsuitable for a poka yoke training.

*Figure 28: An occupational hazard… (Image Roser)*

One possibility I could think of is to stock up on eggs while in Canada or Europe. Dispose of the chocolate and take only the toys with you.

A second option is to look for similar toys without the chocolate. Possible keywords here are vending machine toys or buildable toys. Make sure there is **some assembly required**, or they are **buildable**. With a little bit of looking around, you should be able to find some suitable products for less than $1 per toy.

I hope this small game helps you in training others and also in your daily work. Now go out and improve your Industry!

# 8 Quick Changeover Basics – SMED

*Christoph Roser,February 23, 2014 Original at [https://www.allaboutlean.com/smed-theory/](https://www.allaboutlean.com/smed-theory/)*

*Figure 29: Set up basics (Image Hopefulromntic under the CC-BY-SA 3.0 license)*

One popular approach to battle waste is to streamline changeovers. Changing machines from one set-up to another is often a time-consuming exercise. Hence, in lean manufacturing, reducing changeover times is a well-known method for improving efficiency. In this post, we will go through the basic approach of improving changeover time, also known as *quick changeover* or *single minute exchange of die (SMED)*.

This post is part of a series of posts on SMED, for the others see below:

## 8.1 Priorities!

Most commonly, a SMED workshop is broken into six steps, which will be explained below. However, as with any improvement project, the first question you should ask yourself is, "**Is this my biggest problem right now?**" As always, you should have an overview of the problems you are facing and have them prioritized. When you've decided which problem to address, then you should look for solutions. **Only after finding problems, prioritizing them, and looking for possible solutions, should SMED pop up as one possible answer. Only then should you do a SMED workshop!**

Unfortunately, I too often see examples where a SMED workshop is done only for the sake of SMED, wasting time and effort on improving something that is not really a focus area. Too often, middle managers instruct their subordinates to do SMED without knowing if this is really the best step to improve the company. If you find yourself in this situation, see if you can convince your superior to adjust his/her approach. If you can't convince him – or if you know by experience that your boss is always right – then, for the sake of your career, go ahead and do a SMED.

In any case, regardless if you do a SMED because it is the right thing to do or merely because someone told you to do it, here are the six fundamental steps of SMED.

## 8.2 Preparation

### 8.2.1 Set up a Team

For a good changeover workshop, it is necessary to gave a good team together. This should be between three and five people, including an operator and/or a foreman doing the changeovers and an engineer or technician familiar with the machines and processes.

### 8.2.2 What to Measure

Before you start measuring, you should **make sure that you get the entire process measured**, not just part of it. The changeover itself starts after the last part produced at full speed and ends with the first part produced at full speed. It is easy to overlook, for example, times where the machine is running already but the operator still adjusts the settings and hence the machine is slower than planned. Additionally, there may be actions done before or after the changeover where, for example, a new tool is brought to the machine and the old tool is put back in storage afterward. These should also be observed.

### 8.2.3 Inform the Workers

Whenever you measure times on the shop floor, or even take video, you should inform the workers and their representatives and get their agreement. This makes things go much smoother. Even if you legally have the right to measure and take videos without the workers' consent, it is almost certain that your measurements will be worthless. If the workers disagree with you measuring them, they can easily mess up your measurements by working extra slow. In many cases, you wouldn't notice if they added additional steps to the procedure. Hence, get their agreement.

## 8.3 The Six Fundamental Steps of SMED

### 8.3.1 Measure Changeover Times

The SMED process starts with a detailed observation of the changeover process. The different steps of the process have to be identified for the entire changeover process, and its time has to be measured. Taking video helps, as this allows us to watch the steps again. The time of the video also allows easy measuring of durations. Please remember that whenever you take times or videos, make sure it is accepted by the workers and their representatives.

Also, you should observe more than one changeover since different people will do it differently at different times. Depending on the duration and the frequency of the changeovers, you may be able to watch a different number, but I recommend no less than three different changeovers. Afterward, you should have a **list of steps including an average time to do the step**. It is fine if you don't have a fixed sequence yet, as different operators may do the changeover in a different sequence. We will fix that later. It is also possible that there are some steps done only by some operators. Keep them in the list; we will fix that later too. Below is an example for illustration, where a total of ten steps have been observed.

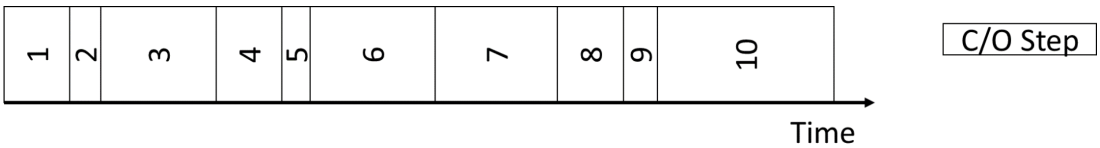


*Figure 30: Step 1: Measure Changeover Time (Image Roser)*

Please note that these observations cannot be delegated, as this observation also gives you and the team a crucial understanding of the process necessary for the next steps.

### 8.3.2 Identify Internal and External Elements

Next, we check which of these changeover steps have to be done while the machine is stopped and which can be done while the machine is still running. These are usually called **External Steps** with a running machine and **Internal Steps** with a stopped machine. Below is a graphic representation, where green indicates external and gold indicates internal steps.

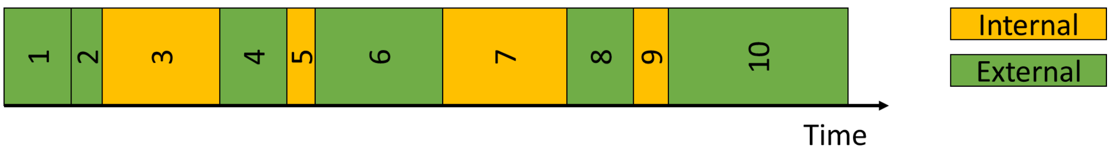


*Figure 31: Step 2: Identify Internal and External Elements (Image Roser)*

### 8.3.3 Move As Many Elements as possible to External

Next we move as many steps as possible to external. This means not only converting internal steps to external, but also ensuring that an external step is indeed done before or after the process interruption. This sounds banal, but you would be surprised how often a changeover happens where the process is stopped and then the workers go get the tools and parts for the changeover.

This can be done before the machine is stopped. Similarly, returning the tools to storage can be done after the machine is running again.

Below is a visual representation of this process. You can see that the time of the stop is already reduced. Hence, you can get more parts out of your process since the stop is shorter.

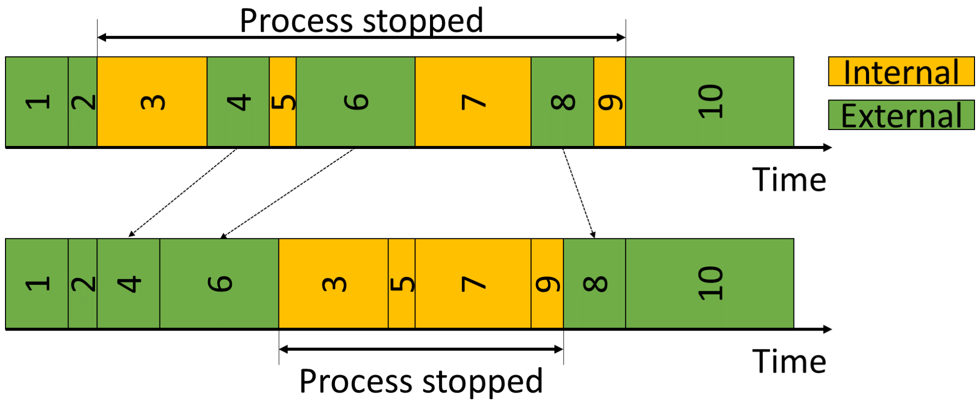


*Figure 32: Step 3: Move External Elements to External (Image Roser)*

### 8.3.4 Shorten Internal Elements

After moving the external steps to external, we now shorten the internal steps. Check if the procedure can be simplified. Check if there are better tools available. Eventually, the new setup may look like the image below, where both the time of the stop and the overall changeover time may be reduced.

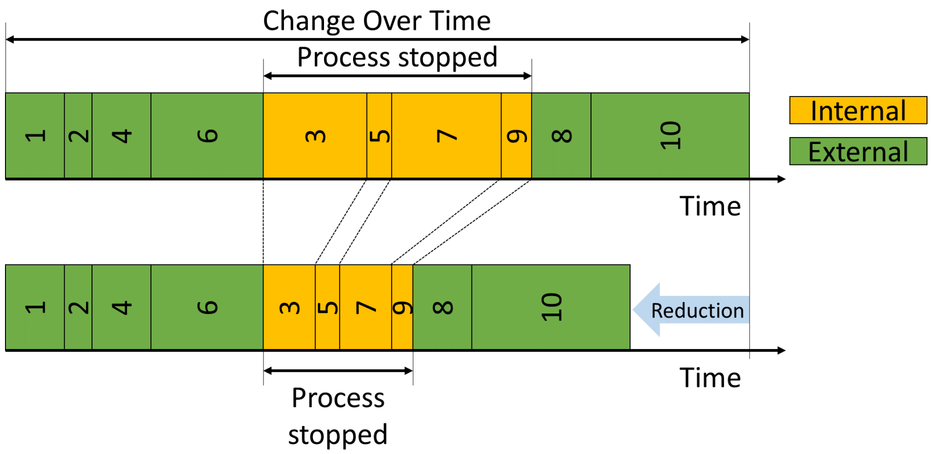


*Figure 33: Step 4: Shorten Internal Elements (Image Roser)*

### 8.3.5 Shorten External Elements

Next we do the same for the external elements. Check if we can shorten the external elements. This will not reduce the stoppage of the process, but it will reduce the overall time of the changeover and hence the workload for your workers doing the changeover.

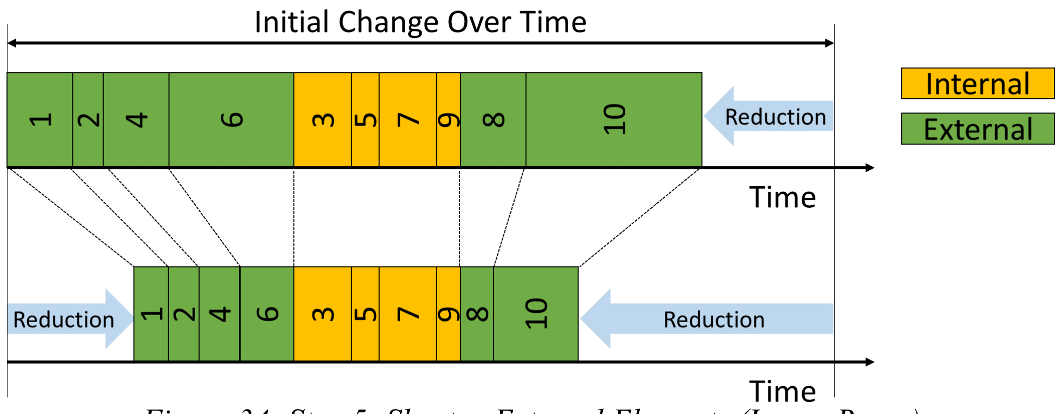

*Figure 34: Step 5: Shorten External Elements (Image Roser)*

### 8.3.6 Standardize and Maintain New Procedure

The last step is the most difficult one and the most frequently forgotten one. It is not enough to do a changeover quickly once; you have to do it quickly every time. So you need to fix the new standard, document it, train all relevant workers in the new standard, and do a process confirmation. Any standard not maintained that way will be soon lost.

For example, you could check every now and then if the standard is still followed. You could have the workers write down the time needed for the changeover and see if it starts to slip. Maintaining a standard is actually not that difficult, but it needs something short in supply in most companies: **Management Time and Attention**!

## 8.4 Practical Tips

Before closing this post, here are a few practical tips. The above six steps are sometimes found in slightly different versions in different sources. This is okay. You also don't need to follow this framework in that order, as long as the beginning and the end of the framework are at the beginning and the end (measure the times first, standardize the new procedure last). For example, if during the shortening of the internal elements (#4), you find a way to make this step into an external step, by all means do so and then move the step to external (#2).

Some SMED frameworks have an additional point: *Repeat the process again*. I disagree. First decide what your biggest problem is now, and if during the identification, prioritization, and solution seeking of the problem you come back to SMED for this process, then do it. Otherwise just repeating it is pointless. Of course, there is more potential that can be found in a second round and this would be nice to do. But **as long as your time is limited, you can't do everything that is nice; you need to focus on what is necessary!**

## 8.5 Potential

These SMED workshops are often quite powerful. If there has never been a changeover workshop for a particular process, then you probably can reduce the changeover time by 50% to 70%. If there has been a previous changeover workshop within the last two years, you can probably reduce it by at least another 30%.

As for the changes, these are often not very expensive. Organizational changes are usually without investment. One SMED workshop I did had as its most popular measure a new plastic shovel for handling granular material, and we got that shovel for free from the supplier of the material. Another workshop found out that the worker had to go from the third floor to the basement every time a valve needed to be turned on or off. Replacing the manual valve with a remote-controlled electric valve effectively gave the plant four weeks of additional production time per year, at a cost of less than $500.

Also, if you manage to reduce changeover time, you should seriously consider not producing more with the available capacity, but performing changeovers more often and getting smaller lot sizes. This way you can usually multiply the effect of the available time by reducing materials. In sum, SMED can be a very powerful tool to improve your processes. I hope this post was helpful for you. Now go out and improve your industry!

# 9 The History of Quick Changeover (SMED)

*Christoph Roser, March 02, 2014 Original at*
*https://www.allaboutlean.com/smed-history/*

*Figure 35: Set up history (Image Hopefulromntic under the CC-BY-SA 3.0 license)*

In the previous post, I explained the basics of a quick changeover. In this post, I will go through the **history of quick changeovers** (also known as SMED). It is quite interesting to learn how things have developed during the twentieth century. The next post will look at different, unusual ways to teach SMED.

This post is part of a series of posts on SMED. For the others, see below.

## 9.1 Henry Ford

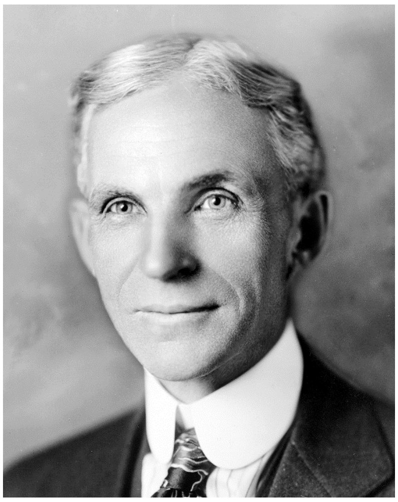

*Figure 36: Henry Ford (Image Hartsook in public domain)*

Standardized quick changeovers were refined at Toyota around 1950. However, for some less-than-stellar examples, we start with Henry Ford and his beloved Model T. Ford rigorously improved his factories to improve efficiency and make the Model T cheaper.

The most famous example was the massive use of assembly lines and specialized machinery. For example, the drill for the holes in the engine block included dozens of drill bits in different sizes. Hence only one pass with this drilling tool would create all the holes needed from that particular orientation.

For Ford, the Model T was the perfect car, and he was trying to create the perfect manufacturing process for it. In his view, the world would never need another vehicle. If the world would have followed Ford's vision, you could still go to your local Ford dealership tomorrow and buy a brand new Model T with the best technology of 1908.

*Figure 37: 1910 Model T Ford (Image Harry Shipler in public domain)*

However, customer demand changed, and by 1927 the Model T was simply over twenty years old and outdated, despite minor changes like adding electric light. Other more modern vehicles rose in popularity. With much hesitation, Ford finally decided in 1927 to change to a new model, the Ford Model A (he restarted the lettering, hence after T, he used A again).

However, while Ford's factories were exemplary examples of efficiency, they were also enormously inflexible. Overall, the changeover led to a six-month standstill at Ford. Of all machines, one quarter had to be thrown out, one quarter could be used as they were, and half had to be extensively retooled. Any company with lesser financial strength than Ford would have gone bust.

Incredibly enough, only a few years later this chaos repeated again. The change in 1931 from Model A to Model B took five months and was equally chaotic.

## 9.2 GM with Alfred P. Sloan


*Figure 38: Alfred P. Sloan (Image Samuel Johnson Woolf in public domain)*

GM, under the management of Alfred P. Sloan, used a completely different approach. While Ford focused on uniformity, Sloan focused on variety. While Ford emphasized the eternalness, Sloan celebrated change. GM presented new and updated models on an annual basis, setting the tact for the current automotive industry.

Naturally, for this they needed much more flexibility. You cannot bring a new model on the market every year if this means closing your factory for a year. Already around 1930, GM managed to do a major model changeover within twenty days, compared to Ford's six months.

## 9.3 Economic Order Quantities

$$Q = \sqrt{\frac{2DK}{h}}$$

*Figure 39: Economic order quantity (Image Roser)*

In 1913, Ford W. Harris developed an equation for an order quantity that minimizes total inventory holding costs and ordering costs. This is known as the *economic order quantity*. The variables in the equation shown on the left are as follows:

- Q: optimal order quantity
- D: annual demand quantity
- K: fixed cost per order or setup cost
- h: annual holding cost per unit

This apparently simple formula was widely used to determine the "*ideal*" lot size or order quantity. Unfortunately, holding costs were usually underestimated, and many underlying assumptions of the equation made the result much less precise than what the numbers suggested.

In any case, large or expensive orders or setups (K) resulted in large orders or lot sizes (Q). As a result, lot sizes grew. It was usually overlooked that the order or setup cost was not fixed but could also be influenced. Nevertheless, in many cases it was easier to simply make larger quantities rather than to go through the effort to change setup times.

## 9.4 Frank Gilbreth and Frederick Taylor

*Figure 40: Frank Gilbreth (Image unknown author in public domain)*

*Figure 41: Frederick Taylor (Image unknown author in public domain)*

However, there were also researchers in the US looking at reduction of changeover time. Probably the most prominent were motion expert Frank Gilbreth and the father of scientific management, Winslow Taylor.

Taylor analyzed non-value-adding parts of setups in his 1911 book, *Shop Management* (page 171). However, he did not create any method or structured approach around it.

Gilbreth studied and improved working processes in many different industries, from bricklaying to surgery. As part of his work, he also looked into changeovers. His book *Motion Study* (also from 1911) described approaches to reduce setup time.

Even Henry Ford's factories were using some setup reduction techniques. In the 1915 publication *Ford Methods and Ford Shops*, setup reduction approaches were clearly described. However, these approaches never became mainstream. For most parts during the 20th century, the economic order quantity was the gold standard for lot sizing.

## 9.5 Toyota and the Quick Die Change (QDC)

Toyota had very different problems in 1950. Both Ford and GM produced cars in enormous quantities. Toyota built only a few thousand cars per year. As a poor company at that time, it could not afford a separate press for every part. Instead, they frequently changed the tools in the presses from one part to the next.

Their problem was that this changeover took between two and eight hours, and Toyota could neither afford the lost production time nor the enormous lot sizes suggested by the economic order quantity. However, on a trip to the US, Taiichi Ohno observed Danly stamping presses with rapid die change capability. Subsequently, Toyota bought multiple Danly presses for the Motomachi plant.

Secondly, Toyota started to work on improving the changeover time of their presses. This was known as *Quick Die Change*, or *QDC* for short.They developed a structured approach based on a framework from the US World War II *Training within Industry* (TWI) program, called ECRS – Eliminate, Combine, Rearrange, and Simplify.

Over time they reduced these changeover times from hours to fifteen minutes by the 1960s and then to three minutes by the 1970s. Other Japanese companies had similar achievements. The Western world, however, was still stuck with changeover times measured in hours. Hence, while Japanese companies changed tools three times per day or more, most Western companies changed tools once per day or less. Lot sizes, of course, were similarly dissimilar.

## 9.6 Shigeo Shingo and SMED


*Figure 42: Shigeo Shingo (Image Roser)*

During the 1970s and 1980s, Western automakers were surprised at the quality and cost of Japanese cars. They wanted to understand the *secret* of these Japanese car makers. Unfortunately, there was little or no literature available in English.

Japanese consultant Shigeo Shingo was able to fill this gap. During the late 1970s, when Toyota's method was already well refined, he participated in one QDC workshop. After he started to publicize details of the Toyota Production System without permission, the business connection was terminated abruptly by Toyota.

Shingo moved to the US and started to consult on lean manufacturing. Besides claiming to have invented this quick changeover method (among many other things), he renamed it *Single Minute Exchange of Die* or, in short, SMED. The *Single Minute* stands for a single digit minute (i.e., less than ten minutes).

As Shingo was able to fill a large gap in knowledge, he rose to fame in the US, albeit he is much less known in Japan and Europe. He promoted the ideas of lean manufacturing, especially SMED.

## 9.7 Modern Time

*Figure 43: Wrench (Image Paul Crawford in public domain)*

Due to this focus of Shingo on SMED, some practitioners believe SMED to be one of the most important methods of lean manufacturing. Sometimes lean manufacturing is considered the same as SMED. **This is not so!** SMED is one of the many tools in lean manufacturing. It is rather like one size of wrench, significant for one particular task, but far from being the most important tool in the tool box. In fact, **the most important part of the tool box is the person using the tools!** Nevertheless, I often encounter practitioners and managers who, rather than having a problem solved or even knowing what their problem is, merely want to do SMED, because that's (supposedly) what Toyota does.

I hope this post was interesting to you, shedding light on the historic developments. I also hope that you fit the solution to the problem and not the other way round, and that the person using the tools is more important to you than the toolbox.

# 10 SMED – Creative Quick Changeover Exercises and Training

*Christoph Roser, March 09, 2014 Original at https://www.allaboutlean.com/smed-exercises/*

*Figure 44: Set up exercises (Image Hopefulromntic under the CC-BY-SA 3.0 license)*

One popular approach to battle waste is to streamline changeovers. Changing machines from one setup to another is often a time-consuming exercise. Hence, in lean manufacturing, reducing changeover times is a well-known method for improving efficiency. This post will show a number of examples where these quick changeovers (also known as SMED) can be practiced in an unusual environment.

This post is part of a series of posts on SMED, for the others see below:

## 10.1 Single-Minute Exchange of … Cocktail?!

*Figure 45: Sidecar cocktail (Image Evan Swigart under the CC-BY 2.0 license)*

I was on a business trip with three protégés doing different lean projects. For some reason, the hotel we stayed at gave each of us a coupon for a free cocktail. My lean-expert mind immediately saw the opportunity for another after-hour training session: Single-Minute Exchange of Cocktail. (Please note: this is not a "change-over" in a strict sense, but it contains many elements of improving a process that are similar to a change over)

In the bar, we sat at the counter so we had a good view of the operations. Next, we agreed on one cocktail that everybody liked. This cocktail had two ingredients, so it was not difficult to make. We used one of the coupons to order a cocktail, and while the cocktail waitress was preparing the drink, we took careful notes of the steps and the times needed for these steps. Naturally, we didn't tell the waitress yet, instead taking our notes inconspicuously.

The process was a mess. The waitress walked to the shelf to get a glass and brought it to the preparation area. Next, she walked to the same shelf and got a paper coaster. On the third trip, she got the first ingredient and filled the glass, then got the next ingredient and a fruit decoration. Overall, it took her well over two minutes between the order and the serve.

After a short time, we ordered the cocktail once more using the next coupon. We observed and measured the procedure a second time. The waitress followed the same steps, again taking well over two minutes. A third order some time later confirmed that she was using the same procedure every time.

While all but me enjoyed their cocktails, we discussed how to optimize the procedure. There was a lot of potential, mostly by picking up more than one thing at the same time and hence reducing walking time. With some discussions, we settled on an improved standard and waved the waitress over.

*Figure 46: Finally… (Image Hoakylan under the CC-BY-SA 3.0 license)*

Combined with a nice tip, we explained to her what we were doing and our new standard and then asked her if she could bring us one more cocktail. This time, however, we asked her if she could follow our standard. The waitress was a bit surprised but agreed. Observing the process again, we found that it took less than a minute for us to get our last cocktail (mine).

Overall, we reduced the cocktail time from over two minutes to less than one minute. While all of us enjoyed our drinks, we noticed that the waitress started to change her patterns for other orders. Obviously, our request got her thinking and she improved her processes herself. I guess the free drink coupons were well worth it for the hotel.

## 10.2 Firefighter SMED

*Figure 47: No time to waste! (Image Sylvain Pedneault under the CC-BY-SA 3.0 license)*

You can find yet another good example for quick changeovers in fire stations. When there is an emergency, speed is crucial. The firemen and their equipment need to get to the problem quickly to save life and property. Hence, they have usually spent quite some time on optimizing their procedures. By visiting a fire station, you can see some unusual but exciting examples for moving internal processes to external.

*Figure 48: Stored with a purpose (Image Reytan in public domain)*

Many manufacturing plants even have their own plant fire brigade. In most plants I know, the plant fire brigade is – luckily – not too busy and more than happy to explain their procedures to visitors. There are lots of details on how they store their equipment, make preparations, and have standards. When the alarm sounds, their goal is to get out the door and to the problem as fast as possible.

While not every fire station has one, you have probably heard of fire poles. These poles allow for sliding downward from the break rooms to the fire engines, which is quicker than taking the stairs. The picture below shows firemen using fire poles during an alarm.

*Figure 49: Firemen sliding down fire poles during an alarm (Image William J. Carpenter in public domain)*

If you look carefully, however, you can also see, for example, that the pants and boots are already set up. The boots are inside the pants, so the fireman just steps into his boots and pulls up the pants; overall a much faster process than first putting on pants, then boots, and then making sure the pants are over the boots. Overall, every fire station is full of well-implemented examples that can illustrate a quick changeover.

## 10.3 Quick Changeover Coffee Please!

*Figure 50: Close to our hearts (Image Jeremy Keith under the CC-BY 2.0 license)*

Yet another good example for practicing SMED is coffee. Most companies and offices have coffee machines. Unless the machine is served by a central beverage provider, it is usually the responsibility of the office to service and maintain the machine. This cleaning/refilling/maintaining could be a wonderful exercise for a quick changeover workshop, not the least because most employees consider the availability of coffee quite important.

Similar to a normal SMED workshop, you can analyze the process to refill water, coffee powder or beans, and milk. Look for internal and external processes, separate them, improve them, and teach your people SMED using a product they truly care about.

## 10.4 Formula 1 Pit Stop

*Figure 51: No time to waste … (Image Francesco Crippa under the CC-BY 2.0 license)*

Another example for visualizing SMED is racing pit stops for changing tires. Naturally, in a race every second counts. Hence, the teams put in an enormous effort to improve their pit stop changeover time, and changing tires and refueling goes lightning fast.

Now most of you probably don’t have access to a race car pit stop; however, videos of many such pit stops are available on the web and they can be used to illustrate quick changeovers. Additionally, videos of race cars are always a crowd pleaser.

One of the best videos I have found is this comparison of a 1950 pit stop at the Indianapolis 500 with a Formula 1 pit stop in 2013 in Melbourne. It is beautiful to see how in 1950 one guy repeatedly used a hammer to loosen the screws of the tires, and changes the tires one by one, whereas in 2013 the change happens almost too fast to see. In my classes, i often slow down the last part to 1/4th or 1/8th speed, so the students can actually appreciate the details of the pit stop. For the protocol, the Indianapolis 500 stop took ~65 seconds, whereas the Formula 1 stop took only ~3 seconds, which is not even the fastest stop on the web. In any case **the improvement since 1950 in pit stops is similar to the improvement since 1950 in die change overs at Toyota**.

*The Video by CpatainCanuck is available on YouTube as "Formula 1 Pit Stops 1950 & Today" at https://youtu.be/RRy_73ivcms*

It is also entertaining to watch pit stop videos where things did not go as planned. In an industrial setting, changeovers should always be at a safe and reliable speed. With race cars, however, they push things to the edge and occasionally loose a gamble or a tire – as Nigel Mansell did in 1991:

*The Video by cmgamer is available on YouTube as "F1: Mansell's pit stop woe [Portuguese GP 1991]" at https://youtu.be/Fl1ZiNws7WE*

I hope you can use some of these ideas to make a SMED training more lively. Now go out and improve your Industry!

# 11 How a Little Bit of Industrial Espionage Started the Industrial Revolution

*Christoph Roser, March 16, 2014 Original at [https://www.allaboutlean.com/industrial-espionage-and-revolution/](https://www.allaboutlean.com/industrial-espionage-and-revolution/)*

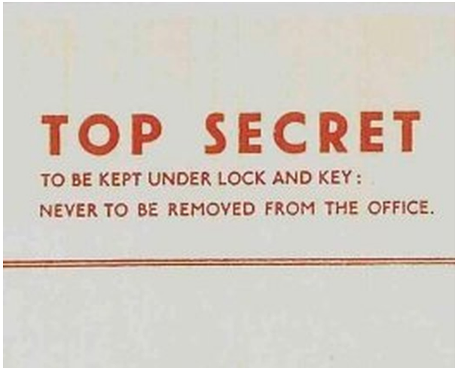


*Figure 52: Top Secret (Image Public Records Office in public domain)*

The Industrial Revolution changed the lives of ordinary people faster and more radically than any other period in history before it. Within only a few decades, small artisan shops were replaced by large factories. The Industrial Revolution started with the mass processing of cotton. Yet, as we will see, this happened only due to significant industrial espionage across multiple countries.

## 11.1 Prelude

Any modern industry is based on large-scale production. Even for highly specialized products, such as machine tools, a company doesn't make only one tool, but it tries to make as many (different) tools as possible. In order to make a profit with mass production, you need to have **large-enough material suppliers** and **large-enough markets**. During the early eighteenth century, there were few products that qualified.

One of the few products that qualified was clothing, especially cheap clothing made from cotton. Pretty much everybody in Europe needed clothes, hence we had a large market even considering the very limited transport capabilities. Since cotton came from America and India, it arrived quite literally by the shipload.

*Figure 53: Oh dear … I can't keep up with you… (Image Detroit Publishing Co. in public domain)*

The bottleneck for processing cotton, however, was spinning. One weaver with an eighteenth-century hand loom with flying shuttles could keep multiple spinners busy. This was especially true since spinning was typically women's work after other chores were done. Hence, the Industrial Revolution started with mass spinning of cotton.

## 11.2 Britain Steals Italian Spinning Technology

One of the first to try mechanized spinning in England was Thomas Cotchett. He built a water-powered mill for spinning silk in 1702. Silk was much easier to spin due to its longer fibers, but back then even more than it is today, it was a luxury product with a limited market. In any case, Cotchett could not get the mechanics sorted out and his company went bust in 1712.

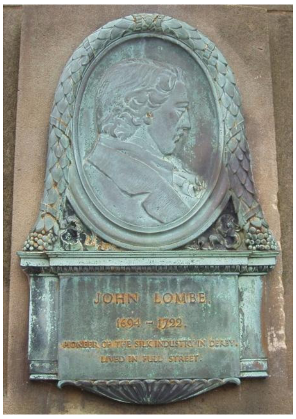


*Figure 54: John Lombe (Image Steve Bowen in public domain)*

One employee, John Lombe, wanted to establish a similar business. However, he was aware of his lack of knowledge of mechanized spinning. Back then, Italy was the technical center of the silk-spinning world, having used water-powered silk spinning since at least 1276, although they never built larger factories. In any case, Lombe decided to do a *study trip* to Italy and learned Italian in preparation. He didn't learn much from numerous silk plant visits, though, and he decided to become an employee of one of these silk-spinning establishments.

With a little bit of bribery to a priest, he managed to get hired. With a little bit more bribery, he convinced his foreman to stay in the workshop at night. Hence he worked during the day and made technical drawings and sketches at night. He hid these drawings in bales of silk that he shipped to his brother in England.

*Figure 55: Lombe's Silk Mill (Image unknown author in public domain)*

Now, his espionage was dangerous. Italy tried to protect its intellectual property, and the punishment was nothing less than the death penalty (and they meant it!). Just when Lombe was about to complete his intelligence-gathering mission, he was found out. He barely made it onto an English merchant ship. The Italians chased that merchant with a military vessel, but the merchant was able to outrun the Italians.

Hence, both Lombe and his drawings arrived safely in England, where Lombe started to establish a factory based on the stolen Italian technology. Naturally, before that he patented *his* technology. The silk mill was a smashing success.

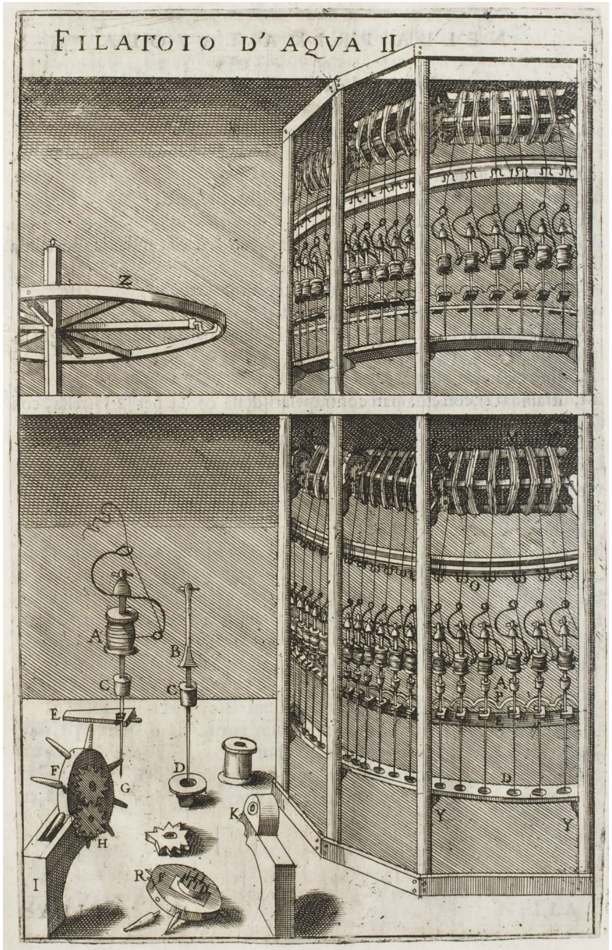


*Figure 56: Spinning mill in Teatro di Machines (Image Vittorio Zonca in public domain)*

In any case, he would not have needed to go through all the trouble. The technical details of the silk-spinning machinery was well documented in a 1607 book, *Theater of Machines* (*Novo Teatro di Machine et Edificii*) by Vittorio Zonca. These drawings were also of much better quality than Lombe's sketches. Copies of it were even available in British libraries.

## 11.3 Italy Retaliates (… or did it?…)

*Figure 57: Poisons are hard to trace … (Image Poeticbent in public domain)*

John Lombe successfully started his silk mill. Shortly thereafter, a beautiful young Italian woman started to work at the factory and befriended John Lombe. And, shortly after that, Lombe's health declined and he died very young and very painfully at age 29 of unknown causes.

Public opinion immediately knew what was going on – the Italian female assassin was sent by the King of Sardinia to poison Lombe. The woman was arrested, but lucky for her the English legal system was rather advanced. During the trial they could not find evidence and the court followed the *innocent until proven guilty* rule. The woman quickly left for Italy before the British would change their mind.

Lombe's brother Henry took over, but within a year he was dead, too. However, since he shot himself in the head, they could not really blame the Italians for that.

*Figure 58: Sir Richard Arkwright (Image Mather Brown in public domain)*

Another British entrepreneur, Richard Arkwright (among others), also improved on the now-British technology. Arkwright adapted the machines for the much shorter cotton fiber, building a cotton-spinning mill. As cotton was much cheaper than silk, demand was much larger, and Arkwright built a series of very profitable mills in the region.

As the Italians tried(unsuccessfully) to protect their secrets, so did the British now that it was *their* technology. As with the Italians, punishment was death, both for exporting technology and for emigration of skilled personnel. Yet, as we will see, that did not work either.

## 11.4 Germany Steals British Spinning Technology

*Figure 59: J. G. Brügelmann (Image unknown author in public domain)*

As Lombe was interested in Italian technology, so was a German businessman, Johann Gottfried Brügelmann, interested in British technology. Brügelmann sent a friend, Carl Albrecht Delius, to Britain. Delius bribed the right people and started to work for Arkwright's Cromford Mill. Not only did he learn about the technology and make sketches, but he also stole spare parts and convinced one British worker to emigrate to Germany. Thus British technology came to Germany. There is one difference, however. Brügelmann credited the British sources.

After establishing his new mill in 1783, he named it *Textilfabrik Cromford* after Arkwright's Cromford Mill.

## 11.5 USA steals British Spinning Technology

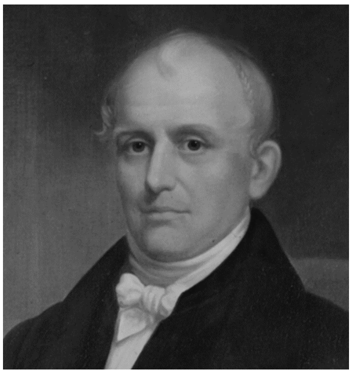

*Figure 60: Slater the Traitor … (Image James Sullivan Lincoln in public domain)*

As for the United States, they did not look for the technology, but the technology came to them. British-born Samuel Slater worked in cotton mills from a young age and had a deep understanding of the technology. However, at age 21, he decided to move to America, despite the obligatory death penalty for emigration of skilled technicians. Using a disguise, he arrived in New York City in 1790.

He soon was able to find two entrepreneurs and his future partners, William Almy and Smith Brown. Almy and Brown had already tried to run a mill similar to Arkwright's, but failed due to lack of technical knowledge. Hence Slater was the solution to their problem, and in 1793, Slater Mill in Pawtucket, Rhode Island opened. This first successful mill was followed by many others, and thus the secret British technology arrived in the US. Hence Slater is known as the *Father of the American Industrial Revolution* in the US. The British, on the other hand, know him as *Slater the Traitor*.

Hence, it is only through industrial espionage that the spinning technology traveled from Italy to Britain, Germany, the US, and subsequently the rest of the world.

## 11.6 Still a Popular Past Time…

Industrial espionage is still common nowadays. It is often associated with China (albeit since Edward Snowden, we know that America is much better at it). Yet, as we saw above, Western industry has also benefited from industrial espionage. While, of course, the owners of technology want to keep their intellectual property for themselves, other countries with less knowledge are dearly interested in this knowledge. Hence it depends entirely on your view if it is *Slater the Traitor*, or *Slater the Hero*. In any case, this whole circle of industrial espionage started with a princess stealing silk worms and mulberry seeds from China, without which there would be no silk in Italy in the first place.

As a citizen of a technology-rich country, of course I dislike espionage. However, I cannot really blame other countries for trying to advance through stolen technology. After all, if Europe and the US hadn't stolen any technology, we would be far from the industrial behemoths we are now. I also believe that it's difficult to keep technology secret. Intellectual property restrictions – albeit nowadays less frequently enforced by the death penalty – can, at best, slow the process down. Sooner or later, others will learn secret technologies. The lesson is: **We constantly need to develop new and better technologies, or we will fall back in the technological race.**

I hope this post was interesting for you. Now go out and improve your industry!

# 12 How to Manage Your Lean Projects – Number of Active Projects

*Christoph Roser, March 23, 2014 Original at [https://www.allaboutlean.com/active-lean-projects/](https://www.allaboutlean.com/active-lean-projects/)*

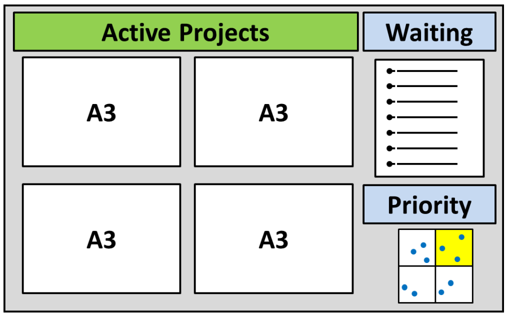


*Figure 61: Project management board (Image Roser)*

Let's face it – **you have more things to do than you can reasonably do in the available time**. A constant stream of tasks or problems are waiting for a lean solution. This two-post series wants to help you with that. In this first post, we will discuss how to avoid work overload using a simple **project management board**. A second post will tell you how to Manage Your Lean Projects – Prioritize.

## 12.1 Prelude – Work Life is Busy

In most industries I know, there are always problems piling up. If your work is related to the shop floor, logistics, or the customer, then the shop floor will provide you with a never-ending stream of issues to be addressed. If you're somewhat more distant from the shop floor, it is usually your manager or your customer providing a stream of tasks. In western management especially, it is common to simply hand down most problems to someone lower in the hierarchy and let that person sort out what's important and what's not. (However, in defense of top management, there are always enough problems left for top management).

In short: You have more work to do than you can do in the available time you have.

## 12.2 Don't Start Them All!

Facing a large number of tasks, **the worst thing you can do is to start them all!** Yes, you may be able to start (almost) all the tasks, but you'll be unable to complete them. Simply managing all the tasks will take so much time that you rarely get anything finished.

For an individual employee, working on two to three topics simultaneously is considered to be the best utilization of his or her time. This, however, does include the daily routine tasks, leaving capacity for only one or two side projects. Anything more will start to clog things up.

For organizations – say a plant or similar entity – there is, of course, more capability. However, these projects probably need a few key people (e.g., a master foreman, an engineer, or a programmer) to make this happen. In this case, they are the bottleneck on the number of projects that a plant can do simultaneously, and the system will get clogged up again.

## 12.3 Analogy: Manufacturing System

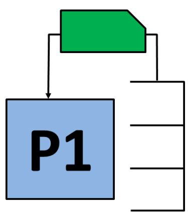


*Figure 62: One Process Kanban Loop (Image Roser)*

In manufacturing, one key concept for a lean manufacturing system is to limit the work in progress. To avoid overloading the system, a new work order is started only if a previous work leaves the system.

The most popular concept in lean manufacturing for this is Kanban, where a new part is produced only if a previous part has left the system. Another possible approach would be a *Constant Work in Progress* system, better known as CONWIP. The latter has advantages for a high-variety, low-volume mix of production. In any case, the workload in the factory has to be limited; otherwise, work in progress will inflate, costs will increase, and delivery times will suffer.

## 12.4 Limit the Number of Active Projects!

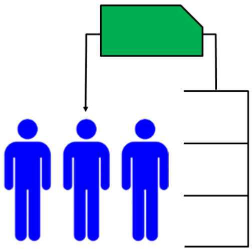

*Figure 63: Tasks Kanban Loop (Image Roser)*

This importance of limiting the number of works in progress also applies to project management. As a manufacturing system starts to clog up with too much work in progress, so will you. Simply managing the projects will take more time than actually advancing projects, and your change process slows down.

The solution is the same: Limit the number of projects that are active simultaneously. Start a new project only after a previous one has been completed. This way you will increase the number of projects completed. Even more important, projects are completed much faster.

## 12.5 The Project Management Board

An simple way to limit the number of projects that are active simultaneously is a project management board. Limit the space for the number of active projects on the board. In the example below, I have left space only for four projects, each represented by an A3 (a single sheet of paper to keep track of the project status, popular in lean manufacturing). All other projects that pop up are added to a waiting list. Only when a previous project is completed does a new project move into its place. Thus you can both limit and keep track of the number of active projects.

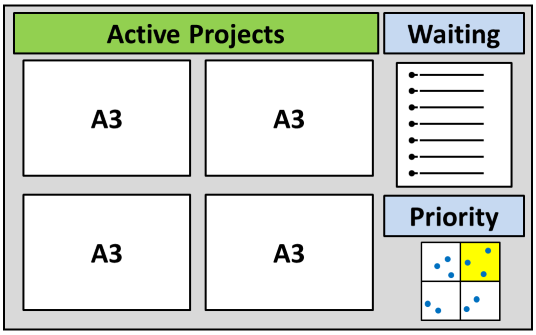


*Figure 64: Example for a Project Management Board (Image Roser)*

## 12.6 How Many Projects Simultaneously?

So how many projects should you have active simultaneously? It depends. As mentioned above, a single person works best with around two to three active projects (including daily chores). However, in the western world, management is used to higher numbers, and telling your boss that you won't start a project because you already have two projects going may raise an eyebrow or two. Depending on your boss, you may take on more projects than ideal for the sake of appearance. I don't like it, but I have been there, too.

As for larger groups, it is also necessary to restrict the number of ongoing projects. For example, if you manage a plant, multiple people will take on different projects. However, the restriction here is the people needed to make the projects work (e.g., the master foreman, engineers, or programmers). Hence I also would not shoot too high, but the details depend heavily on your plant.

## 12.7 Next: Prioritize

Once a project is completed, a new project is selected. In my post next week, I will tell you all about how to prioritize and select a project among many projects.

# 13 How to Manage Your Lean Projects – Prioritize

*Christoph Roser, March 30, 2014 Original at [https://www.allaboutlean.com/manage-lean-projects-prioritize/](https://www.allaboutlean.com/manage-lean-projects-prioritize/)*

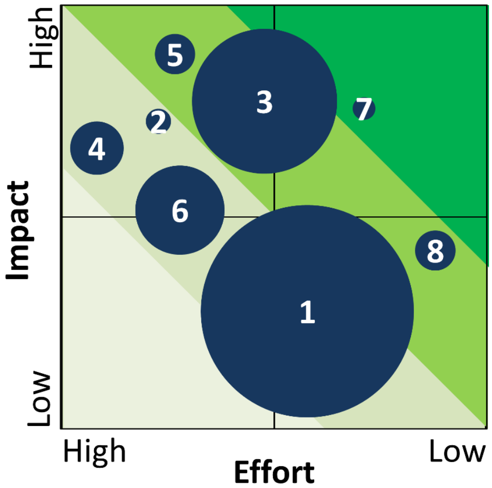


*Figure 65: Impact Effort Matrix (Image Roser)*

In our first post of this series, we discussed how to avoid void work overload using a project management board. The key was to limit the number of active projects. Start a new project only when a previous one is completed. This second post now details which project to start next. Here I want to emphasize the importance of **prioritization**. I describe some simple tools on how to quickly determine the most important task at hand.

## 13.1 Wrong Reasons for Picking the Next Project

In the previous post, we determined it was best to start a new project only when a previous project was completed. The question is now, among the many different projects waiting, which one do we start? There are many different ways of **how not to pick the next project**. Just picking one is already much better than starting with all tasks, but there are still plenty of wrong reasons to pick a task:

- Random Pick
- First Come First Serve
- Last Come First Serve (the older ones are being forgotten, and it shows action on new problems)
- Quickest to Do
- Most Annoying or Powerful Task Giver

What we want is the biggest bang for the buck. Which project will give us the largest benefit for our effort?

## 13.2 The Overkill – Cost Benefit Analysis

*Figure 66: Costs vs Benefits (Image J.-H. Janßen under the CC-BY-SA 3.0 license)*

The obvious solution to determine the project with the best cost–benefit ratio is to do a cost benefit analysis. A **cost benefit analysis** determines a joint metric (usually monetary), including all the costs and benefits for each project. Future costs and benefits may be discounted with inflation to estimate a current day value. After calculating the cost benefit for all possible projects, the project with the largest benefit is chosen.

A variation of this is the time until the **return of investment (ROI)**. In this case, the time when the upfront costs are returned by the benefits is calculated. In most industries, this ROI is desired to be less than two years, (i.e., the project should pay for itself within two years). The most preferred project is the project with the fastest return on investment.

However, in my view for most lean projects, a cost benefit analysis or a ROI analysis is overkill. There are two reasons for that. First of all, a cost benefit analysis is, in my experience, usually very imprecise. Besides requiring a lot of current data, it also needs substantial data on future events to give a reasonably accurate value. Even if the current data is available, data on future events is nothing more than guesswork. In the worst case, highly optimistic assumptions are made to push a particular project through or highly pessimistic assumptions are made to stop another project (just watch the TV news on political projects and you know what I mean…).

Secondly, **a cost benefit analysis is time consuming and therefore expensive**. It will take quite a lot of man hours to put together a good analysis. This may be worthwhile for multi-million-dollar projects, but most lean projects are on a much smaller scale. Hence, for lean projects, it is usually not worth the effort. In other words, **the cost benefit analysis of doing a cost benefit analysis is negative**.

## 13.3 My Preferred Approach – Impact Effort Matrix

For my everyday practical decisions, I prefer a much cheaper and faster version of the cost benefit analysis: an impact–effort matrix. There are different versions of this matrix found on the web, often with slightly different names. In essence, however, one axis shows the *effort/cost/difficulty/time* that has to be put into a project and the other shows the *impact/value/benefit/profit* that the project will yield.

To create such a matrix, a knowledgeable group should get together (a representative of the workers, leadership, engineering, logistics, etc., as needed) and quickly evaluate each project based on their gut feelings on both axes. The absolute placement is less relevant; rather, the relation of the projects to each other is of importance. This way dozens of projects can be evaluated within just a few minutes. An example result is shown below.

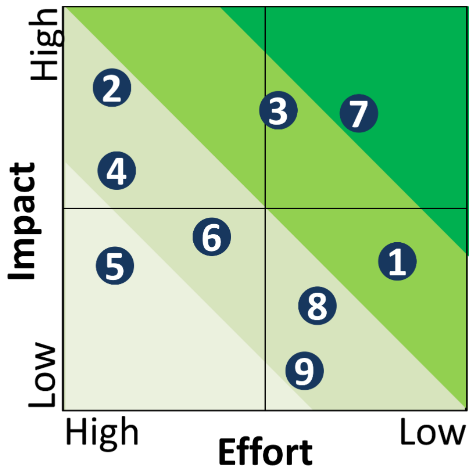


*Figure 67: Impact Effort Matrix, with project 7 being most desirable (Image Roser)*

Of course, since the whole estimation is based on gut feeling, the precision is lacking. But then, a full cost benefit analysis also often lacks precision. Additionally, the question is not which project to do, but which project to do **first**. A close second project will not be erased forever but will also be done eventually, just a bit later.

In the example above, the most desirable projects are in the upper right corner, where the projects have a big impact but require little effort. The best project to do next is the project closest to the upper right corner. In the example above, project number 7 brings the largest benefit for the effort. Hence, **such a matrix is a very quick and accurate enough method to prioritize your projects**.

## 13.4 Some Variations

There are some variations possible. I already mentioned above that the axes may have **slightly different labels**, albeit to similar effect. The axes may be called, for example, *effort/cost/difficulty/time* and *impact/value/benefit/profit*. Depending on how you orient the axes, of course, the ideal projects may be in a different corner.

A variation may also be to include a **third data set,** where the third set is represented by the size of the bubble as shown below. Thus you can add a third factor in the evaluation. For example, you could split impact into financial benefit and non-financial benefit. Other possible third variables are prestige, customer preference, or strategic importance (although the last one is often mixed up with "*the CEO really really likes that one…*").

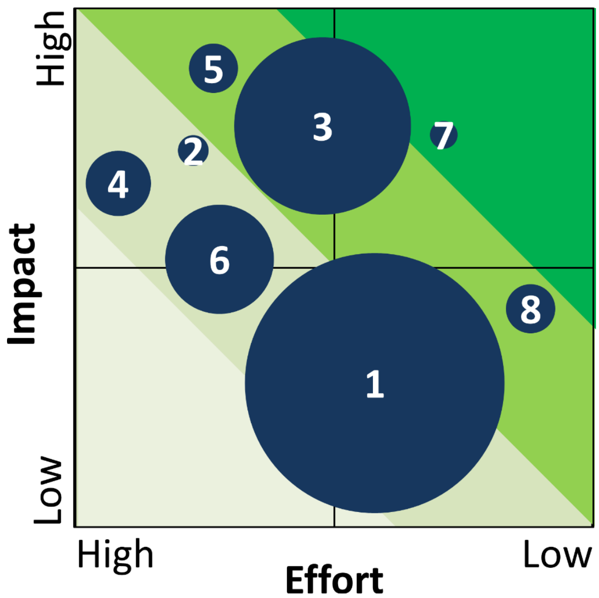

*Figure 68: Impact Effort Matrix with a third variable (Image Roser)*

However, in my experience, a third variable makes things more murky and often confuses more than helps. Hence **my advice is: Stick to two variables!**

Another variation is to **split the matrix into four or nine fields** and start processing the fields in a certain order. You can even **give the fields fancy names** like "*Stars*" or "*Go*" for the upper right in my example, and "*NoGo*'s" or "*Stop*" for the lower left. Consultants like to do that; this sounds more professional.

As said above, the impact effort matrix is a very quick but useful tool to make sure you put your effort in the right project. I hope this post helps you in your daily work. Contact me if you have any questions. And now go out and improve your industry!

# 14 A Lean Obituary for Maybach – A Cautionary Tale About Cost of Complexity

*Christoph Roser, April 6, 2014 Original at https://www.allaboutlean.com/maybach/*

*Figure 69: $439,000 gift with every car purchased (Image Janee under the CC-BY-SA 3.0 license)*

With the end of last year, Daimler stopped selling its flagship vehicle, Maybach. I would like to use this opportunity to talk about the danger and harm to your company by increasing the number of product types sold. As an illustrative (and expensive) example, I would like to split the total cost of the Maybach in its individual parts (as far as I can estimate them). My hope is that this motivates you to reduce, or at least no longer increase, the number of variants in your product portfolio.

## 14.1 The Maybach Story

*Figure 70: Maybach Logo (Image Endlezz under the CC-BY-SA 3.0 license)*

Maybach was a German luxury car maker. Operations started in 1909, and the last passenger car was built in 1940. In 1997, Daimler announced the revival of the Maybach brand, last built in 1940. The goal was to build a top-of-the-line luxury car that had no equals. Money was no object. This was just one of many bad decisions by then Daimler CEO Jürgen Schrempp (also responsible for the disastrous "Marriage in Heaven" with Chrysler). In any case, whenever money is no object, it will become expensive.

The base price of the cheapest Maybach was around $350,000, but additional options could easily multiply the price. The average sales price of every unit was probably at least $500,000. Sales were optimistically expected to be around 2,000 units per year. In reality, however, this was highly overestimated, and only a few hundred vehicles were sold worldwide per year.

Additionally, there were many different Maybach models available, splitting the low sales number over different versions. Additional options were, of course, available. For cars in this price range, the question is not so much what options the maker offers, but what extras the customer wants. Examples included mini fridges for champagne, real granite interior, and air-conditioned seats. Here's a list of Maybach models sold:

- Maybach 57 – 570 cm long

- Maybach 57 S – S for *Spezial*, having, for example, more engine power and a different suspension among other things
- Maybach 57 S Coupé – two door version
- Maybach 62 – 620 cm long
- Maybach 62 S – S for *Spezial*, having, for example, more engine power and a different suspension among other things
- Maybach Zeppelin – limited edition, more powerful engine, also available in 570- and 620-cm length
- Maybach Landaulet – sliding convertible roof for rear seats
- Maybach Exelero – designed for speed exceeding 350 km/h (initially considered a prototype, but a few units sold at about $8 million per vehicle)
- Maybach Guard – armored version for high-profile customers

Overall, the venture was a financial disaster. With every car sold, Daimler lost $439,000, or about $1.3 billion in total. In 2013, Daimer CEO Dieter Zetsche finally pulled the plug. Overall, between 1997 and 2013, only 3,000 units were sold, less than 200 per year. The primary reason for this financial disaster was too-low sales for too many different variants. Hence the fixed costs killed any chance of profit.

## 14.2 The Largest Cost Factors

### 14.2.1 Development

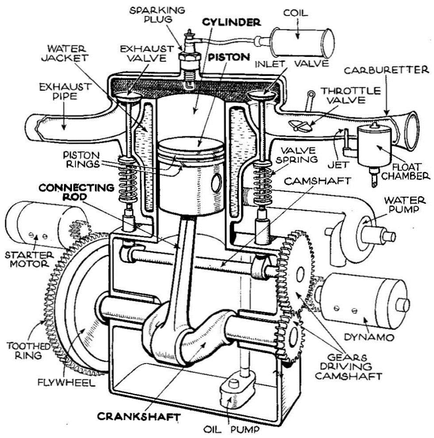


*Figure 71: A generic engine drawing (Image Andy Dingley (scanner) in public domain)*

Cost of complexity starts with development. Every new product has to be developed, including all necessary components. With cars, it is said that development of a new car will cost between $1 billion and $2 billion. With Maybach, I took a conservative estimate of $1 billion development cost for all variants combined. This does not include, for example, tooling and paperwork below which may have been included in the development cost. Overall, the **$1 billion development cost spread over 3,000 cars over lifetime added around $330,000 to each and every car**.

### 14.2.2 Tooling

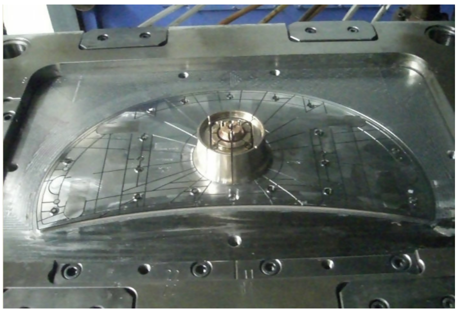

*Figure 72: Injection Molding Tool (Image Blue tooth7 under the CC-BY-SA 3.0 license)*

To produce, you need tools. Depending on your business, these tools may be expensive. If you are making cars, say, for example, a Maybach, you need lots of tools. Especially, the tools for the sheet metal presses are insanely expensive, as are the tools for injection-molded parts. You also may occur additional costs by changing tools or scrapping tools due to design changes or manufacturing problems.

For Maybach, I estimate that they paid around $300 million in tooling cost, adding another $100,000 to every car sold.

### 14.2.3 Paperwork

*Figure 73: Paperwork (Image Tom Ventura under the CC-BY 2.0 license)*

Do not underestimate the importance of paperwork! It is said that in the car industry, a single part number over its lifetime will cause costs of around $50,000 simply for the paperwork. The number has to be created, the documentation filed, updated, maintained, updated again for changes in the system, documented, etc. It is easy to see that this may cost $50,000 for a single number.

It is said that around 30,000 part numbers are needed to produce a single car. As for Maybach, I assume (hope!) that they utilized many parts from other vehicles. Nevertheless, I estimate that around 8,000 parts may have been created for the different Maybach versions. Hence, in sum this created **additional costs of around $400 million merely for the paperwork, or another $130,000 per car!**

Granted, car manufacturers have higher requirements on documentation than most other industries. Nevertheless, even in less complex technical industries you can expect paperwork cost of around $10,000 for every individual part number.

### 14.2.4 Raw Material and Finished Goods Inventory

*Figure 74: Typical Warehouse (Image Axisadman under the CC-BY-SA 3.0 license)*

To make cars, you need parts. While there is lots of talk about Just-in-Time deliveries with low inventory, most Western car makers still have weeks' worth of inventory in a single plant and months' worth of inventory in their supply chain.

Unfortunately, the fewer products you sell, the higher your inventory becomes per unit sold. Take, for example, finished goods. If you want to have your product in stock and readily available, you need at a very minimum one part in stock. Now, if you sell one part per year or ten thousand per year, the cost of your inventory as a part of the unit cost goes up.

Granted, if you sell more parts, you need more inventory for a good availability, but the inventory increases much more slowly than the number of parts sold. Overall, the more you sell of one product, the less inventory you need per unit sold.

With Maybach, sales were abysmal. Making another (very!) conservative estimate, I believe they had at least four months' worth of inventory and finished goods in the supply chain. Estimating $500,000 per car for an average of 187 cars sold per year, four months of inventory represents $30 million of tied-up cash. In traditional bookkeeping, this is now multiplied by the cost of capital (sort of the interest rate for borrowing $30 million to put them on the shelf), usually on the magnitude of 10%–15%.

However, this traditional cost of capital does not include the handling cost, storage cost, logistics operation, and organizational effort. It does not include the cost of defective goods, aged products, or goods damaged while handling. Overall, I believe the cost of having inventory is closer to 25% of the value of the inventory per year. Hence, $30 million of Maybach inventory would create **expenses of around $8 million per year, or around $41,000 per vehicle for only its inventory.** On the other hand, $41,000 per vehicle is small fry compared to the other expenses.

### 14.2.5 Manufacturing

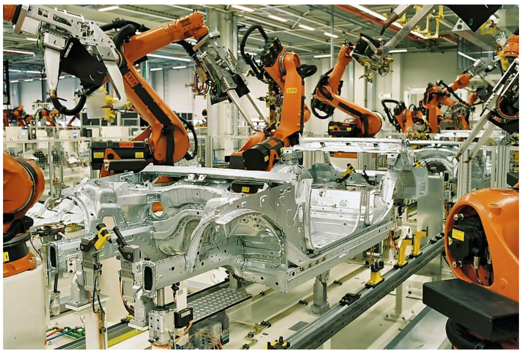

*Figure 75: Car manufacturing (Image BMW Werk Leipzig under the CC-BY-SA 2.0 Germany license)*

Let's not forget, you also have to actually produce the vehicle. Again, taking general industry knowledge, the actual production cost including raw materials, labor, energy, and so on is around half of the retail car price. As for the Maybach, **the actual cost of production may therefore have been around $250,000 per vehicle**.

Of course, due to the low quantities produced, Maybach was anything but an automated line. The car was probably mostly handmade wherever possible. The ideal condition for manufacturing is to make lots of units of a single part. The more you increase your variety, the more effort is needed to switch between products, train workers, shift around raw materials, and so on. In that aspect, Maybach was probably a very inefficient production.

### 14.2.6 Sales

*Figure 76: Mercedes-Benz dealership (Image Martin Falbisoner under the CC-BY-SA 3.0 license)*

You also need to sell the product. With manufacturing, the more units you sell of the same product, the cheaper your sales cost will be. In automotive, a common estimate is to assume sales as 25% of the total sale price, including advertising, show rooms, and so on.

With Maybach, again the 25% is probably a conservative estimate. In Daimler's view, the Maybach was too good for a common Mercedes showroom, so new, exclusive showrooms for the Maybach were built. Considering the total number of sales, these rooms were probably not too busy.

In any case, assuming 25% of the vehicle price for sales gives sales cost of about $125,000 per car or $375 million over lifespan.

### 14.2.7 Spare Parts and End-of-Life Ramp Down

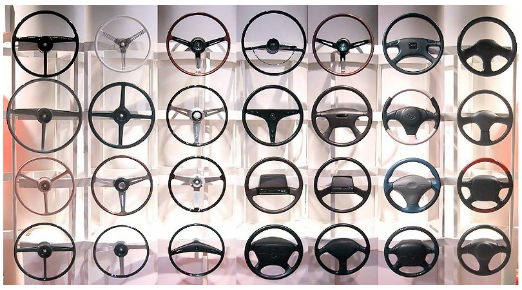

*Figure 77: Different steering wheels (Image Chris 73 under the CC-BY-SA 3.0 license)*

Finally, last year in 2013, Daimler pulled the plug and stopped the sales of Maybach. Unfortunately for them, **they have to provide spare parts for at least another ten years!** This is a major drag on resources for a company. Usually there are two options:

**Option 1**: Keep on manufacturing parts. This is unpleasant and expensive. The machines and tools were usually designed for much larger quantities. Running them for a few hours every year is quite a waste of resources. They have to be maintained, set up, the workers have to be trained, the material suppliers have to be kept active, quality control has to maintain the standards, and so on. Alternatively, you can spend even more money on downsizing the tools and machines, which is also quite a drag.

**Option 2**: Put enough spare parts in stock to last for ten years. Naturally, this is also an unpleasant option, as it ties up lots of capital, not to mention the storing, handling, and organizational expenses. There is the additional risk that parts may become defective. Or you may run out of parts before the ten years are over. Or you may have too many parts left after ten years, which you now can throw away. In any case, not a good option either.

In reality, most manufacturers try to compromise by producing for a few years before creating a stockpile for the remaining time and scrapping the old tools. Maybach will probably have to stock spare parts for the next ten years, long after production ceased. It is hard to estimate the cost of these spare parts, but it is again not to be underestimated.

## 14.3 Wrap Up

Overall, the Maybach venture was a huge loss for Daimler. Honestly, this was already pretty clear to me (and many others) when Daimler started to produce Maybachs. Yet, it seems business rationale went out of the window in favor of gearheads wanting to build the perfect car.To me it seemed like the former CEO, Mr. Schrempp, treated Daimler as his personal toy box to build himself a dream car. When cost calculations did not add up, sales numbers were probably adjusted upward, and additional fuzzy factors like "*good for the brand image*" added. Luckily, current CEO Mr. Zetsche finally pulled the plug on this crazy venture.

According to official numbers, Daimler lost about $1.3 billion. However, as this is very embarrassing for Daimler, I suspect that the official numbers are only the bare bones. There are probably many more losses related to Maybach that are accounted for somewhere else to make the officially reported losses smaller. The true losses may much higher, and I wouldn't be surprised if they exceeded $2 billion.

The graph below shows an estimate of the costs of a car averaged throughout the production run between 1997 and 2013 (but not accounting for inflation). Please keep in mind that many of these numbers are my rough by-the-seat-of-your-pants estimations and not official Daimler data.

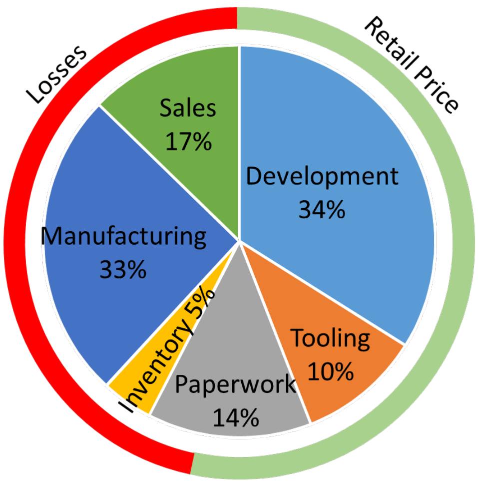


*Figure 78: Maybach Cost Structure Estimate (not official Daimler data!) (Image Roser)*

The main problem is the low number of units sold. The first three major cost-drivers – development, tooling, and paperwork – make up more than half the total cost. Yet these three are all more-or-less fixed costs. The cost is split evenly over the number of cars sold. Hence the more cars sold, the smaller the cost per car – so, as in Daimler's case, the less cars sold, the higher the cost.

The second three points – inventory, manufacturing, and sales – are traditionally variable costs (i.e., assumed to be the same on a per car basis). However, even there, larger numbers will reduce the costs, albeit less than for variable costs. Overall, Maybach was killed by its small numbers. According to my numbers, they would probably have to sell seven times as many vehicles just to barely break even. Please also note the large share of expenses for paperwork!

However, similar things happen every day in industry, except that the exotic product is not killed but kept in the portfolio. I have seen many companies where, on a smaller scale, complexity escalated and the number of product types multiplied while the total units sold did not change much. As an effect, cost went up and times got tougher for the companies.

If there is anything I want you to take with you after reading this (rather long) post, it is: Try to keep your number of product types under control, or even reduce them if possible! The cost associated with dividing the same number of units sold on more product types is significant!

I hope this was interesting for you. Now go out and improve your industry!

## 14.4 Same Story, different Maker…

*Figure 79: Same story, different maker… (Image M 93 under the CC-BY-SA 3.0 Germany license)*

Other car makers are not immune either to such expensive toys that please mostly management. The Volkswagen version of such a toy is the 1200 horsepower **Bugatti Veyron**. At a cost of at least €1.69 million only 425 vehicles (if you can call them that) have been sold. Production is stopping, and the last 25 vehicles on stock will be sold in the next few months. **The total loss for VW is estimated to be €1.7 billion**, even more than for the Maybach. Also akin to the Maybach, the large development cost plus the number of special options killed any chance of profitability. In any case, VW chairman Ferdinand Piëch surely must have gotten his excitement out of this automotive wet dream. However, it seems VW is a slower learner than Daimler, as VW is considering an even bigger successor for the Veyron. **I strongly believe that this successor will turn out to be a similar financial disaster in the billion-euro range**.

# 15 The Difference Between Lean and Six Sigma

*Christoph Roser, April 13, 2014 Original at*
*[https://www.allaboutlean.com/lean-and-six-sigma/](https://www.allaboutlean.com/lean-and-six-sigma/)*

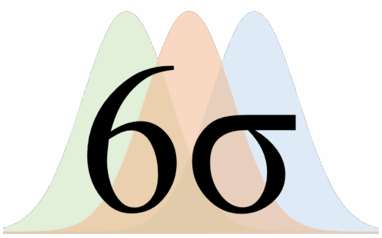


*Figure 80: Six Sigma (Image Roser)*

Lean Six Sigma (also abbreviated as 6σ) seems to be everywhere in industry nowadays. There are tons of consultants, job offers, projects, and articles about Lean Six Sigma. In this post, I would like to talk about **where Six Sigma comes from, its difference from lean manufacturing, the reason for its popularity, and its shortcomings.**

## 15.1 The Origins of Six Sigma

Six Sigma was originally a method for quality control, developed around 1986 at Motorola by Bill Smith. As such, it was a latecomer to the wave of quality control methods and tools that originated during World War II, like statistical process control, Total Quality Management, Zero Defects, and others. Six Sigma gained much popularity when General Electrics CEO Jack Welch introduced Six Sigma at GE in 1996, and it has been a consistent buzzword in manufacturing ever since. The graph below shows the likelihood of Six Sigma being mentioned in books. It started around 1985 with Motorola and really took off in 1996 with GE. (Source: Google Ngram Viewer)

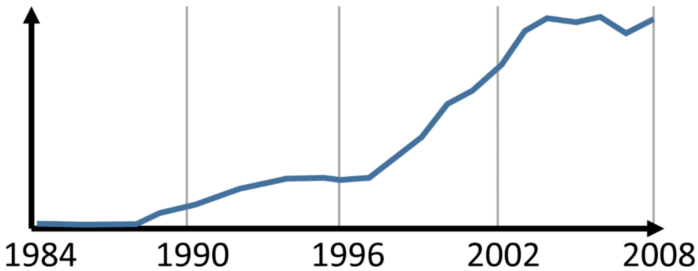


*Figure 81: Occurrence of Six Sigma in Literature (Image Roser)*

## 15.2 The Fundamentals of Six Sigma

Six Sigma started as quality control. I have the feeling the underlying idea was a "*more is better*" approach, where they simply increased the demands on quality and increased the requirements on tolerance levels. Many quality measurements do have a normal distribution. The distance from the center of the distribution is measured in standard deviations, or Sigma. Six Sigma simply requires the tolerance limits to be at least six standard deviations away from the center.

The graph below shows a blue standard normal distribution, with one standard deviation and six standard deviations shown. This is an ideal six sigma distribution, where the tolerance limits are six sigmas away from the center.

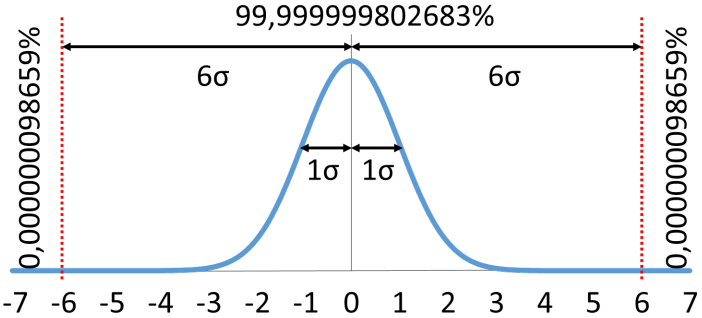

*Figure 82: Six Sigma over a normal distribution (Image Roser)*

In this case, 99.999999802683% of all parts produced would fall within the allowed tolerance limit, and only 0.000000098659% on either side. **This gives a total of only 0.000000197318% defects, or 0.001973175 parts per million (PPM).** Pretty good, isn't it? (Hint: No, it's not!)

However, Six Sigma realized that the mean is not always necessarily in the middle of the tolerance limits to begin with. Even if they are in the middle when measured, they may shift over time. Hence they allowed an additional shift of the distribution by 1.5 standard deviations to either side. Therefore, the distance to the closest tolerance limit may be only 4.5 standard deviations.

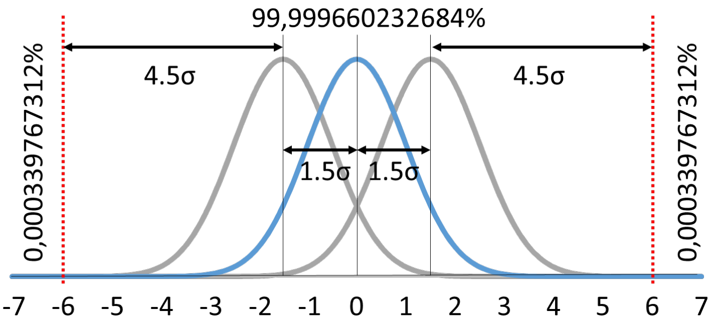

*Figure 83: Six Sigma over a normal distribution with 1.5 Sigma Shift (Image Roser)*

In this case, there are only 0.000339767312% of all parts outside the closer side (with a negligible 0.000000000003% on the other tail, so the true number of parts outside of the limit is 0.000339767316%). Hence, 99.999660232684% of all parts fall within the specification limit.

## 15.3 Six Sigma Does Not Work

You may have noticed above that I am skeptical of Six Sigma. There are a number of reasons why I believe it does not work.

### 15.3.1 Why Six?

First of all, why Six Sigma? Why not five or seven? Same goes for the 1.5 sigma shift. Why 1.5 sigma, and not one or two? There isn't really any basis behind it. I think the main reason is that the phrase *Six Sigma* is catchy. Six Sigma simply sounds better than Five Sigma. Additionally, this also sets a very high demand on quality. Often, in management and consulting, it's popular to set extremely high demands, hoping that at least some of them will materialize, or to have a readily available reason for blame if the project fails. But overall, the demands are very unrealistic, which brings me to my next point.

### 15.3.2 Unrealistic Demands

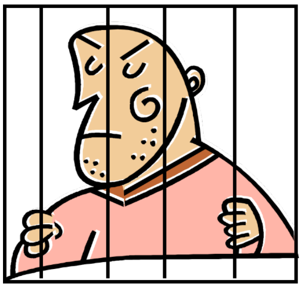

*Figure 84: The only one in the US? (Image Roser)*

The demands of Six Sigma are simply unrealistic. With the original Six Sigma requirements, 99.999999802683% of all parts would have to be good. If you apply this requirement to the population of the United States of 313.9 million people, there would be less than one defect. This means, for example, less than one person in the US would be hospitalized. Or, less than one person in the US would be incarcerated. It is easy to see that this is a very unrealistic demand, no matter whether we talk about people or products.

However, nowadays Six Sigma demands are truly only 4.5 sigma due to the shift of 1.5 sigma as explained above. Now only 99.999660232684% of the parts have to be good. This means almost two thousand times more defects than before. Yet, taking the US population as an example again, only about 1,000 people would be hospitalized or incarcerated in the US. Still highly unrealistic in my opinion.

For reference, there are almost one million hospital beds in the US, of which around 0.5 million are occupied at any given time. This is the equivalent of 3.2 Sigma. If you prefer the incarceration rates example, there were 7.0 million adults in the correctional system in 2011 (2.2 million were in prison, with another 4.8 million on probation or parole). This is the equivalent of 2.3 Sigma.

### 15.3.3 No Consideration of Cost-Benefit

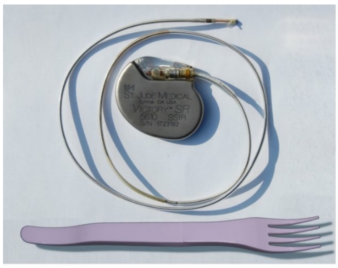

*Figure 85: Pacemaker and plastic fork: 6σ quality for both? (Image J. Heuser and Lionel Allorge under the CC-BY-SA 3.0 license)*

Six Sigma also completely ignores the relation of costs vs. benefits. To achieve even a relaxed 4.5 Sigma quality rate is expensive. Is it worth it? This depends heavily on the product, the market expectations, and the competition. Let's take two illustrative examples, a pacemaker and a plastic fork.

A pacemaker should work reliably for a long time. Failure of the pacemaker can mean death, or at least a major operation to exchange the product. Hence the cost of a defect is rather high, and it may be sensible to set high quality requirements.

On the other hand, a plastic fork is a cheap and disposable utensil. If it breaks, it usually does not harm anybody and is easily replaced. Hence the cost of a defect is rather low. It is possible to make stronger forks, but this comes at a price. Yet plastic forks are purchased exactly for their cheap price and disposable nature. Therefore it makes no sense at all to have high quality requirements on plastic forks.

Six Sigma, however, makes no differentiation regarding the cost of defect or the trade-off between the price for quality and the cost of defects. There is also no mentioning of the time to market, which is also influenced by quality improvements. If there is no cost-benefit trade-off, everything including the plastic fork should have Six Sigma (i.e., 4.5. sigma).

### 15.3.4 Stupid Reliance on Numbers

Six Sigma is based merely on tolerance limits and standard deviations. However, merely complying with the tolerance limit does not necessarily mean that the product is good. The tolerance limits may be wrong. Combinations of limits within tolerance may in sum be outside a tolerance – or a critical aspect may not be measured or even be measurable, and has no tolerance limit. Six Sigma has the highly dangerous belief that if the numbers match, then everything is fine. This goes contrary to my lean experience that only the real product counts, and relying on numbers will go haywire.

### 15.3.5 Metadata on Six Sigma Failures

Six Sigma was created by Motorola and GE. Motorola was going downhill, falling behind Nokia in 1998 and being split in two in 2011. Another company, 3M, significantly reduced Six Sigma because it was stifling creativity.

CNN did some analysis of Fortune 500 companies. Of the companies that started large Six Sigma programs, 91% have supposedly performed below the average of the S&P 500 since. Overall, many companies are reducing or have stopped their Six Sigma efforts. Please note that by this I mean the original Six Sigma standard deviation approach above, not the Lean Six Sigma described below.

## 15.4 Six Sigma Now Includes Lean

Even Six Sigma proponents are aware that the mindless application of the Six Sigma quality requirements are not beneficial. However, since then Six Sigma has expanded its scope. **Nowadays, Six Sigma usually means Lean Six Sigma**. The Six Sigma community incorporated the approach of lean manufacturing and its toolbox, rebranding it as Lean Six Sigma. This lean approach comes originally from Toyota, and lean manufacturing is nothing else than an (often flawed and misunderstood) implementation of the Toyota production system. **In my opinion, the Lean Six Sigma approach focuses too much on the methods and too little on the outcomes**, hence I believe it is less useful than normal Lean.

In any case, Six Sigma is not the only one trying to get in the steering seat of the lean manufacturing bandwagon. Total Quality Management (TQM) also offers lean trainings, as does the German work optimization organization REFA, Total Productive Maintenance (TPM), Methods-Time-Measurement (MTM), and others. However, Six Sigma is by far the most successful organization doing so, since they had a stroke of genius...

## 15.5 A Stroke of Genius – Black Belt Certifications

*Figure 86: Ooooh…Black Belts! (Image Gotcha2 under the CC-BY-SA 3.0 license)*

In 1987, Six Sigma trainer Dr. Mikel Harry came up with a new, catchy name for his trainings: **Six Sigma Black Belts**. Now you don't just get a certificate, you get a black belt. You are now *almost a Bruce Lee of lean manufacturing*. Or maybe not. In any case, its allegory to martial arts made Six Sigma trainings quickly become popular. Courses for black belts sold like hotcakes. Nowadays, there are a number of different belts you can earn, from beginner to champion level:

- Yellow Belt
- Green Belt
- Black Belt
- Master Black Belt
- Champion and Project Sponsor.

Try as you may, there is no official Toyota certification for being a lean expert (which would also go against Toyota's philosophy on its production system). Yet our industry craves certifications. The next best thing is to be a current or former Toyota employee. However, there is a limited supply on Toyota employees, and to become one requires more than a one-week training course (I worked for Toyota for five years, for example).

Industry believes the second next best thing is a Six Sigma certificate. Subsequently, there is a significant demand in industry for Six Sigma black belts and so there are also numerous training courses offered by various institutions. However, I am convinced these are all nothing but a beginner's training. You cannot learn lean manufacturing in a classroom with the exception of a few basics.

*Figure 87: A newly certified Master Black Belt! (Image Deutsche Fotothek under the CC-BY-SA 3.0 Germany license)*

Do you remember when you learned to drive a car? With a few days' worth of training, you were able to move around, hopefully not hitting anything else. But back then you were anything but a good driver. It takes years of driving to become truly proficient (and some people seem to never make it at all 🙂). This is the same with lean manufacturing. Even with a good instructor, a Six Sigma black belt training is nothing more than your learner's permit. This doesn't even consider the many instructors in Six Sigma who frankly have no idea what they are doing, or the many online Six Sigma courses of dubious quality.

I consider myself to have lots of experience in lean manufacturing, with many years at Toyota, McKinsey, and Bosch. This usually duly impresses others in industry. Nevertheless, I still occasionally get the question, "... *but do you have a Six Sigma black belt?*" **One day I swear I will take a $199 online six sigma black belt course just to shut those people up.**

## 15.6 Wrap Up

To summarize, I need to distinguish between the original Six Sigma tolerance requirements and Lean Six Sigma. **The original Six Sigma tolerance requirements do not work! Period! Don't even try!**

**Lean Six Sigma, on the other hand, is as successful or flawed as any other lean approach.** In my view, they are all just (usually flawed) copies of the Toyota production system. They often rely too much on rituals and numbers, and not enough on common sense and shop floor observations. In this, Six Sigma has even a higher tendency to rituals (black belts), methods, and numbers (six sigmas) than others, and neglects the actual outcome and performance.

On the other hand, there surely are also Six Sigma experts who make a positive difference and know what they are doing, just as there are some lean experts who have experience. Hence, if you are doing improvement projects, I don't care what you call it as long as it is done with common sense and shop floor observations. If you like the Six Sigma label, go for it. Just don't expect me to be impressed by a fancy belt. Instead, **do real improvement in real industry that shows lasting results!** Similarly, if you are looking for support for your improvement projects, it doesn't matter if it is someone calling himself Six Sigma or Lean, as long as he or she has experience. Unfortunately, a master black belt alone is not a certificate of experience, but merely a certificate of participation in a classroom training. **Try to find someone who knows what they are doing, even though they usually are not the cheapest consultant available** (see also How to Find a Good Lean Consultant).

I hope this post was interesting to you. Feel free to give me a feedback if you want. And now **go out and organize your industry!**

# 16 The Problem of Losing Kanban – Different Kanban Types

*Christoph Roser, April 20, 2014 Original at [https://www.allaboutlean.com/losing-kanban/](https://www.allaboutlean.com/losing-kanban/)*

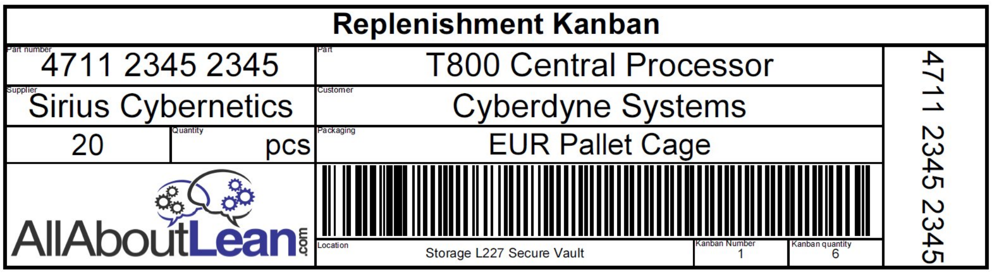


*Figure 88: Kanban card (Image Roser)*

Pull production using Kanban is one of the major achievements of the Toyota Production System and hence lean manufacturing. The work in progress is limited by the number of Kanban. Overproduction is avoided by producing only if a part is taken out of the supermarket and the Kanban card is returned to the start of production. However, this **Kanban system works only if the Kanban returns to the start of production. Losing Kanban means not reproducing goods sold**. In this post I would like to talk about different methods to prevent the loss of Kanban, including different Kanban types.

## 16.1 The Problem of Losing Kanban

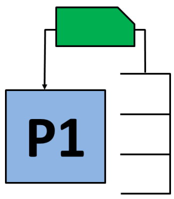


*Figure 89: Simple Kanban Loop (Image Roser)*

Kanban contain information about the type and number of products to be produced, where, and when. A working Kanban circle is essential for a working pull production. In many factories, Kanban is a simple sheet of paper. Unfortunately, in many factories, workers also have the **habit of throwing out random sheets of paper** found in material bins. In the often-confusing workplace, an important paper Kanban often gets thrown out like an unimportant sheet of scrap paper.

Or, to bring an even worse example, one plant laminated their Kanban in plastic covers. Unfortunately, these laminated Kanban made excellent ice scrapers for cars. Hence, every winter Kanban started to disappear quickly, since the employees used them to scrape the windows of their cars. Naturally, without Kanban, production started to have hiccups.

## 16.2 Countermeasures Against Losing Kanban

### 16.2.1 Stable and Robust Kanban Standards

One of the first things you should do for Kanban systems is to **make the system robust**. Is there a clearly defined place where the Kanban are attached to the material? Is it attached well, or is it likely to fall off during transport? For example, for larger iron products I had good success with magnetic Kanban that simply stuck to the part. Is there a defined place, or does the worker have to walk around the larger part to find the Kanban? Do you have a clearly marked Kanban box at the supermarket and at the start of production? Do you have a visual management to easily see how many Kanban are where? Your Kanban system has to be robust to reduce the likelihood of losing Kanban.

Furthermore, you should not cut your number of Kanban to the bare bones. It is always good to have at least some slack of maybe one additional card, so that the system does not break down immediately if one card goes missing.

### 16.2.2 Educate Your Workforce

*Figure 90: The honor of the shop (Image katorisi under the CC-BY-SA 3.0 license)*

Your workforce needs to know and understand the importance of these Kanban. Kanban need to be treated as important information for your production. In fact, the word Kanban comes from the Japanese word for shop sign, where the sign is not only a sign but the representation of the honor of the establishment.

Hence, you need to train your people about the significance of the Kanban. Importantly, not only the workers handling Kanban on a regular basis need to know about it; others that may or may not handle the Kanban at one point also need to know about it.

### 16.2.3 Digital Kanban

One way to reduce the losses of Kanban is by going digital, using, for example, an MRP system. You could print out a new copy of the card every time a product needs to be replenished. Hence there would be less handling of the cards, and hence less possibilities to lose them. On the other hand, I am always careful about going digital. In my experience, it usually works well in theory, but in practice there are more than enough problems arising from the use of computer systems. Overall, computers are a mixed blessing. In your case they may work, or maybe not. You decide.

### 16.2.4 Heavy Metal Kanban


*Figure 91: Heavy metal kanban (Image Roser)*

What definitely worked for me was to replace paper Kanban with metal Kanban, in this case attached to pallet cages. The shop floor lost too many paper Kanban, both intentionally (by workers throwing them away) and unintentionally (the cards fell off or slipped underneath the material). Switching to larger 30 x 30-cm painted metal plates with Kanban attached solved this problem.

The metal cards no longer fell off or slipped under the material. Even if they did, **the weight of the kanban card also gave mental weight to the worker**. Workers no longer threw out these heavy metal Kanban simply because they were heavy and looked important.

### 16.2.5 Boxes as Kanban

Of course, even bigger and heavier than a metal Kanban is to use **the whole box as a kanban**. In other words, the information is permanently attached to the box. Rather than returning the Kanban to the start of production, the entire box is returned and refilled. Similar for carts transporting the material, where the Kanban is permanently attached to the entire cart with the material.

### 16.2.6 No Kanban At All

Of course, the easiest way not to lose Kanban is to not have any in the first place. Unfortunately, this requires some special circumstances and is not always possible. However, it is not impossible. If the manufacturing system is only a single station adjacent to the supermarket, the worker can simply see the content of the supermarket and replenish the material with the least amount of stock. In other words, if the quantity of one product is nearing empty, the worker produces more of this product. However, this works only if the Kanban loop is small, having only one worker and not too many products.

## 16.3 Detecting Lost Kanban

*Figure 92: Magnifying glass (Image Roser)*

No matter how good your system is, at one point you will lose a Kanban. Even Toyota loses Kanban sometimes. For that reason, Kanban are usually numbered. Every now and then **the number of Kanban have to be checked**.

For digital Kanban, it is possible to have the system on a look-out automatically. If a number no longer circulates, it may be missing and need to be replenished. Paper Kanban are easiest to count if all the Kanban are in one place. For example, if for one product type all Kanban are in the supermarket, the number of Kanban are easy to count. If only one or two cards are missing, check if they are waiting for or are in production, or if they have been lost.

Such checks for missing Kanban have to be done on a regular basis. For newly established Kanban systems, I would do it more frequently until I got a feeling about the frequency of losing cards. The frequency of such Kanban checks can then be adjusted according to prior experience.

I hope this post was helpful for you. Now go out and improve your industry!

# 17 Cost of Complexity

*Christoph Roser, April 27, 2014 Original at [https://www.allaboutlean.com/cost-of-complexity/](https://www.allaboutlean.com/cost-of-complexity/)*

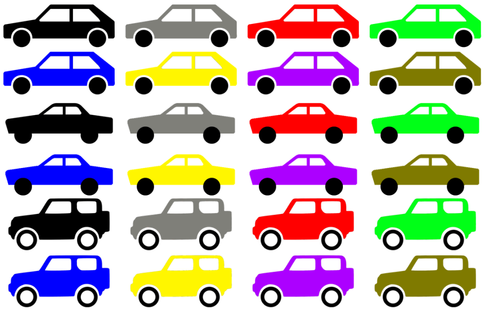

*Figure 93: Array of cars (Image Roser)*

The cost of complexity can significantly impact the bottom line of manufacturing companies. According to A. T. Kearney, the top 30 companies in Germany could earn €30 billion more if they would reduce complexity, increasing their EBIT by three to five percentage points. After discussing the cost of complexity in a previous post, using the Maybach as an example, this post describes the general levers influencing complexity cost.

## 17.1 Example: Lego – A Success Story

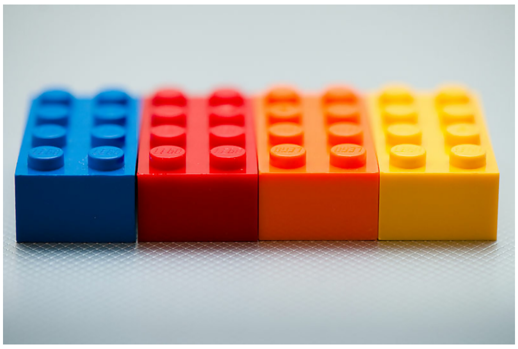

*Figure 94: Lego Bricks (Image Kenny Louie under the CC-BY 2.0 license)*

Reducing the number of variants can make an enormous difference in your bottom line. One highly successful example is the Danish Lego Group, maker of the famous Lego bricks. From its founding in 1932 until 1998, it made a profit every year. However, after 1998 the company went through enormous (self-made) problems and nearly collapsed in 2004.

That's when Jørgen Knudstorp took over (a former McKinsey consultant like myself). He managed an enormous turnaround, making Lego the second largest toy maker worldwide. One of his key measures was to reduce the number of different Lego pieces from 12,900 to 7,000, a reduction by almost half. He eliminated the color dark gray, leaving white, light grey, and black. The shapes of bricks now get reused; for example, the brown Lego croissant is also a white architecture element. This saved €50,000 by not requiring a new mold. He slashed the lifestyle part of Lego that sold watches and t-shirts. Even the Lego theme park got sold.

This reduction had a significant positive impact on their overall costs, and Lego is now again a very strong and highly profitable company.

## 17.2 Example: Automobiles – A Mixed Story

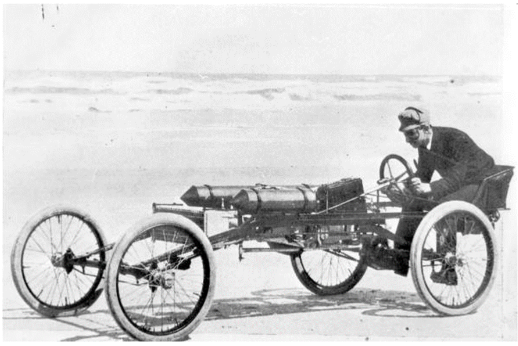

*Figure 95: Ransom E. Olds in the Olds Pirate racing car at Ormond Beach, Florida in 1896 or 1897. (Image LeSesne, Richard H. in public domain)*

Probably the best example of a large number of variants for complex products is automobiles. In a previous post I went into great detail about the Maybach. Naturally, with automobiles customers expect to have a number of selections available to choose from. The days of Henry Ford's Model T, available only in black, are long gone, and good riddance!

However, the number of variants still affects the bottom line. For example, both GM and Volkswagen offer a number of very similar cars under different brand names. In effect, they are competing with themselves, or – as it is called in industry jargon – they "cannibalize" themselves. They try to ease the pain by using different platform or module strategies. However, the large number of models is still a major overhead cost compared to Toyota, which sells even more cars but with much less models and variations.

Even within the same model, the number of options are relevant. For example, Mercedes offered an electrically extendable trunk floor for its S-Class. Most customers, however, viewed this as a gimmick, which is kind of obvious to me too. Even salespeople didn't know much about this option since they rarely sold a car with it.

## 17.3 Sources of Complexity Costs

Complexity can appear in different parts of industry. Probably most relevant is the **product portfolio,** also influencing the **supply chain**, **raw materials**, the **number of processes**, **brands**, and **packaging.** Roughly 20% of the products generate 80% of the value, and probably quite a few products burn more money than they make. Since my focus is on lean manufacturing, I will go into more detail for these groups.

However, don't forget about other areas causing complexity, including **market segments**, **customer portfolio**, **technologies** and **IT systems** used, and different **organizational structures**.

### 17.3.1 Development and Tooling

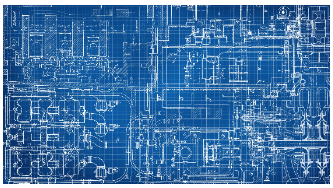

*Figure 96: Blueprint (Image xresch in public domain)*

Every new product needs to be developed, which will increase the fixed costs. The new product may also need custom tools, which adds even more fixed costs. All of this has to be earned again. On the plus side, cost accounting usually is able to associate most of the development costs with the product, so these costs are usually known.

### 17.3.2 Paperwork

*Figure 97: Paperwork (Image Tom Ventura under the CC-BY 2.0 license)*

Paperwork is not to be underestimated. For example, a part number in automotive will generate about $50,000 over lifetime for only creating and maintaining the number and associated documentation. This does not include any development or production, only the office paperwork for the part number.

Granted, automotive part numbers are high-maintenance part numbers, but even less demanding manufacturers can easily generate costs of $10,000 per part number over lifetime. That's all money you have to earn again! The problem is compounded by the fact that a new product usually has more than one new part number. If there are ten new part numbers, this would represent an expense of $100,000 over lifetime just for the paperwork.

Worst of all, in traditional cost accounting, this expense does not really pop up with the part number, but hides the cost in some general overhead categories. The paperwork associated with the product is often not even known.

### 17.3.3 Raw Material and Finished Goods Inventory

*Figure 98: Typical Warehouse (Image Axisadman under the CC-BY-SA 3.0 license)*

To sell products, you need stocks. You definitely need raw material stocks. Unless you produce exclusively on order, you also need stocks of finished goods. The more you sell of one part number, the less stocks are needed per unit sold for the same delivery performance. In reverse, if you divide your sales on more than one stock-keeping unit, the numbers sold go down per part number and the required stock per unit sold increases – or your delivery performance goes down.

However, inventory is not only waste (muda), but the biggest waste of all the seven types of waste. Excess stocks negatively affect a multitude of other parameters. Inventory is a multiplier of problems. It ties up cash, lead times are longer, quality problems are detected later, quality problems may result from longer storage, material has to be handled, and so on. In sum, significant costs are associated with inventory, only a fraction of which are accounted for in traditional bookkeeping.

If you are out of stock for finished goods, the customer is affected and this leads to lost sales, penalty payments, and a bad reputation, all of which are usually hard to quantify. In that sense, a lack of raw materials affects *only* your own production, creating chaos on the shop floor due to a switch in production schedule and re-organizing of the manufacturing process.

### 17.3.4 Training – and Forgetting

To produce new products, your employees have to be trained to produce the new product. The more different products they have to remember, the more likely it is that they will forget something. Hence not only do training costs increase, but also defect costs. Naturally, this training is not only in manufacturing, but also in sales and service. It is embarrassing if the salesperson does not know the product – but unfortunately it happens all too often.

### 17.3.5 Spare Parts and End-of-Life Ramp Down

Finally, there is a requirement for providing spare parts. In most Western countries, this is usually at least ten years after the stop of production. However, this means you either have to produce small quantities of spare parts for another ten years or keep ten years' worth of spare part stock. Neither option is desirable. Production in small quantities is very expensive. You need to re-train the workers for the small batch of materials every few months. You need to get small batches of material from your suppliers (if they are still around). You have to dig up and set up the old tools again. Even with the higher prices for spare parts, you probably will not break even if all costs are included.

Putting spare parts in stock for multiple years is sometimes the better option, but still expensive. You probably need whole warehouses for nothing but spare part storage. All these costs happen only at the end of the product life cycle, and hence they are hard to estimate at the beginning, let alone determine when production will end. In any cases, the person starting the development of the back-then new product will be long gone.

## 17.4 Summary

**Cost of complexity by introducing new product is a silent killer of revenue**. It usually does not show up in bookkeeping very well, but the harm is done regardless of the numbers. Yet in Western industry there is still a trend toward "*more is better,*" and the product portfolio is more and more segmented to chase even the tiniest sliver of a possible market. Besides, for upper management it usually looks better to introduce new products than to phase out old ones.

Even on the lower levels, this problem is not always understood. I had quite a few complexity reduction projects, where – if everybody would have gotten their way – there would have been **more products after reduction than before**. I have seen companies where enormous efforts were undertaken and resistance had to be overcome to eliminate two old products with very minor sales, while at the same time twenty new products were introduced at a whim. Manufacturing was collapsing under the complexity, material and finished goods availability was abyssal, total inventory increased, and chaos reigned everywhere.

Don't make the same mistakes. if you can, eliminate products and reduce the number of new products started. Do it like Jørgen Knudstorp and steer your company toward profitability. **Reduce your inventory and improve your industry!**

## 17.5 Sources


- T. Kearney: How Much Does Complexity Really Cost?, 2007
- Wikipedia: Complexity management

# 18 How Many Kanbans? – The Kanban Formula, Part 1

*Christoph Roser, May 4, 2014 Original at [https://www.allaboutlean.com/kanban-formula-part1/](https://www.allaboutlean.com/kanban-formula-part1/)*

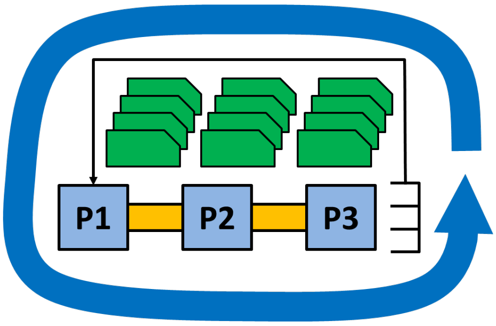


*Figure 99: How many Kanbans? (Image Roser)*

One frequent and tricky question when designing a pull system is to determine **how many kanbans** to use in the system. There are two possible approaches. First, you can **calculate the number of kanbans** using a kanban formula. Due to the length of the process, I have broken this into two posts (For the second part click here). Alternatively, you can **estimate the number of kanbans** and adjust the system as it is running (as shown in a third post).

## 18.1 Kanban Calculation Fundamentals

The number of kanbans defines the performance of a pull system. If you use too few, you will have constant problems with interruptions and missed deliveries or idle workers and processes. If you use too many, you waste space and money for inventory. Of course, if you have the choice between missed deliveries/idle workers or two more parts on the shop floor, I would go for two more parts. Hence in kanban calculations, it is customary to err on the conservative side and, in case of doubt, use more kanbans.

### 18.1.1 Factors Influencing the Calculation

Overall, there are five factors that determine the number of kanbans in a system. The first four are rational and are shown in the picture below. The fifth one is not very rational, but it is still needed for the system to work smoothly. These five factors, in the order we will cover them below, are:

- **Regular Time of Customer**: How many parts does the customer need in a certain period?
- **Regular Time of Replenishment System**: How long does it take to replenish a product in your production or supply system?
- **Fluctuations of Replenishment System**: If there are problems in the replenishment system, what problems do we want to cover?
- **Fluctuations of Customer**: If the customer orders more quantity, or the same overall quantity but less frequently, which fluctuations do we want to cover?
- **Safety Margin**: Do we want to add additional kanbans so personnel feels more comfortable with the system?

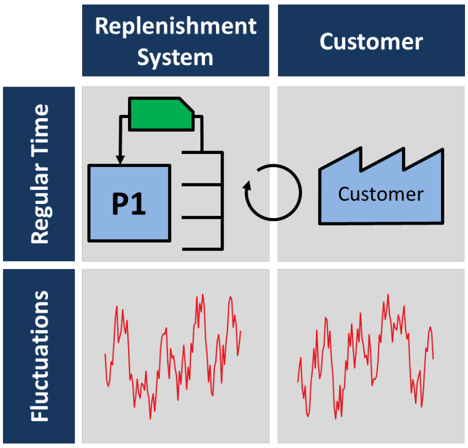

Figure 100: Kanban Factors (Image Roser)

The first two factors will be explained in detail below. The other three factors will be described in the second part of this series of posts on Kanban calculation.

Of course, a major underlying assumption for the kanban calculation is that the system can deliver parts faster than the customer needs them. **If your system is too slow, no amount of kanbans will increase your delivery performance. A second assumption is that raw materials for the kanban system are always available.**

### 18.1.2 Precision of the Kanban Calculation

*Figure 101: No, it is not! (Image Lucasbosch under the CC-BY-SA 3.0 license)*

Kanban formula, kanban calculation … it sounds like physics or science, it all sounds so precise. But let me be very clear on one point: **It is not precise! The kanban calculation is nothing more than a very rough estimate** using many assumptions. Slightly different but equally valid assumptions may easily change the result by 30% or more. I will point out the assumptions and their effects below to show you the level of *precision* of the kanban formula.

## 18.2 Kanban Calculation – Part 1

Below are the mathematical calculations (estimations!) to determine the number of kanbans. Important: **You need to calculate this separately for every product type that you want to put in your kanban stock!** Do not calculate this only once for the sum of all product types and then split the kanbans according to volume of the product types. This will not work!

### 18.2.1 Regular Time of Customer – Customer Takt

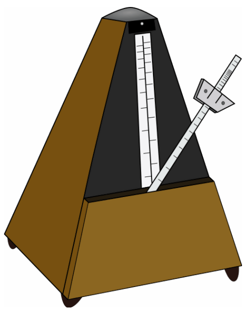
*Figure 102: The customer takt (Image unknown author in public domain)*

The demand on our kanban system is set by customer demand. The average time between parts ordered by the customer is the basis for converting delays in the system into needed kanbans. We need the so-called **customer *takt*** (where *takt* comes from German and means tact, pulse, or timing). If you have multiple kanban loops in sequence, always take the final customer of the system, not only the demand by the next loop.

To calculate the customer *takt,* you first need to decide which time period you want to look at. This could be, for example, a week or a month. Then you need to estimate the working hours of your system during this time period. Next you need to estimate the total number of parts delivered to the customer in the future during this time period. The customer *takt* is now simply the total available working hours of your system divided by the total customer demand during that period. Now you have the average time between the demand for a single product (i.e., your customer *takt*).

For example, say you decide that you want to look at the next four weeks. During these four weeks, you work five days per week with two shifts of seven hours each. Hence in total you have 280 work hours available during the next four weeks, or 1,008,000 seconds (4 weeks x 5 days x 2 shifts x 7 hours; with 3600 seconds per hour).

You estimate that the future demand by your customer during the next four weeks is 36,000 parts. Dividing your 1,008,000 seconds by 36,000 parts gives you a customer *takt* of 28 seconds per part. Hence, on average your customer will order one part every 28 seconds.

I mentioned above that the kanban calculation is a **very rough estimate**. We already have some uncertainty here. Will your system really work 280 hours, or will there be a meeting, a strike, overtime, a day off, or some other interruption? Also, for your customer demand, will the customer really order 36,000 parts? Or will it be more parts due to your customer running out of stock, or less parts if your customers's demand goes down? All this adds uncertainty. My advice is to make a good estimate, but don't overdo it. There are much more fuzzy things to come below.

### 18.2.2 Regular Time of Replenishment System – Replenishment Time

Next we look at the time needed for one kanban to make a complete circle. If a part is taken out of the supermarket, the kanban is sent back for replenishment. The time between the kanban leaving the supermarket and the kanban coming back to the supermarket attached to a part is hence known as the **replenishment time**. For our kanban calculations, this replenishment time is needed to estimate the number of kanbans to supply the customer while the supermarket is restocked.

One important part of this replenishment time is the time from the beginning of the actual processing at the first process until the part with the kanban comes back to the supermarket. This time is known as the **lead time**. For easier understanding, we start our calculations by determining the lead time (i.e., the time for the material flow).

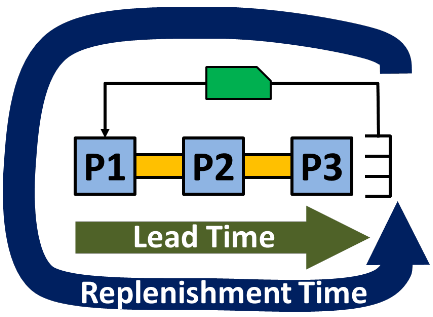

*Figure 103: Lead and replenishment time (Image Roser)*

*18.2.2.1 Lead Time*

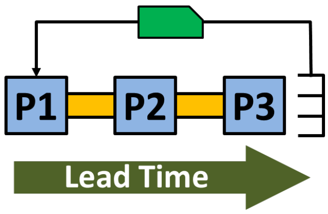


*Figure 104: Lead Time (Image Roser)*

The lead time can be calculated rather straightforwardly using Little's Law. Little's Law, named after its discoverer, John Little, determines (for our purposes) the lead time based on the number of parts in the system and the speed the parts are leaving the system. The law is quite simple, rather precise, and in my view very beautiful.

$$Lead\ Time = \frac{Inventory}{Throughput}$$

For example, if you have an inventory of 100 parts in the system and the throughput states that there are 10 parts leaving per hour, then the total lead time is 10 hours (100 parts divided by 10 parts per hour). A good example is waiting in a supermarket line. If there are ten people in front of you and on average the check out staff serves two people per minute, then you will have to wait five minutes.

The law is widely valid and quite precise. Unfortunately, the imprecision comes from getting the data, which adds more fluffiness to our **very rough estimate**. **What number to use for the parts in your system?** Of course, you can count them now, but will this still be valid tomorrow? With respect for kanban calculations, I recommend a conservative approach. Take the maximum number of parts that fit in your system (i.e., assume all your FiFo lanes are full and all your machines are loaded to capacity). It may or may not happen, but you still want your kanban system to work when it happens.

Secondly, **how fast are your parts leaving the system?** Here again you could use different numbers. You could use the inverse of slowest cycle time, or the long-term average throughput, etc. I usually use the long-term average throughput or the inverse of the customer *takt* (which should be similar anyway). In this way I have also already included fluctuations and losses in the system.

Additionally, you must not forget **changeover times**. If a kanban arrives at the first process and then has to wait for the set-up (changeover) of the first process, then this time has to be added to the lead time too. If multiple processes in serial or parallel order have changeover time, you have to keep an eye out for overlaps. **How much does the lead time increase in total due to changeover times?**

Of course, if your lead time includes **delays for bulk processing or shipment**, you have to take this into account too. For example, if your kanban loop includes shipping from China, then the ship takes two months including customs, no matter how many parts are on the ship. In this case, the lead time would be two months.

*18.2.2.2 Replenishment Time*

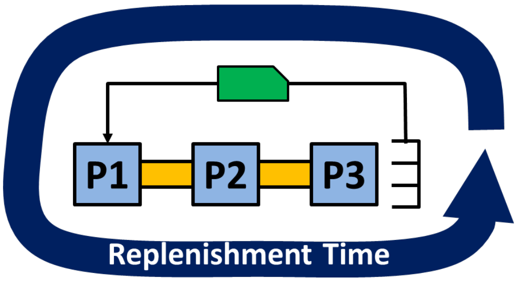


*Figure 105: Replenishment Time (Image Roser)*

The replenishment time now consists of both the time of the material flow (the lead time) and the time for the information flow. Since we just calculated (estimated!) the lead time, we now merely have to determine the time for the kanban from the supermarket to the start of production.

The first part is the **waiting time of the kanban at the supermarket after the part has been taken out and the physical movement of the kanban**. For example, if every hour a team leader brings the kanban from the collection box at the supermarket to the production, the average waiting time of a kanban at the supermarket would be 30 minutes. However, kanbans can wait up to 60 minutes if a part was taken out of the supermarket just after the team leader collected the cards. Nevertheless, the kanban system still has to work. Hence we assume here the time between pickups as the waiting time at the supermarket.

Secondly, a lot size for production may not only be one kanban but multiple kanbans. For example, if production starts only for a lot size with multiple kanbans, **the first kanban has to wait for the remaining kanbans of the lot until a lot is complete and it can be processed**. While the average waiting time is shorter, the **maximum waiting time is the lot size in kanban minus one**. Using a conservative approach, we hence take the maximum waiting time. if your lot size is 10, the waiting time is 9 kanbans; if your lot size is 25, the waiting time is 24 kanbans; and so on. We could now convert the number of kanbans into waiting time, but later on we want to convert the time back into kanbans. Hence, here we keep the waiting time in kanbans to add them later to the kanban total.

Finally, a lot size may not be processed immediately. There already may be **other lots waiting for processing before a kanban in the latest lot gets its turn**. This is usually a major part of the replenishment time. Unfortunately, this is also very hard to estimate. I have emphasized above that the kanban calculation is only a **very rough estimate**. This part here is the kicker in terms of imprecision. The waiting time for other lots can fluctuate wildly. What I usually do is assume that for every high-runner product, one lot size (which may be multiple kanbans) is waiting in front of the latest lot.

For example, assume you have 10 types of product, 5 of which are frequent high runners, and each of them has a lot size of 4. In this case, the latest lot may wait for 4 other lot sizes representing 16 kanbans (if it is a high runner too), or 5 other lot sizes representing 20 kanbans (if it is a less frequent exotic part). But again, this is only **the roughest of the very rough estimate**. Here +/- 30% are easily possible depending on your assumptions. Determining all other factors (customer *takt,* parts in line, time between parts, etc.) in high precision is a waste since this estimate negates all this precision. It is almost impossible to get precise data here, but you can’t ignore it since it is a big part of the kanban loop.

As for the lot size above, the waiting time for other lots can be expressed in kanbans, which we could now convert into time just to convert them back later into kanbans. However, my preference is to keep these as kanbans and merely add them to the total later.

In the second post on kanban calculation, I will describe how to include the **fluctuations of both our own system and the system on the customer side, before tallying it up and adding**

**the safety margins**. The final post will then describe a different approach using kanban estimation and maintenance of the number of kanbans.

# 19 How Many Kanbans? – The Kanban Formula, Part 2

*Christoph Roser, May 11, 2014 Original at https://www.allaboutlean.com/kanban-formula-part2/*

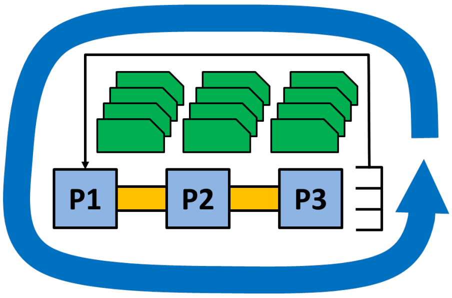


*Figure 106: How many Kanbans? (Image Roser)*

This is the second post on kanban calculation (if possible, please read the first post on kanban calculation first). There are two possible approaches. First, you can **calculate the number of kanbans** using a kanban formula (due to its length, split into a first post and this second post). Alternatively, you can **estimate the number of kanbans** and adjust the system as it is running (as shown in a third post).

## 19.1 Kanban Calculation – Part 2

Overall, there are five factors that determine the number of kanbans in a system. The first four are rational and are shown in the picture below. The fifth one is not very rational, but it is still needed for the system to work smoothly. These five factors, in the order we will cover them below, are:

- **Regular Time of Customer**: How many parts does the customer need in a certain period?
- **Regular Time of Replenishment System**: How long does it take to replenish a product in your production or supply system?
- **Fluctuations of Replenishment System**: If there are problems in the replenishment system, what problems do we want to cover?
- **Fluctuations of Customer**: If the customer orders more quantity, or the same overall quantity but less frequently, which fluctuations do we want to cover?
- **Safety Margin**: Do we want to add additional kanbans so personnel feels more comfortable with the system?

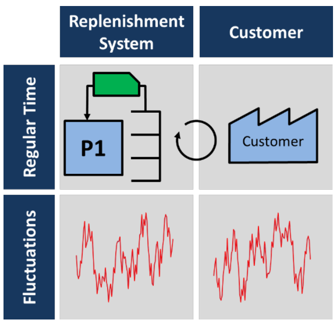


*Figure 107: Kanban Factors (Image Roser)*

Out of these five factors, the first two were covered already in my previous post How Many Kanbans? – The Kanban Formula, Part 1.

### 19.1.1 Fluctuations of Replenishment System

*Figure 108: Just a second …. (Image James Salmon in public domain)*

The system delivering the new products naturally will have hiccups. Not everything will go according to plan, and sometimes there will be delays. Average delays and losses have already been included when calculating the lead time. When calculating how fast the parts were leaving the system, we used the long-term average performance of the system. Hence we already included long-term average losses.

What we did not include were short-term problems. For example, assume your system has technical problems and is down for two hours. You would need to have enough kanbans in the system to cover these two hours until the system can catch up again. Similarly, if you want to cover breakdowns up to four hours' duration, you would need four more hours in kanbans.

Unfortunately, no matter which time you cover, you can easily imagine a problem that would be longer than the covered time, however unlikely. Here **you have to decide what you want to cover and at what point you decide to take the bullet and run out of stock** rather than keep insane amounts of stock available all the time. This decision should be based on previous experience with the reliability of your system, and the amount of problems your company has if the customer misses his parts. Keep in mind that so far we have always used conservative estimates for other factors, hence your total covered time is likely to be higher than the time you add here.

### 19.1.2 Fluctuations of Customer

*Figure 109: Customers … sometimes a tragedy, sometimes a comedy (Image unknown author in public domain)*

The fluctuation of the customer is similar. Here we have two factors to consider. First of all, not all customers have their parts delivered one by one. It is more common for a customer to have **multiple parts shipped at the same time** or even only once per week or once per month.

However, the system as calculated above so far only ensures that you have one kanban worth of parts in your system at any given time. If your customer wants five kanbans worth of parts in one shipment, you need to add four more kanbans. Please keep in mind that a kanban may represent more than one part.

For example, you estimate that your customer usually has shipments of 200 parts at one time. Yet you have only one kanban in the system representing 20 parts. Hence you need to add 9 additional kanbans to cover the bulk shipments.

Secondly, **your customer may or may not order as many parts as estimated by the customer *takt***. If he orders less, you do not run out of parts. If he orders more, you may need additional kanbans. The key here the replenishment time. If your customer orders more, your system will produce more but be delayed by the replenishment time. Hence you need to cover any additional demand during the replenishment time to give your system time to catch up.

Therefore, you need to estimate what a possible **additional peak demand within a replenishment time** could be. This demand has to be covered by adding additional kanbans. For example, if you estimate that besides the average 100 parts ordered during the replenishment time, your customer may order 100 more, then you would need 5 additional kanbans if each kanban represents 20 parts.

### 19.1.3 Calculating the Total Number of Kanban

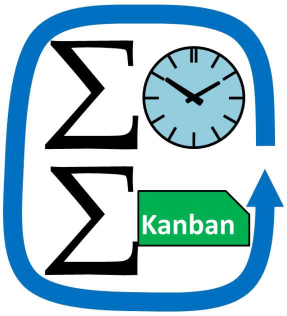


*Figure 110: Time and Kanban (Image Roser)*

Now we have everything together – except for the safety factor – to estimate the number of kanban. We have a number of times that we can sum up:

- Lead time (material flow) from 2.1 in my previous post
- Waiting time of kanbans in the supermarket (as part of the replenishment time) from 2.2 in my previous post
- Duration of breakdowns and other problems in our system we want to cover from 3. above.

We also have a number of kanbans that we can sum up:

- Lot size formation from 2.2 in my previous post
- Waiting for other lots from 2.2 in my previous post
- Customer batching orders from 4. above
- Additional peak customer demand from 4. above.

Summing up the time, we now have to convert the time into the number of kanbans. For this, we need the customer *takt* (from 1. above). Dividing the total time by the customer *takt* represents the number of parts that we need to cover. Dividing this further by the number of parts per kanban gives us the number of kanbans.

For example, assume we calculated a total time of 4:04 hours, or 14,640 seconds. Dividing this by our customer *takt* of 28 seconds per part gives us 522.86 parts. Further dividing this by 20 parts per kanban gives us 26.14 kanbans needed to cover the different times. Don't round this number yet.

Next we add the different number of kanbans from above to the kanbans needed to cover the time. For example, assume we had another 20 kanbans from lot size, customer batching, etc. Our total would now be 46.14 kanbans. (Still don't round this number yet.)

### 19.1.4 Safety Margin

*Figure 111: Safety gear (Image Compliance and Safety LLC under the CC-BY-SA 3.0 license)*

The last thing to add would be the **safety margin**. Technically, this is usually not needed. The kanban calculations above – for all their uncertainty – are usually quite conservative, and you may get away with even fewer kanbans. However, in many plants, shop floor personnel or lower management have negative experiences with upper management cutting margins too thin, hurting plant performance and therefore creating problems, especially for the people on the shop floor. Plus, your problems may be bigger than you think they are.

The safety factor is a way of giving additional safety to people who worry if the numbers match or if there will be a mess on the shop floor afterwards. Hence we simply add either more kanbans or a percentage to the kanbans calculated so far, until the people involved (possibly including yourself) feel more comfortable. Strictly speaking it is not necessary, but **the few extra kanbans are usually worth the peace on the shop floor**.

At this point we can also round the number of kanbans. As our previous calculation was far from precise, we do not necessarily need to round up. If our total stands at 61.2 kanbans, I would be happy to also round down. For 61.9, I would probably round up. Usually I include the rounding as part of the safety margin discussion or decide based on gut feeling about the conservative numbers used so far.

And that's it. There you have it. You have estimated the number of kanbans needed for a kanban loop. Just keep in mind that this is only a **very rough estimate**. In the next and last post of this short series, I will present alternative methods to determine the number of kanbans, including comments on how to maintain and update the number of kanbans in the system. Now go out and **improve your industry!**

# 20 How Many Kanbans? – Estimation Approach and Maintenance

*Christoph Roser, May 18, 2014 Original at [https://www.allaboutlean.com/kanban-estimate/](https://www.allaboutlean.com/kanban-estimate/)*

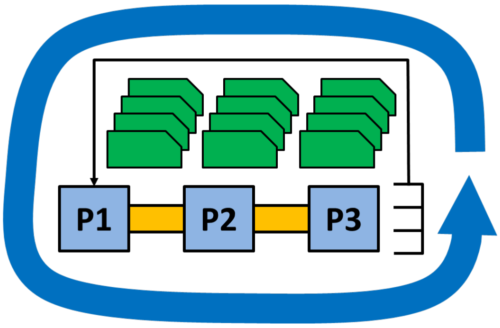


*Figure 112: How many Kanban? (Image Roser)*

In my previous two posts, I described how to calculate the number of kanbans (Post 1 and Post 2). However, this calculation is complex, and the result is nothing more than a very rough estimate. Hence my preferred method for determining the number of kanbans is, broadly speaking, "*just take enough, and then see if you can reduce them.*" In this post, I would like to explain this approach and also discuss how and when to update the number of kanbans.

## 20.1 Simply Estimate the Number of Kanbans

When determining the number of kanbans, rather than going through the calculations, you could simply estimate the number of kanbans. For this you need a bit of experience, but it is doable. I also recommend not doing it alone; instead, do this as part of a group that includes a foreman or team leader from the affected shop floor.

Of course, this estimation is also not very precise. I usually go for a conservative number, where I believe I'll definitely have enough kanbans. Having many parts instead of a few is better than missing deliveries or idling workers. *But isn't lean all about reducing material?* Not all, but yes, it is one aspect of lean. Once your kanban system is up and running, of course you should verify if the number of kanbans fit the system.

## 20.2 Verify if the Number of Kanbans Fit the System and Adjust if Needed

How do you verify if the number of kanbans fit the system? Simple. You track your supermarket inventory. Ideally, you may have a distribution as shown below. The graph shows the inventory for one product type in your supermarket, which can vary between zero (stock out) and the maximum of all kanbans being in the supermarket. **This graph below would be an ideal distribution. You never run out of stock, and since your supermarket is never full, you also never run out of work.**

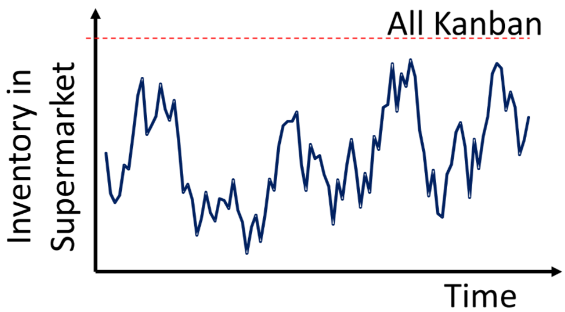


*Figure 113: Ideal number of kanban (Image Roser)*

In reality, however, you may touch both the upper and the lower limit sometimes. **Touching the upper limit is no problem**. Especially if you work in larger batches, this may happen frequently. In this case your graph may look like the graph below.

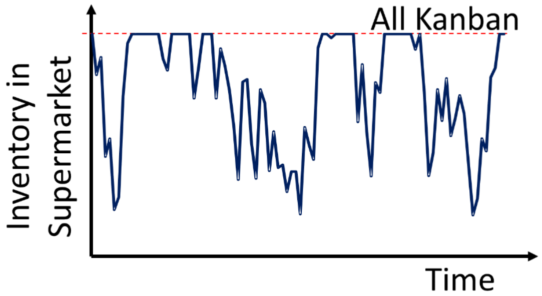


*Figure 114: Also good number of kanban (Image Roser)*

Occasionally, however, you may run out of stock. As shown in the example below, your system ran out of stock once during the observed period. Of course, more kanbans could have buffered you against this stock-out, but you have to decide if this is worth the additional kanbans. If it happens very infrequently, you may decide to live with it rather than increasing your inventory.

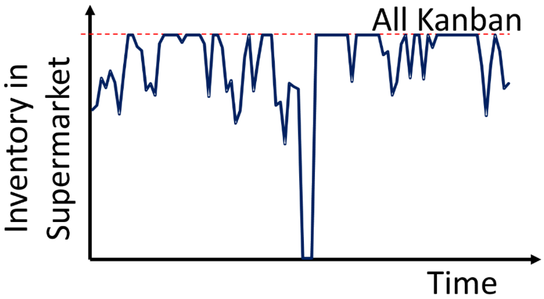


*Figure 115: One Bump is not too bad (Image Roser)*

On the other hand, if your graph looks like the graph below, then you have serious problems with your kanban system. Assuming that your system is not the bottleneck but could deliver the demand, the situation below is a sign of **not enough kanbans**. But by the time you get that graph, both your customer and your boss have probably already told you that they are not happy with your system.

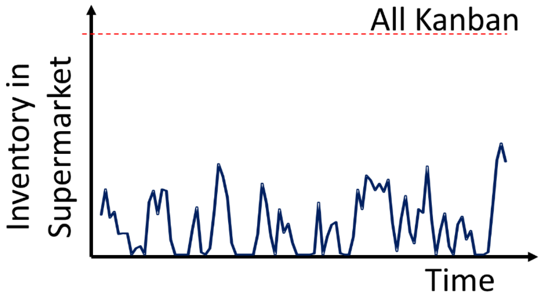


*Figure 116: Too few kanban (Image Roser)*

Finally, there is also the possibility of a graph as shown below. You always have a good inventory, and often all your kanbans are in the supermarket. In this case you may have **too many kanbans**. Consider removing a few kanbans out of the system to get closer to the first or second picture above. The number of kanbans you could remove altogether is the distance between the lowest inventory and zero (i.e., in the example below, about half of the kanbans are not needed). Of course, my advice would be to start slowly and remove maybe 25% of the kanbans rather than half of them. Then continue to observe and, if needed, remove more.

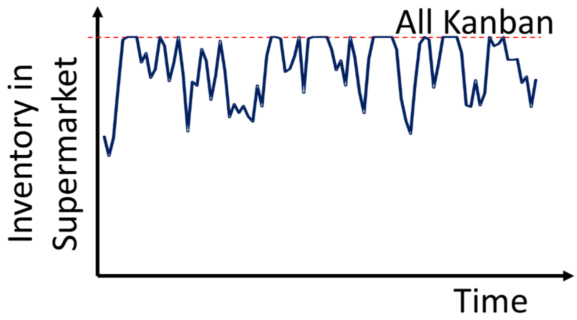


*Figure 117: Too many Kanban (Image Roser)*

Through this observation of supermarket inventories, you can adjust your number of kanbans by observing your real system with real data, avoiding all those rough estimates in the kanban formula. Naturally, even if you used the kanban formula, it is advisable to verify the results through your inventory levels. If you constantly run out of stock despite your kanban calculation, then you do not have enough kanbans, regardless of what the calculation said.

Overall, a normally functioning kanban system has – very roughly – about half of the kanbans with parts in the supermarket; the other half is waiting for processing or being processed. Of course, the larger your batches, the higher your average inventory level (since you need more kanbans for the batches).

## 20.3 Check Occasionally or Seasonally

Production systems are constantly changing. The number of kanbans that work today may be insufficient or too much two months later. After establishing the kanban system, you need to keep an eye on it. If the customer or the system changes, you may need to update the number of kanbans. One common example is seasonality. During the season, you may need more kanbans than during the off season. In this case, add kanbans at the start of the season and remove them afterwards.

I hope this post was helpful for you. Please let me know if you have any feedback or questions. Otherwise, go out and improve your industry!

# 21 Toyota Employee Relationship Crisis and Countermeasures 1990's

*Christoph Roser, May 25, 2014 Original at https://www.allaboutlean.com/toyota-employee-crisis-1990/*

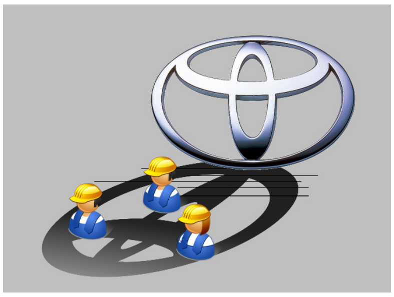

*Figure 118: Employee Relations at Toyota (Image Roser)*

Toyota has developed what is probably the finest production system in the world, the Toyota Production System. There is general consensus in the rest of the world that its methods and philosophies can significantly improve efficiency and quality, to the point that anything Toyota does is admired and copied. Some practitioners seem to wear rose-colored glasses when talking about Toyota. However, like any company, Toyota does have its fair share of problems and mishaps to deal with, from the 1950 near collapse, to the US gas pedal recalls during 2009–2011. This post will discuss the employee relationship crisis at Toyota around 1990 and Toyota's countermeasures.

## 21.1 Causes of the Employee Relationship Crisis

*Figure 119: Overworked worker (Image Roser)*

During the late 1980s the Japanese economy was booming. Like most products during the boom, cars also experienced increased sales. Hence, the demand on the Toyota factories increased. However, at the same time, due to the aging population and the undesirability of manual work, Toyota was facing a labor shortage. To make up for this shortage, Toyota significantly increased its use of temporary labor. At the peak of the bubble in 1991, this temporary workforce exceeded 10% of the total workers.

Nevertheless, it was not enough. Overtime was needed. Back then Toyota had a shift pattern of two 8-hour shifts separated by four hours for maintenance... and overtime. However, no matter how you put the shifts, one shift was always partially overlapping with the unpopular graveyard shift between midnight and 6:00 a.m. Already in 1987, the average worker put in 2,224 hours per year, or 44-hour work weeks assuming two weeks of vacation. By 1991 this increased even more to 2,315 hours per year or 47 hours per week. On average! Furthermore, overtime could be announced on short notice within the same day, wrecking the schedules of the employees' personal lives. Toyota was pushing its workers to the breaking point. Even the most motivated workers were exhausted after working 45+ hour weeks for years.

Additionally, the payment system did not honor the overtime well. In many Japanese companies, having an employee work overtime is cheaper than hiring more workers. Overtime is also usually compulsory.

## 21.2 Employees Voting with Their Feet

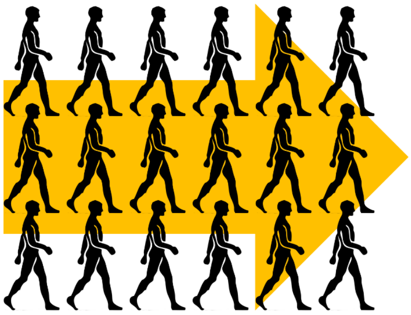

*Figure 120: One out of Four left every year (Image Roser)*

For young Japanese, assembly work was unpopular. The work was considered 3-K, where the 3 K's in Japanese stand for *Kitanai*, *Kitsui*, and *Kiken*, or dirty, difficult, and dangerous. Employment in the service industry was much easier work for the same money. Plus, most in the service industry worked reasonable daylight hours, not graveyard shifts. Especially not 45+ hour-per-week graveyard shifts.

For historic reasons, workers in Japan do not have a works council representation that is worth its name. Hence, the main ways for workers to show their dissatisfaction was to change jobs. And this they did. Turnover peaked in 1991 with **1/4th of all recent hires leaving the company per year**. That was a very strong statement.

Toyota prides itself on its good relationship with its employees. Toyota also prides itself on its lifelong employment system (see also Consistency at Toyota – The Board of Directors of the Toyota Motor Company). Finally, Toyota prides itself on being one of the most prestigious and desirable companies in Japan. However, 25% of the new hires strongly disagreed. Something was going very wrong. **Fortunately, one of the most outstanding features of Toyota is its ability to adapt and improve**!

## 21.3 Toyota's Countermeasures

In 1992 Toyota started a *humanization of the production system and of work* in its Kyushu plant. A joint effort between management and workers tried to address the following issues:

**Salary system**: The system for compensation was adjusted to increase fairness of the salary. The target speed or production norms were measured differently. Pressure was to be put more on purchasing than on labor. Finally, all employees were encouraged to take all their annual holidays (not taking holidays sounds crazy to Westerners but is common in Japan).

**Training**: Initial training was changed from two weeks at headquarters to nine weeks on the shop floor, giving employees more time to learn and adjust. This measure seems to have been especially effective in reducing turnover rates. Training of already hired employees also intensified.

**Hierarchical Adjustments**: Due to automation, workers who were historically team leaders no longer had teams. Yet reducing their position back to normal worker would have reduced their salaries. Hence, new classes of "experts" were created.

**Workplace Ergonomics**: 200 million yen were invested in making work places more ergonomic, using small conveyors, better lighting, adjustable platforms, and other gadgets that made life at the assembly line easier.

**Automation**: 1.1 billion yen were invested in automation, focusing especially on the most demanding tasks.

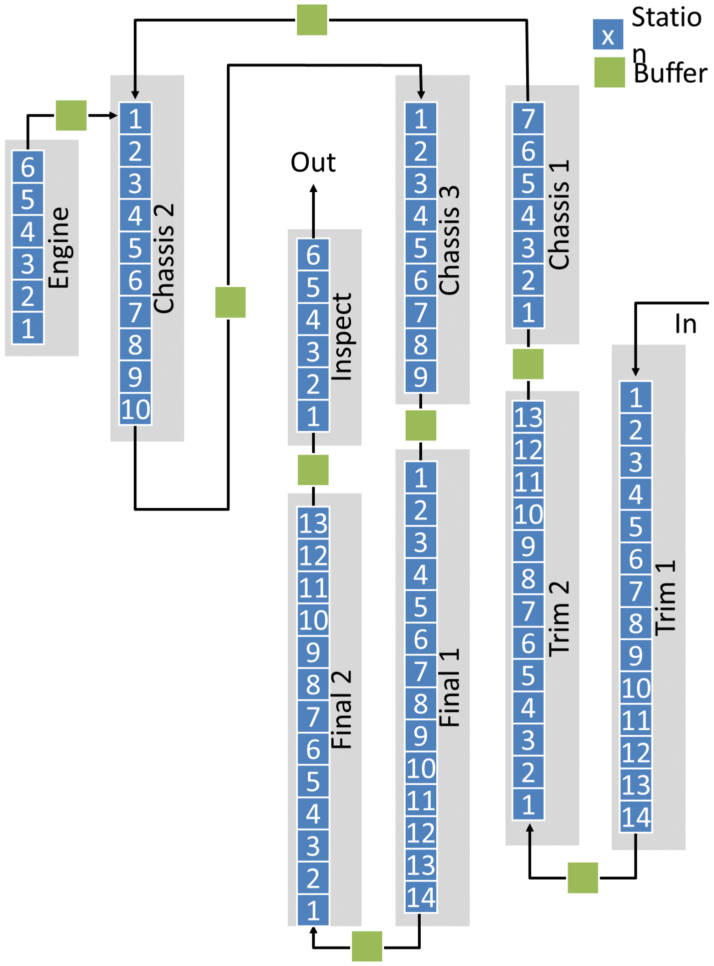


*Figure 121: Current Layout of Toyota Motomachi Plant (Image Roser)*

**Restructuring of the Assembly Lines**: Long continuous assembly lines were broken down into smaller segments. This allowed better social structures. Small buffers reduced the impact of problems and hence the burden on other segments. These small buffers also permitted slightly more flexibility in the use of the employees' time. (See my detailed post Evolution of Toyota Assembly Line Layout – A Visit to the Motomachi Plant.) However, so far not all plants have been restructured that way.

**Change of Shift Patterns**: Shift patterns are now 6:25-15:15 and 16:10 to 1:00. Additionally, there is a 45-minute lunch break and regular 10-minute breaks at other times. While working till 1:00 a.m. is still tedious, it beats working even later. Maintenance, however, still has to deal with the third graveyard shift. Overtime has been significantly reduced.

## 21.4 Did it work? Partially

*Figure 122: It has to work! (Image John Oxley Library in public domain)*

After all the effort by Toyota to improve the well-being of its employees, did it work? The situation probably improved. However, international expansion keeps putting pressure on the workforce, as many skilled workers are sent abroad to train overseas employees in the Toyota way. Even the Toyota president, Akio Toyoda, admitted in the wake of the 2010 gas pedal crisis that growth at Toyota "*may have been too quick"* (but he may have been more worried about the technical side).

On the other hand, many manufacturing plants I have seen worldwide do have a disengaged and stressed workforce. **Confining human individuality to the demands of a manufacturing system is difficult.** I believe that Toyota truly wants to improve the lot of their employees, but at the same time they don't want to destroy their fine-tuned and beautiful production system. There are also examples of plants where Toyota has a very motivated and engaged workforce with absenteeism much lower than industry average. (A popular example was the recently closed NUMMI plant in the US, where under GM management absenteeism was sky high – but when reopened with the same staff under joint Toyota and GM management, absenteeism was greatly decreased).

Toyota does have its problems, but it's also trying to solve them. Making a production system work with human individuality is difficult. Toyota excelled at one system and is not doing too bad with the other. Overall, I believe Toyota is still a very good employer, having the world's best production system.

# 22 Culture of Quality – A Comparison of Toyota and GM Recalls

*Christoph Roser, June 1, 2014 Original at https://www.allaboutlean.com/toyota-gm-recalls/*


*Figure 123: Return to Sender (Image Roser)*

One of the main aspects of lean manufacturing is quality. This post discusses the differing attitudes regarding quality in different corporate cultures. In particular, the **Toyota brake recalls and the GM ignition recalls are compared**.

## 22.1 Introduction

The world is not perfect. The idea of zero defects is usually unrealistic. Occasionally, even with the best safety measures, a defective car slips through automotive production lines. Depending on the severity of the problem, the maker can or must fix the problem even for products that have already sold. For the least serious problems, a technical service bulletin is issued and the car is fixed at the next check-up without the customer ever noticing. For more serious problems, the maker can choose to issue a voluntary recall. The most serious problems lead to a mandatory recall ordered by the National Highway and Traffic Safety Administration (NHTSA). In either of the latter two cases, the general public is informed that they should have the problem fixed as soon as possible.

Due to the complexity of modern products, especially automobiles, recalls are a part of life. Every major auto maker is in the news regularly for recalls. In average every car sold in the US every is recalled at least once throughout its lifetime. However, to ensure safety for the consumer it is necessary that recalls are done quickly to fix the problem before anybody gets hurt.

## 22.2 The Toyota Recalls – (Relatively) Speedy Recall

*Figure 124: Toyota Logo (Image Toyota for editorial use)*

Between 2009 and 2011, Toyota issued different recalls related to accelerators in some of its models. The first recall addressed the problem of a floor mat from a different vehicle being able to jam the gas pedal, which caused an accident with four fatalities. Soon after the accident, Toyota issued a voluntary recall for the affected vehicles.

One year later, Toyota received reports of sticking accelerators, where in rare instances the accelerator did not completely return to zero when released (tests showed that even with almost full acceleration, simultaneously using the brake would stop the vehicle). Hence Toyota issued another recall. Yet a third recall was for hybrid anti-lock brake software problems. Overall, 9 million vehicles were recalled worldwide.

There were numerous deaths initially connected with the sticking accelerator, but the NHTSA eventually concluded that driver error, especially "*pedal misapplication*" was the cause of these accidents. The first accident with four fatalities due to the jammed floor mat was the only accident caused by technical problems related to the Toyota accelerator recalls.

Overall, Toyota issued these recalls relatively promptly after receiving information about problems. While the government fined Toyota for a delay in recalling, this delay pales in comparison to the delays of GM discussed below. Toyota did, however, mess up the public relations side of these recalls, with the public receiving somewhat confusing information about the actual cause of the problem.

## 22.3 The GM Recalls – Saving 90 Cents Per Vehicle is Worth More than 13+ Lives

*Figure 125: GM Logo (Image General Motors for editorial use)*

GM has also been in the news for its recalls. The problem at GM was an incorrectly designed ignition switch that could turn off while driving. Unfortunately, without engine power, the vehicle lost its power steering, power-assisted brakes, and function of the airbags. Hence it gets more difficult to steer, more difficult to brake, and if you hit something your airbags wouldn't deploy. GM issued a recall in 2014.

However, as it turns out, GM had known about the problem since 2005. Fixing the problem would have cost $0.90 per vehicle, whereas the expected warranty costs were only around $0.10-0.15 per vehicle (see email excerpt below). Later reports claimed a cost of only $0.57 to fix the switch.

The con of the change is that the piece
cost of the ignition switch went up around $0.90 and
would require $400K in tooling to add the almost 500K in volume.

The warranty offset for the new switch is in the $0.10-0.15 range.

*(Excerpt from GM-internal Email turned over to the Federal government)*

*Figure 126: Excerpt from GM Email on the GM Recalls (Image US Government in public domain)*

Hence, GM decided not to fix the problem and also not to release information about it to the public or the authorities. Subsequently, the problem continued and the death toll mounted. In May 2007, GM finally decided to fix the problem for new cars but not to recall the older vehicles.

However, when fixing the problem for the new car, they made a major mistake. **They did not give the new part a new part number!** There is a solid rule in industry that a new part must have a new part number to keep track of what is what. This leads to suspicion that this may have been a move to hide evidence. Hence it seems that they not only delayed the new part and the recall, but also may have tried to hide the evidence.

So far, GM officially claims *only* 13 deaths associated with the faulty switch, although other sources claim higher numbers up to 300 fatalities and more.

Even as evidence of GM dragging its feet is mounting, there is new information about a similar case regarding **GM airbag recalls**. In March, GM submitted a less-urgent customer-satisfaction campaign related to airbag problems. The very next day, the NHTSA forced GM to upgrade this to a full recall. Again, GM had known about this problem since 2008 and acted on it only in 2014.

The cost of the ignition recall is now at $1.3 billion, with possibly more to come. This by far exceeds the initial estimate of $0.10-$0.15 per vehicle.

## 22.4 The Government Reaction

During the Toyota recall, the US government came down pretty harshly on Toyota. While stern measures are needed to deter bad behavior, Toyota seemed to get a much rougher treatment when compared to other car makers before (e.g., the Ford "Exploder" or Ford tire issues). In foreign news it was suspected that the US government was less reluctant to hurt a foreign automaker than it was to hurt domestic manufacturers (even though Toyota does have more US domestic content than many other US manufacturers). It also appeared that there was a certain *schadenfreude* about quality problems at Toyota, which is famous for its quality.

It did not help that Toyota bumbled the public relations side of the recall. Toyota president and CEO Akio Toyoda appeared before a congressional hearing, but despite apologizing did not come across very smooth. Toyota, however, did not make the mistake of blaming its customers for the accidents. Toyota also (so far) has not picked on GM for the GM recalls.

In the past, GM has gotten away with recall problems much more easily than Toyota. Even for the current recall, there seems to be not yet as much pressure on GM as on Toyota – yet. However, GM CEO Mary Barra was also called for a congressional hearing, and my impression is that the heat is increasing.

GM is already focusing on avoiding such problems in the future. Unfortunately it is not clear how much technical actions have been taken. On the other hand, we know from released documents the measures to **make problems sound nice**. For example, for internal communication GM listed 69 words that cannot be used. GM also gave some suggestions for alternative phrases. Both are listed below:

always, annihilate, apocalyptic, asphyxiating, bad, Band-Aid, big time, brakes like an "X" car, cataclysmic, catastrophic, Challenger, chaotic, Cobain, condemns, Corvair-like, crippling, critical, dangerous, deathtrap, debilitating, decapitating, defect, defective, detonate, disemboweling, enfeebling, evil, eviscerated, explode, failed, flawed, genocide, ghastly, grenadelike, grisly, gruesome, Hindenburg, Hobbling, Horrific, impaling, inferno, Kevorkianesque, lacerating, life-threatening, maiming, malicious, mangling, maniacal, mutilating, never, potentially-disfiguring, powder keg, problem, rolling sarcophagus (tomb or coffin), safety, safety related, serious, spontaneous combustion, startling, suffocating, suicidal, terrifying, Titanic, unstable, widow-maker, words or phrases with a biblical connotation, you're toast

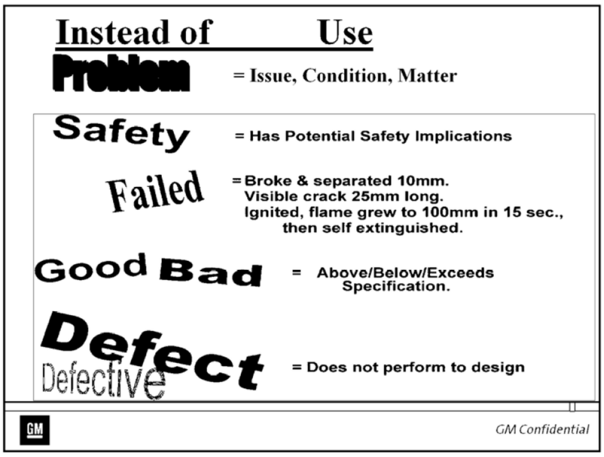


*Figure 127: GM Newspeak from official GM slides (Image NHTSA in public domain)*

## 22.5 Summary

Overall, it seems that quality is still taken much more seriously at Toyota than at GM. Toyota issues recalls relatively quickly and tries to fix the problem. GM seems to drag its feet, may have tried to hide problems, and works hard at making problems sound less daunting than they are. The new GM CEO Mary Barra uses lots of words to state that GM is changing (the old GM before bankruptcy and hence not liable versus the new GM after bankruptcy and hence liable). Unfortunately, experience shows that words from industry bosses are cheap. Even if Barra is serious, changing the culture of a company is a major project that will probably by far exceed her tenure at GM.

In any case, it is my hope that the government doesn't let GM get away with what it's done and that it pursues justice as vigorously as it did with Toyota.

# 23 About Shifting Bottlenecks

*Christoph Roser, June 8, 2014 Original at [https://www.allaboutlean.com/shifting-bottlenecks/](https://www.allaboutlean.com/shifting-bottlenecks/)*

*Figure 128: One empty green wine bottle (Image Roser)*

Improving **system capacity** requires you to find the **bottleneck**; however, **bottleneck detection** is a tricky business. The main problem is that most bottlenecks are not static, but move around. In this post we will look at the behavior of bottlenecks on the shop floor. This is the first post in a series of posts on bottleneck detection. Subsequent posts will look at the flaws of commonly used methods to find the bottleneck and describe two new reliable methods for finding the bottleneck on the shop floor.

## 23.1 Definition of a Bottleneck

Before we delve into details about bottlenecks, I want to define what a bottleneck is:

> *The bottleneck in a system for any given time is the process that constrains the system capacity at this time.*

Hence, a bottleneck is the process that limits (at the moment) the output of the system. This definition will be more important later on.

## 23.2 Types of Production Systems

With respect to bottleneck behavior, production systems can be seen in different ways.

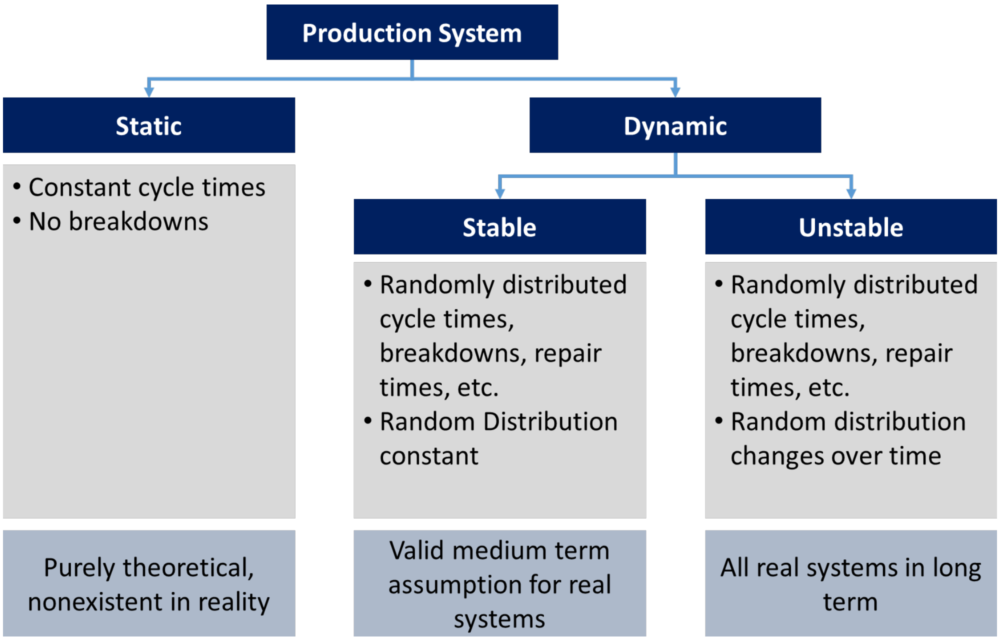


*Figure 129: Classes of production systems for bottleneck behavior (Image Roser)*

### 23.2.1 Static Systems

The easiest systems with respect to bottleneck detection and capacity management are **static systems**. In these systems, there is no random fluctuation. There are no breakdowns, change-overs, or any other changes. Every time, the system behaves just like every time before.

It is easy to find the bottleneck in such systems. Simply **take the process with the longest constant cycle time, and you have the bottleneck**. All buffers before the bottleneck will be always full or approaching infinity, and all buffers after the bottleneck will be always empty.

Unfortunately, **such systems do not exist in reality**. In reality, there are fluctuations in cycle times. In reality, there are failures, with a random time between failures (Mean Time Between Failure, or MTBF) and a random repair time (Mean Time To Repair, or MTTR).

Hence, in reality there are no static production systems. This is why it's baffling to me how many bottleneck detection methods assume or require a static system to work.

### 23.2.2 Dynamic Systems

In reality, the world is dynamic. **The behavior of any real system is subject to countless random events**, which makes the system different every single time. These random events create different probability functions, describing how the randomness behaves. These dynamic systems can be further divided into two subgroups.

### 23.2.3 Stable Dynamic Systems

A **stable dynamic** system is a dynamic system that has randomness; however, the randomness itself does not change over time. For example, if the randomly distributed cycle time has a mean with the value of "x," this "x" does not change over time. The random behavior today is the same as the random behavior tomorrow or next week.

It is easy to see that stable dynamic systems also do not exist in reality. Most systems change, with new machines added and old ones removed, with continuous improvement changing the system behavior, with old products no longer being produced but replaced with new products. If nothing else, a system is created at one point and deconstructed or destroyed at another point.

However, **for a shorter time a stable dynamic state is a valid assumption**. While your shop floor will look and behave totally differently ten years from now, the changes are often negligible if you look only at next week. Hence, a stable dynamic system can be a valid assumption.

### 23.2.4 Unstable Dynamic Systems

As described above, no systems are stable forever. Hence, in the long run, all real systems are unstable dynamic systems.

## 23.3 Shifting Bottlenecks

Dynamic systems have one major impact on bottlenecks: **In dynamic systems, bottlenecks shift!** The bottleneck may change over time. For example, if a process has a breakdown, then the bottleneck may change to this process.

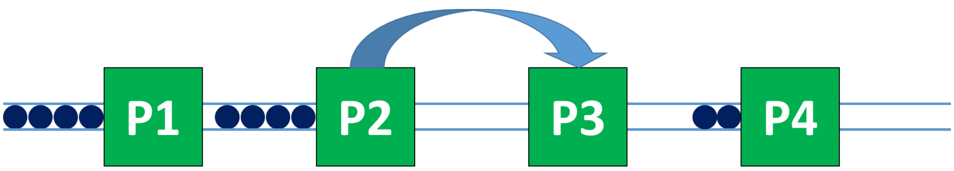


*Figure 130: The bottleneck changes with breakdown of Process P3 (Image Roser)*

In my experience, such shifting bottlenecks are the norm on most shop floors. A shop floor sometimes feels more like a sequence of problems rather than a stable system. Hence, bottlenecks do change. Depending on the buffer between the processes, bottlenecks may change quicker or slower. I have seen systems where the bottleneck changed from one process to the second to the third within less than a minute. Plus, I have the method to actually see such changes in action (as I will describe in a later post). But before that I have to clarify a common misconception regarding bottlenecks.

## 23.4 Long-Term and Momentary Bottlenecks

In industry, many people see a bottleneck as a constant. There is one process that is the bottleneck, and all others are not. This is unrealistic. As we have seen above, bottlenecks change. These shifting bottlenecks are the system constraint for only a certain period of time, so they are **momentary bottlenecks**. Long-term bottlenecks can be determined based on how long each process was the momentary bottleneck. The process that was most frequently the momentary bottleneck is also the biggest long-term bottleneck, but it by no means has to be the only long-term bottleneck.

As such, in order to find the long-term bottlenecks, you always have to find the momentary bottlenecks first. At Toyota, there is a saying regarding to bottlenecks:

> *"Never Ever Use Averages for Bottleneck Detection!"*

Hence, it is surprising to me how many flawed bottleneck detection methods are based on long-term averages. These methods can do nothing but fail.

In the next post we will see a list of commonly used but flawed bottleneck detection methods, and then we will move on to an accurate theoretical and an accurate practical bottleneck detection method.

# 24 Common Bottleneck Detection Methods that do NOT work!

*Christoph Roser, June 15, 2014 Original at [https://www.allaboutlean.com/failed-bottleneck-detection-methods/](https://www.allaboutlean.com/failed-bottleneck-detection-methods/)*

*Figure 131: Two empty green wine bottles (Image Roser)*

**To improve your system capacity, it is a must to find and improve your bottleneck**. However, finding the bottleneck is difficult. Most methods used in industry fail at finding the bottleneck. As discussed in my previous post on Shifting Bottlenecks, this is mostly due to bottlenecks being dynamic and frequently shifting from one process to the next. In this post we will look at common bottleneck detection methods used in industry. More importantly, we will find out more about **failures of bottleneck detection methods commonly used in industry**. Subsequent posts look at bottleneck detection methods that actually DO work!

## 24.1 Shifting Bottleneck Reference System

To demonstrate the reason for the **failure of pretty much all commonly used bottleneck detection methods**, I will use a simple system as an example and reference system. The system has only three processes (P1, P2, and P3) and four buffers of limited capacity. For easier understanding, the system will be a static system (see Shifting Bottlenecks) – except that the static cycle times change halfway through the observed time. The buffers are assumed to be small enough so that they run empty or full quickly during the two phases of the observation.

The system is visualized below. For the first half, process P1 is the clear bottleneck with a cycle time of ten minutes per part. After half the time the system is running, cycle times change. The cycle time of process P1 is reduced to 5 minutes, and the cycle time of process P3 is increased from five to ten minutes. Hence, the bottleneck shifts from process P1 to process P3.

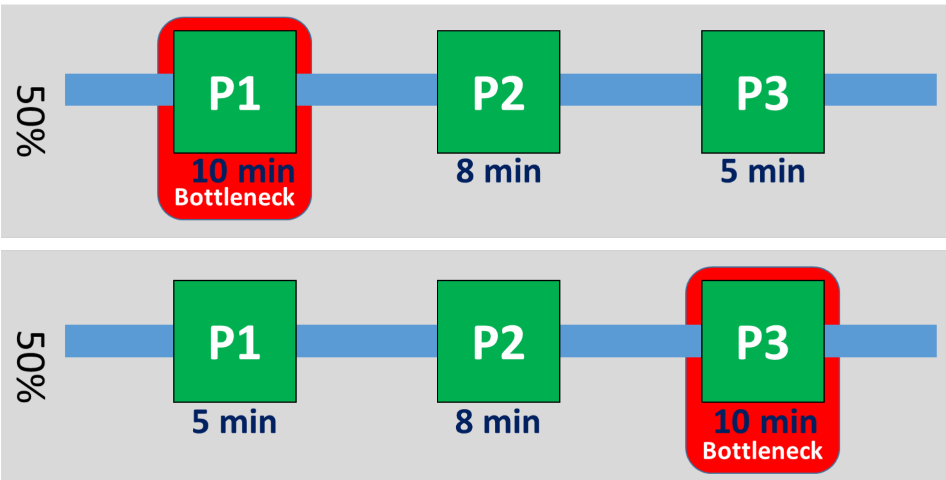


*Figure 132: Shifting Bottleneck Reference System (Image Roser)*

We defined the bottleneck as follows:

*The bottleneck in a system for any given time is the process that constrains the system capacity at this time.*

For the first half of the time, system capacity will only change if there is a change in the cycle time of P1. Hence, the bottleneck is at process P1 for the first half of the time. Similarly, for the second half of the time, the bottleneck is at process P3. Please note: **Process P2 is never the bottleneck**!

As for the reason for the change in system behavior – it doesn't really matter. In reality it may have been a change in the product produced, a bug in the software, a failure of the operator, or a minor defect in the machine that changed the behavior. In reality you may also have larger buffers, Nevertheless, while the effect usually won't be as drastic as in the example above, real production systems frequently have shifting bottlenecks that lead to the effect above. Also, please remember that the example above was selected for ease of understanding.

For practical purposes, we assume furthermore that the total time the system is running is long enough that the transition of the bottleneck from P1 to P3 is almost instantaneous compared to the observed time. Using this example system above, we now will test the most commonly used industrial bottleneck detection methods.

## 24.2 Average Cycle Time

In industry, probably the most popular method used to find the bottleneck is to look at the cycle times. The idea is that **the process with the longest cycle time is also the bottleneck**. Unfortunately, this does not work for shifting bottlenecks or changing cycle times.

Let's look at our reference system below. Process P1 has a cycle time of ten minutes and five minutes for half of the observed period, and hence an average cycle time of 7.5 minutes. Similarly, process P3 also has an average cycle time of 7.5 minutes. Process P2 never changes and has an average cycle time of 8 minutes. According to the bottleneck detection method using average cycle times, process P2 must be the bottleneck – except that in reality it never was. **The average cycle time method finds the bottleneck in a process that never ever was the bottleneck!**

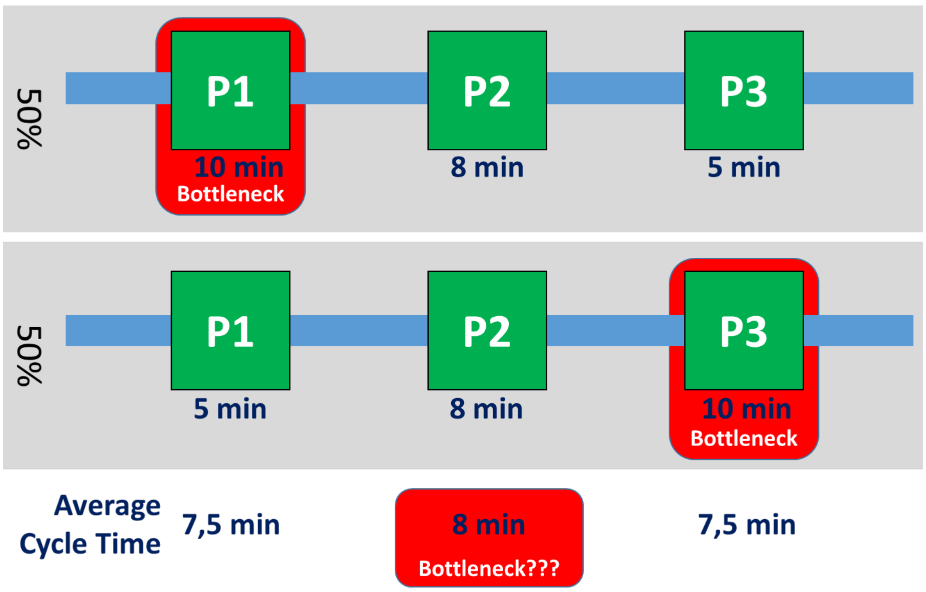


*Figure 133: Failure of average cycle time to detect shifting bottlenecks (Image Roser)*

Okay, you could argue that you would have to use the average cycle time method twice for different systems. However, please remember that the system above was created so the behavior can be easily understood. In reality, there will not be such a sharp distinction between two subsystems, but rather an ever-changing real system. Nevertheless, the flaws of the average cycle time method still apply to real systems. In summary, **bottleneck detection using average cycle times does not work!**

## 24.3 OEE or Utilization

A variant of the method using cycle times is the method using the Overall Equipment Effectiveness (OEE) or Utilization (for details on OEE, see my series of posts on measuring and fudging the OEE). Here, the utilization or OEE is used to find the bottleneck. The idea is again that **the process with the highest OEE or utilization is the bottleneck.**

Again, let's look at our reference system below. For half of the time, Process P1 has an OEE of 100% and P3 of 50%. For the second half, these OEEs change. Process P2 always has a constant OEE of 80%. Since there is a part leaving the system every ten minutes constrained by the bottleneck, Process P2 has to wait two minutes and work eight minutes out of ten minutes. Hence, Process P2 has an OEE of 80%.

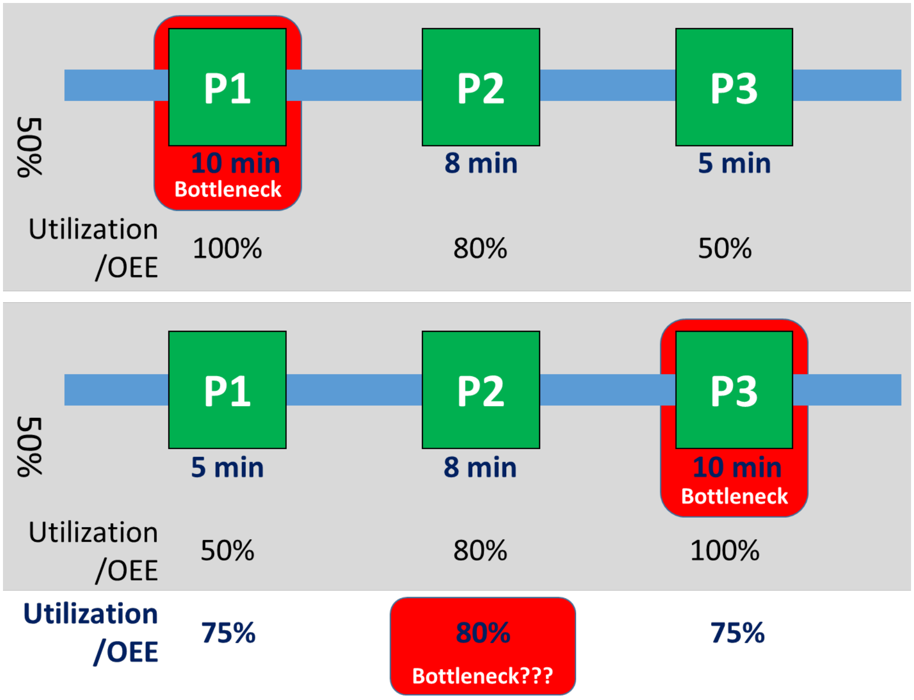


*Figure 134: Failure of OEE or utilization to detect shifting bottlenecks (Image Roser)*

Now we average the OEE over our two subsystems. Process P1 and P3 will both have an average OEE of 75%, while process P2 has an OEE of 80%. Hence, according to the method process, P2 must be the bottleneck – except it never ever was the bottleneck in reality. **The OEE method or utilization method finds the bottleneck in a process that never ever was the bottleneck!**

For reference, bottleneck detection using OEE can be slightly modified by including additional losses in the OEE, including speed losses, quality losses, and availability losses (See What is OEE?). Only waiting times for parts or transport (starving or blocking) should not be included in this modified OEE method. Nevertheless, the results would be the same and this change merely fine-tunes a fundamentally flawed method. In summary, **bottleneck detection using OEE or utilization does not work!**

## 24.4 Average Inventory Levels

Another commonly used method for **bottleneck detection is through inventory levels**. The idea is that a buffer that is rather full indicates a bottleneck downstream, whereas a buffer that is rather empty indicates a bottleneck upstream. This approach is valid as long as you don't use averages. In fact, it is one of the two cornerstones of my own "bottleneck walk"; however, the approach falls apart as soon as we start to use averages.

Let's look again at our reference system. For the first half, Process P1 is the bottleneck. All buffers before are full, all buffers afterward are empty (and we simplify here the occasional part passing through as still empty). Similarly, for the second half, Process P3 is the bottleneck; all buffers before are full, and all buffers afterward are empty. Again, for simplification reasons we assume that the bottleneck shift from P1 to P3 is rather quick compared to the overall time period.

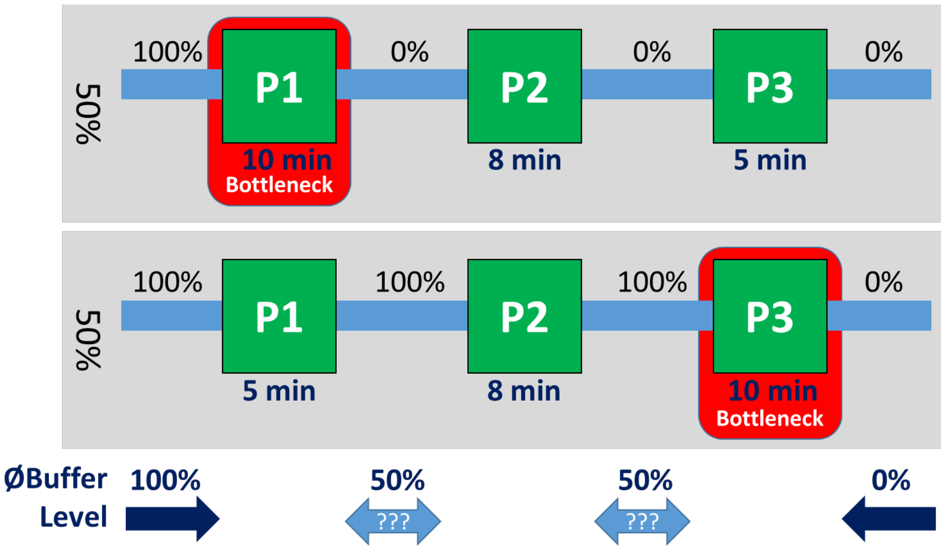


*Figure 135: Failure of average inventory levels to detect shifting bottlenecks (Image Roser)*

Taking the average, we will find that the first buffer is always full, indicating a bottleneck downstream. The last buffer is always empty, indicating a bottleneck upstream. So far so good. However, the two buffers in the middle are both 50% full, giving no clue as to where the bottleneck really is. Hence **the method using average inventory levels does not find the bottleneck**.

In reality there might be more random events, and an average of exactly 50% is rare. However, deciding which direction the bottleneck is, based on a 49% or 51% inventory level, is quite daring in my opinion. Furthermore, regardless of which direction the method picks, it misses out on one of the two bottlenecks in the system. In summary, **bottleneck detection using average inventory levels does not work!**

## 24.5 Average Percent Blocked or Starved

Finally, we look at **bottleneck detection through the percentage of a process being blocked and starved**. A process is blocked when the process cannot give its completed parts to the next buffer or process. A process is starved when the process is waiting for new parts to arrive. The idea is that a blocked process indicates a bottleneck downstream and a starved process indicates a bottleneck upstream. As for inventories, this approach does work and is the second cornerstone of my own "bottleneck walk." However, as soon as you start to use averages the method breaks apart.

Let's look again at our reference system. For the first half, process P1 is neither starved nor blocked, whereas processes P2 and P3 are starved for 20% and 50% respectively (i.e., waiting for two and five minutes out of ten). Similarly for the second half, processes P1 and P2 are blocked for 50% and 20% respectively. Again, for simplification reasons we assume that the bottleneck shift from P1 to P3 is rather quick compared to the overall time period.

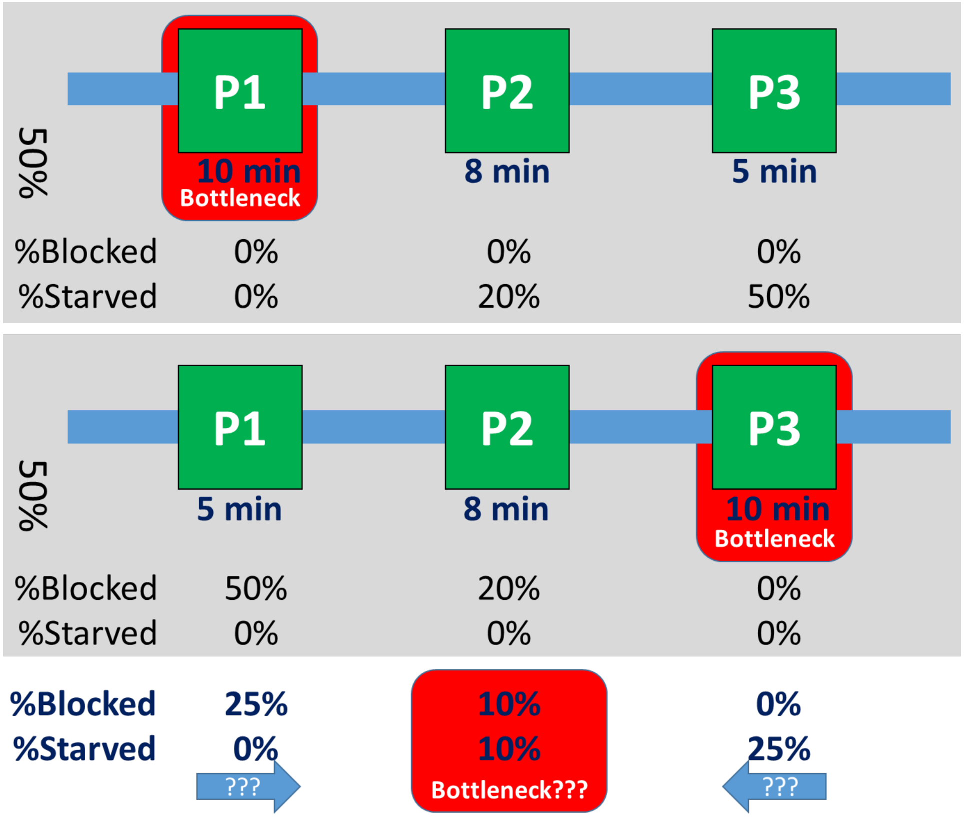


*Figure 136: Failure of Average Percent Blocked or Starved to detect shifting bottlenecks (Image Roser)*

In average, Process P1 is blocked 25% and starved 0%, indicating a bottleneck downstream. Similarly, Process P3 is blocked 0% and starved 25% of the time, indicating a bottleneck upstream. Process P2 is each starved and blocked 10% of the time. Since processes P1 and P3 both point at process P2, and process P2 has the lowest percentage of being starved and blocked, the method could consider process P2 as the bottleneck – except that process P2 was never ever the bottleneck. Hence, **the method using percentages blocked and starved does not find the bottleneck**.

Again, in reality the results would be less clear. However, even if by chance the method would not find process P2 but one of the other processes, it would still miss half of the shifting bottlenecks. This also applies to fancier scientific approaches using average percentages blocked and starved as, for example, by Kuo et al 1996 (*Kuo, Chih-Tsung, J. -T. Lim, and Semyon M. Meerkov. "Bottlenecks in Serial Production Lines: A System-Theoretic Approach." Mathematical Problems in Engineering 2 (1996): 233–276.*). In summary, **bottleneck detection using percentages blocked and starved does not work!**

## 24.6 Concluding Remarks

As seen above, pretty much all methods used in industry to find the bottleneck do not work in reality. As Toyota long ago found out:

*"Never Ever Use Averages for Bottleneck Detection!"*

**Any bottleneck detection method using averages will go haywire with shifting bottlenecks.** Since most people in industry use methods with averages, most people will have an opinion on bottleneck detection, but they are mostly wrong. As part of my work in industry on bottleneck detection, I usually ask the people of the plant beforehand where they think the bottleneck is. People are usually quite sure they know the bottleneck (both management and white- and blue-collar workers), but the detailed analysis proves most of them wrong. **Between 50% and 75% of the people pick the wrong process as the bottleneck.**

Even worse, since they do not reliably identify the bottleneck, they improve a process that has little or no influence on the overall system capacity. **The time, energy, and money they put into improving a non-bottleneck will not yield any improvement of the overall system and, in summary, will be a total waste of effort.**

In my subsequent posts I will show different methods to find the bottleneck reliably even for shifting systems. Best of all, my most favorite method – the "Bottleneck Walk" – does not even need any time measurements or mathematical calculations, but instead relies only on simple observations and an easy graphical analysis.

## 24.7 See also

If you prefer an academic source for citation, use this:

Roser, Christoph, and Masaru Nakano. "A Quantitative Comparison of Bottleneck Detection Methods in Manufacturing Systems with Particular Consideration for Shifting Bottlenecks." In Proceedings of the International Conference on the Advances in Production Management System. Tokyo, Japan, 2015.

# 25 Mathematically Accurate Bottleneck Detection 1 – The Average Active Period Method

*Christoph Roser, June 22, 2014 Original at https://www.allaboutlean.com/average-active-period-method/*

*Figure 137: Three empty green wine bottles (Image Roser)*

This post describes an **accurate way to detect the bottleneck in manufacturing systems**, based on the average times a process is waiting or active. The method determines the primary bottlenecks in the system much more accurately than other methods commonly used in industry. The method was developed by me during my time at the Toyota Central R&D Laboratories in Japan. Subsequent posts look at other bottleneck detection methods that actually DO work!

## 25.1 The Basics

A machine or process can be in different states at any given point in time. In most cases, we can't tell whether a process is the bottleneck based simply on the knowledge of the process state. For example, if the process is currently working, it may or may not be the bottleneck.

However, there are some process states where **we can tell with certainty that the process is not a bottleneck at a particular moment**. For example, if the process is waiting for material, then the process cannot be the bottleneck at that moment. Some other process must starve this current process, hence some other process must be the bottleneck at that time. Below is the list of possible states where the process is definitely not a bottleneck:

- Waiting for Material (starved)
- Waiting for Transport (blocked)

In general, whenever a process is waiting for someone or something else, it is not the bottleneck. Some other process must be the temporary bottleneck at that moment. Hence, there are some instances when we can say for sure that a process is not the bottleneck. In turn, there are a number of process states where the process can be the bottleneck. These may include, for example:

- Working (hopefully most of the time)
- Breakdown
- Under Repair
- Regular Maintenance
- Changeover

For the following discussions, we call these states *active* (in the sense of *not waiting*) and the above waiting states *inactive*.

## 25.2 Duration without Waiting Determines Bottleneck

The basic idea of this method is that the longer a process is active without interruption by a waiting time, the more likely it is the bottleneck. A process frequently interrupted by waiting times is unlikely to be the bottleneck. This is the fundamental underlying idea for the next two methods for determining the bottleneck. In both cases, we measure the duration that each process is active without interruption. Please note that if, for example, the process goes from working to repair to working without ever having to wait for material or transport, it is considered one uninterrupted active period.

## 25.3 The Average Active Period Method

**The Average Active Period Method simply measures the average active time a process is active.** In most cases, one process (or at most, two) will clearly stick out, having a much longer average active period than any other processes.

Below is an example of such an analysis. A system consisting of eight processes in line was analyzed. The cycle times were all around five minutes, with random variation from cycle to cycle. Measuring the average active period, one process (M4) clearly stuck out with an average active duration of about 15.000 minutes. In other words, the process was working for 15.000 minutes in average before being interrupted by a waiting time (i.e., before being interrupted by another process). This was by far the longest average active period in the system. All other processes barely showed up on the graph, with an average working only for one or two cycle times before being interrupted by waiting for another process.

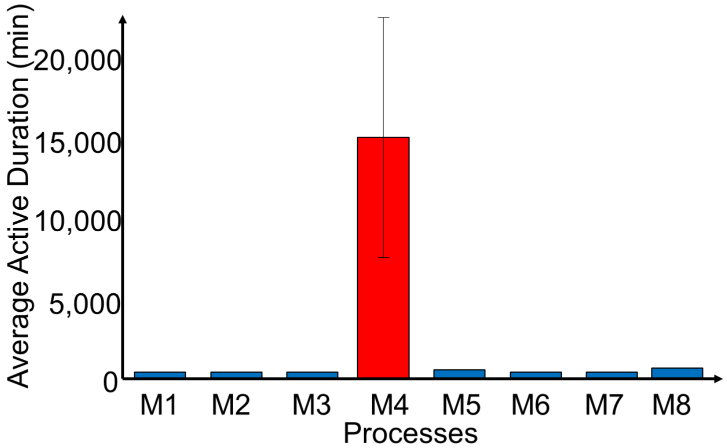

*Figure 138: Results of an Average Active Period Bottleneck Detection (Image Roser)*

To be on the safe side, I also calculated the confidence intervals of the average active periods. Naturally, the confidence interval of the bottleneck process M4 was wide, indicating that the average active duration was fluctuating. Also, while rare, the process M4 was sometimes waiting on one of the other processes. Nevertheless, the confidence intervals of the active periods of the other processes were much smaller, also in the magnitude of a few cycle times. It was **above 99% certain that process M4 had the longest average active period**. Hence the result was very clear. **Process M4 was definitely the primary main bottleneck in the system**.

## 25.4 How Did I Find that Method?

I initially found this method by making a mistake. During my time at Toyota, I was researching production systems. For this I programmed myself a small simulation with a number of processes in series, having randomly distributed cycle times. Just for kicks I decided to measure the average cycle time.

After running the simulation, most results turned out reasonably well. These average cycle times were all on the magnitude of the mean cycle time of the random distribution I used, albeit a bit on the high side. However, one process stuck out. Rather than having the average cycle time I expected, it was around 10.000 times that!

Puzzled, I decided to investigate further. It turns out that I had a small bug in my program. Rather than measuring the cycle times, I had measured the sum of all cycle times without interruption by waiting times. After fixing that bug, I got the results I expected.

However, this got me thinking. Why on earth did one process stick out so much? Well, it turned out that this was the slowest average cycle time and, in this case, the bottleneck. Voila, by making this mistake I found my method to detect the bottlenecks!

## 25.5 Some Special Situations

Above, I stated that the process cannot be the bottleneck whenever it is waiting for material or transport. There are a few more situations where it may not the bottleneck, but this depends on your view on the analysis.

For example, the process could also be waiting for an operator or for a mechanic. In this case, you have to decide if you want to consider the operator and/or the mechanic a separate entity in your bottleneck detection. If you do, then the process is inactive at that time. However, for simplicity purposes I usually consider operators and mechanics to be a part of the working process. Hence If there is a missing operator, the process (with operator) could still be the bottleneck, rather than having the operator only as the bottleneck.

## 25.6 References


- Roser, Christoph, Masaru Nakano, and Minoru Tanaka. "A Practical Bottleneck Detection Method." In *Proceedings of the Winter Simulation Conference*, edited by Brett A Peters, Jeffrey S Smith, D. J Medeiros, and Matt W Rohrer, 2:949–953. Arlington, Virginia, USA: Institute of Electrical and Electronics Engineers, 2001.

# 26 Mathematically Accurate Bottleneck Detection 2 – The Average Active Period Method

*Christoph Roser, June 29, 2014 Original at https://www.allaboutlean.com/active-period-method/*

*Figure 139: Four empty green wine bottles (Image Roser)*

This post describes a second **accurate way to detect the bottleneck in manufacturing systems**, based on the precise times a process is waiting or active. The method is highly accurate, not only giving the likelihoods of different processes being the (temporary) bottleneck, but also estimating the improvement of the entire system capacity if the bottleneck(s) are improved. It is also possible to observe the shifting of these bottlenecks over time. The method was developed by me during my time at the Toyota Central R&D Laboratories in Japan. See below for a complete list of posts on this series on bottlenecks.

## 26.1 The Basics

As discussed in the previous post, **the longer a process is active without interruption by a waiting time, the more likely it is the bottleneck**. A process frequently interrupted by waiting for material or for transport (starved or blocked) is unlikely to be the bottleneck. In the previous post, we measured the average time (active period) a process is not interrupted by waiting times. *Active* in this sense means *not waiting* (i.e., any uninterrupted sequence of working, repair, breakdown, changeover, etc.).

In this post, we now look at the longest active period at any given moment. The process with the longest active period at that moment is the bottleneck.

## 26.2 The Analysis

Assume you have a system with four processes. For these four processes you measure the times the process is active (working, breakdown, under repair, regular maintenance, changeover, etc.), and inactive (waiting for material, waiting for transport). If you now plot these measurements over time, it may look like the figure below. The black horizontal lines represent active periods, with inactive periods between the short vertical lines.

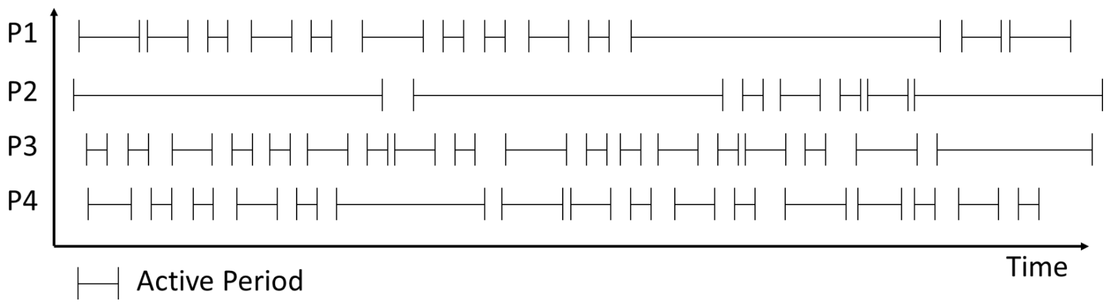


*Figure 140: Active Period Bottleneck Detection – Initial Data (Image Roser)*

You will see that in all likelihood the length of the lines is not distributed evenly. The two basic fundamentals of the active period method are:

- At any given moment, the process with the longest uninterrupted active period is the bottleneck.
- During the overlap at the end of the longest uninterrupted active periods, the bottleneck shifts from one process to another process.

Applying these requirements will give a bottleneck behavior as shown below:

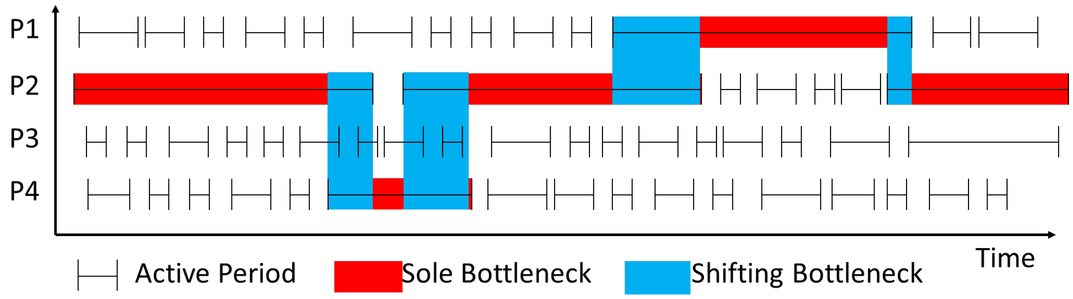


*Figure 141: Active Period Bottleneck Detection – Solution (Image Roser)*

Here, the longest uninterrupted active periods are marked in red. During these times, the corresponding process is the sole bottleneck in the system. However, even the sole bottleneck is eventually interrupted by another process, and hence is no longer the bottleneck. Another process will then have the longest active period and will be the bottleneck. During the overlap between the periods, the bottleneck will shift from one process to another process. In the graph above, this is marked in blue.

Hence, this approach lets you watch the shifting of the bottlenecks over time. In the example above, initially Process P2 was the bottleneck. The bottleneck then shifted to P4, before shifting back to P2. Afterward, P1 was the bottleneck, before P2 became the bottleneck again. Process P3 was never the bottleneck.

## 26.3 Summary Data

Based on this analysis, it is possible to see how the bottleneck changes over time. Furthermore, it is possible to calculate the likelihood of each process being the sole or shifting bottleneck. The summary analysis below shows that process P2 was most often the bottleneck, being the sole bottleneck 55% of the time and the shifting bottleneck another 20% of the time. If you want to improve your system, you should improve process P2.

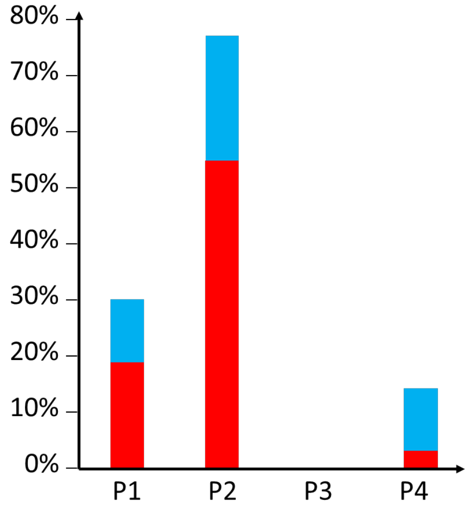


*Figure 142: Active Period Bottleneck Detection – Summary (Image Roser)*

However, P1 was also the sole bottleneck almost 20% of the time, with another 10% as the shifting bottleneck. While much less than P2, it is not quite insignificant. If there are easy ways to improve P1, it may be good for the system too. P4 was almost never the bottleneck, and P3 was definitely never the bottleneck, having no influence on the overall system capacity. Hence the method gives you a precise likelihood of each process being the bottleneck.

## 26.4 Predictions

Knowing these bottleneck probabilities, it is even possible to estimate the improvement of the overall system based on the improvements of the bottleneck. The percentages of the sole and sole & shifting bottleneck are the lower and upper boundary of the ratio of any improvement of the bottleneck improving the whole system. For example, if a process is the bottleneck 80% of the time, then a one-second improvement in the cycle time of the bottleneck will lead to a 0.8-second improvement of the mean time between parts for the entire system.

In the graph below, a system was analyzed for its bottleneck. The improvement of the system was predicted to be within the dotted lines for an improvement of the primary bottleneck. The true system improvement fell right between these lines until eventually the process investigated was no longer the primary bottleneck.

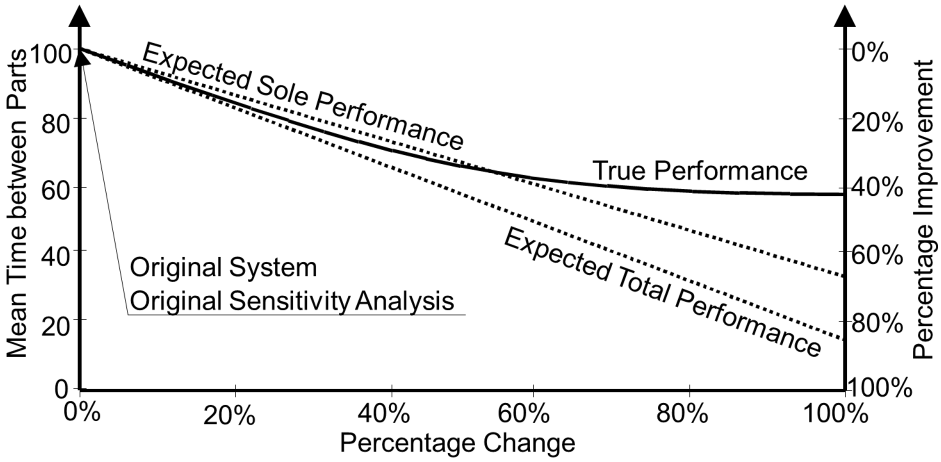


*Figure 143: Active Period Bottleneck Detection – System Changes (Image Roser)*

While this prediction is probably not needed for practical applications, it does prove the accuracy of the bottleneck detection method.

## 26.5 Requirements of This Method

The method works well for all kinds of systems, including job shops, parallel systems, etc. It has been tested successfully for complex real-world systems with dozens of processes. As long as the system is connected (i.e., not two separate independent systems), the method works.

On the downside, it has a very high data requirement. You need to know exactly when each process is active or not. In many cases, this data is difficult to obtain. It does work very well for simulations where you have all the data you need available, and it does work for highly automated systems where the data is collected via computers.

If the data is not available or the system is less automated, then I highly recommend The Bottleneck Walk – Practical Bottleneck Detection Part 1, presented in my next post. This is **by far my preferred method in practice!**

## 26.6 Sources


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- Roser, Christoph, Masaru Nakano, and Minoru Tanaka. *Detection and Monitoring of Shifting Bottlenecks*, 2001.

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- Roser, Christoph, Masaru Nakano, and Minoru Tanaka. “Shifting Bottleneck Detection.” In *Winter Simulation Conference*, edited by Enver Yucesan, C. -H Chen, J. L Snowdon, and John M Charnes, 1079–1086. San Diego, CA, USA, 2002.
- Roser, Christoph, Masaru Nakano, and Minoru Tanaka. “Throughput Sensitivity Analysis Using a Single Simulation.” In *Winter Simulation Conference*, edited by Enver Yucesan, C. -H Chen, J. L Snowdon, and John M Charnes, 1087–1094. San Diego, CA, USA, 2002.
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- Roser, Christoph, Masaru Nakano, and Minoru Tanaka. “Tracking Shifting Bottlenecks.” In *Japan-USA Symposium on Flexible Automation*, 745–750. Hiroshima, Japan, 2002.
- Roser, Christoph, Masaru Nakano, and Minoru Tanaka. “Utilization Vs. Throughput: Bottleneck Detection in AGV Systems.” In*Proceedings of the Logistic System Symposium*, 67–70. Nagoya, 2002.

# 27 The Bottleneck Walk – Practical Bottleneck Detection Part 1

*Christoph Roser, July 6, 2014 Original at https://www.allaboutlean.com/bottleneck-walk1/*

*Figure 144: Five empty green wine bottles (Image Roser)*

The bottleneck walk is far and wide my most favorite method to detect bottlenecks on the shop floor (not only because it was developed by me, but also because it is really good!). You can **detect shifting bottlenecks**, using **no math whatsoever** and **no time measurements**, simply by **walking along the production line** and observing the line. It's almost too easy to believe, but it works like a charm! Due to the length of this topic, I have broken the article into two posts. This first post details how to find the current temporary bottleneck. The second post details how to determine the big picture regarding the bottlenecks. See below for a complete list of posts on this series on bottlenecks.

## 27.1 The Observations

The bottleneck walk is based on a few simple observations in a flow production system. You observe selected inventories and processes to determine the bottleneck. You don't need any measurements that can't be observed by merely looking at the production system. Neither do you need any calculations.

### 27.1.1 Observing Processes

One part of the bottleneck walk is observing processes. If you look at a process or a machine, you can see the process in different states. It could, for example:

- be working on a part;
- be set up for the next product (see for example SMED);
- be having a breakdown;
- be waiting for material (starved);
- be waiting for transport of a completed part (blocked); or
- be under maintenance.

The above examples are probably the most common ones, although there are more for specific cases. Merely by looking at these process states, we cannot say if a process is the temporary bottleneck at that time.

However, we can say for sure when it is not the bottleneck! Whenever the process is waiting for something else, it cannot be the bottleneck. Even more, if we know the process is not the bottleneck, we can say in which direction the bottleneck is.

- If the process is waiting for parts, the bottleneck is somewhere where these parts come from.

- If the process is waiting for transport or is blocked, the bottleneck is somewhere where the parts go to.

Of course, this also holds true for branches. For example, if there are two parts needed for the process and one of them is missing, then the bottleneck is in the direction of this missing part.

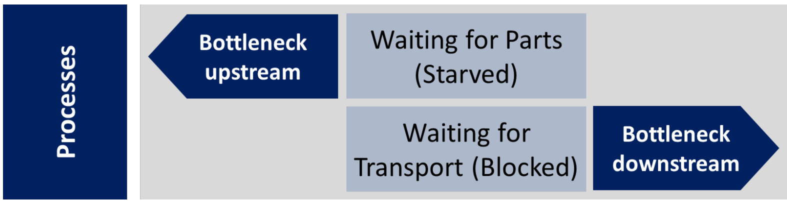


*Figure 145: Process Bottleneck Direction (Image Roser)*

When observing inventories, there is one thing that you can keep in mind to make your observations easier. Since most systems usually have similar cycle times, there is usually not much waiting going on. Hence with many observations you would see only a few waiting times.

However, there is one trick: When you observe a process and find the process working on a part, then you should wait for the process to complete its work. After the part is done, can the process start the next part right away, or does the process has to wait? If the process has to wait, what does the process have to wait for? Even a tiny delay waiting for parts or transport can make a difference here. **In my experience, it is possible to observe waiting times down to a quarter of a second or less. These tiny waiting times determine the bottleneck direction.**

Of course, if the next part is processed without delay, we cannot observe the bottleneck direction. This, however, is usually not a problem, as we will see later.

### 27.1.2 Observing Inventories

A similar approach is done for inventories. First of all, an inventory cannot be the bottleneck. If anything, a process transporting the inventory may be the bottleneck, but the inventory itself will not be the bottleneck. Depending on the state of the inventory, we can also tell the direction of the bottleneck.

- If the inventory is empty or rather empty, the bottleneck is probably upstream.
- If the inventory is full or rather full, the bottleneck is probably downstream.
- For an approximately half full inventory, we cannot tell the direction of the bottleneck.

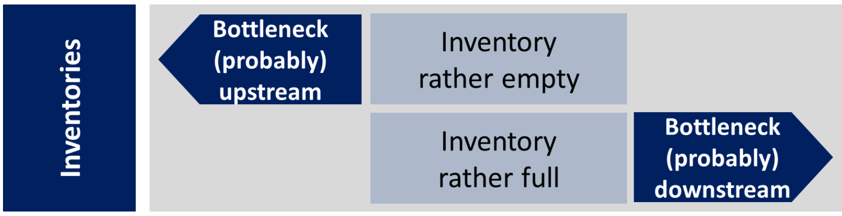


*Figure 146: Inventory Bottleneck Direction (Image Roser)*

Again, a simple observation of an inventory tells us the direction of the bottleneck—or, to be more precise, the likely direction of the bottleneck. Observing a process usually gives a clear answer regarding the bottleneck direction. Inventories, on the other hand, just give a likely direction of the bottleneck. The more the inventory is empty, the more likely the bottleneck is upstream. The more the inventory is full, the more likely the bottleneck is downstream.

We know when an inventory is empty. If the inventory has a defined upper limit, as for example in a FIFO lane, we also know when the inventory is full. However, not all inventories have a clearly defined upper limit. In some cases the limit depends on where else the worker finds more room to put the finished goods. In this case, the definition of "*full*" depends on the gut feeling of the workers regarding the inventory being rather full. Not perfect, but for our purposes good enough.

Based on my practical experience, I usually divide the inventory capacity by three.

- If the inventory is 1/3rd full or less, the bottleneck is upstream.
- If the inventory is between 1/3rd and 2/3rd full, we do not know the direction of the bottleneck.
- If the inventory is more than 2/3rd full, the bottleneck is downstream.

## 27.2 Where is the Bottleneck?

Walking along the production line and observing the bottleneck direction in multiple locations now tells us the location of the current bottleneck. I usually draw arrows in the direction of the bottleneck. Whenever two arrows point at each other, there has to be a bottleneck in between.

For the following examples I use a simple system consisting of four processes and five FIFO inventories with a maximum capacity of four parts each as shown below. For the inventories, I consider zero or one part in the inventory as a sign of an upstream bottleneck. Three or four parts are a sign of a downstream bottleneck. If there are exactly two parts in the inventory, we cannot tell the bottleneck direction.

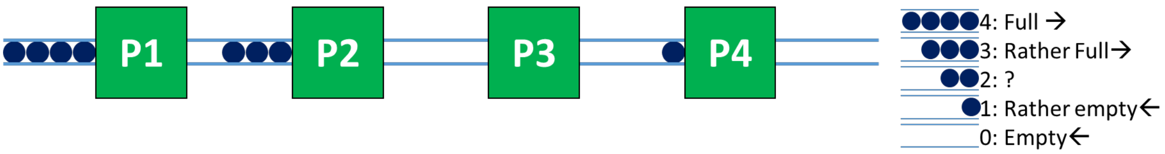


*Figure 147: Example Bottleneck System (Image Roser)*

### 27.2.1 Ideal Case: One Bottleneck, All Data Conclusive

In the ideal case, we can get the bottleneck direction at all observed processes and inventories except for one process. All directions point to this one process. The example is shown below. The direction of the bottleneck based on the inventories can be seen clearly.

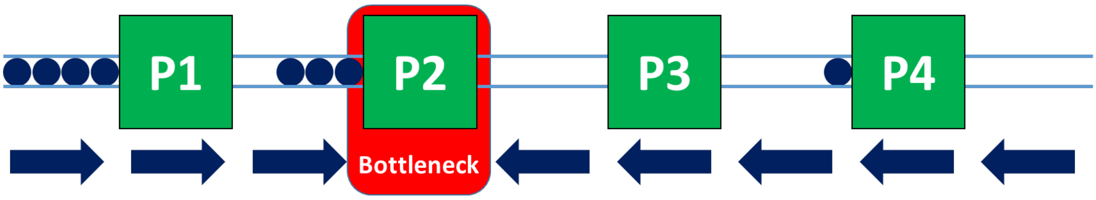


*Figure 148: Ideal Case Bottleneck (Image Roser)*

The bottleneck direction for processes is based on observations. In other words, process P1 had a small time waiting for transport after each part (blocked), and processes P3 and P4 were waiting for material after each part.

Since all the arrows point at P2, this process must be the bottleneck at this moment.

### 27.2.2 Real Case: Not All Data Conclusive

In reality, of course, you may not always get good data for every observation. In my experience, however, this is usually not a problem. Even if some directions are missing, you can still get good observations about the bottleneck.

The example below does not have a complete set of directional arrows. Nevertheless, all arrows point at process P2, which must be the bottleneck.

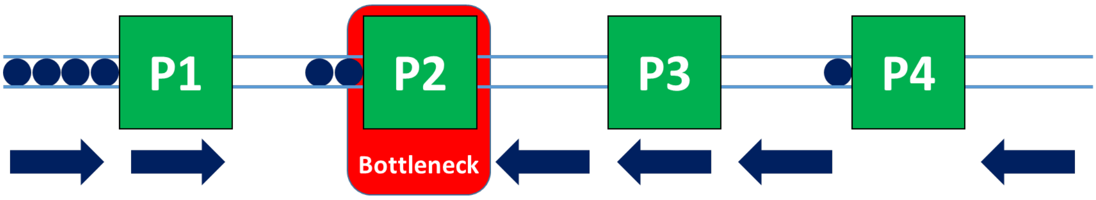

Figure 149: BN Real Case (Image Roser)

### 27.2.3 Possibility: More than One Bottleneck

Of course, there is also the possibility of two bottlenecks at the same time as shown below. This is the case if the bottleneck is about to shift. At this time we do not yet know if the bottleneck shifts from process P2 to P4, or from P4 to P2, or if there will be a shift at all.

For example, it may be that there is a temporary disturbance at process P4, which starts to influence its surroundings. However, the problem may be resolved before it also affects P2. In any case, we know that the bottleneck is neither P1 nor P3. In any case we will still use such data below.

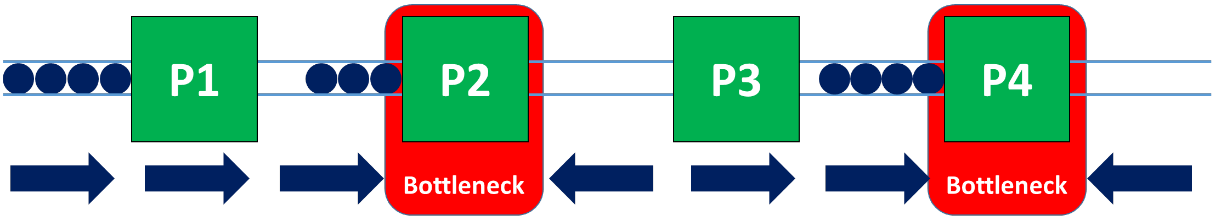

Figure 150: Two Bottlenecks (Image Roser)

Very similar is the situation below, except now the two potential bottlenecks are adjacent to each other. Again, the observation is valid even though we do not know the direction of the shift or if the shift of the bottleneck will be completed at all.

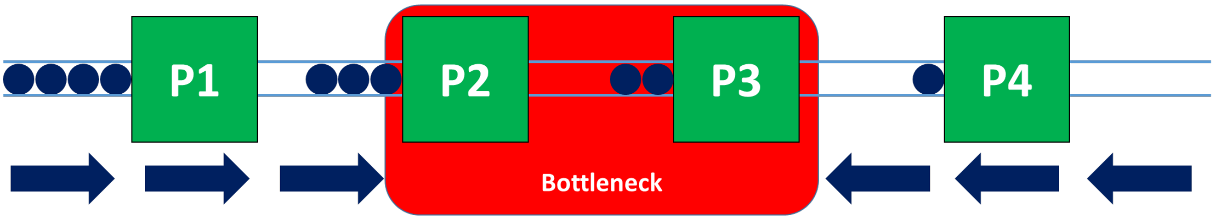

Figure 151: Two sequential bottlenecks (Image Roser)

### 27.2.4 Possibility: Bottleneck Outside the System

Another possibility is that the bottleneck is outside the observed system. In the example below, the material supply is lacking. The system itself could do more, but the supplier is the bottleneck.

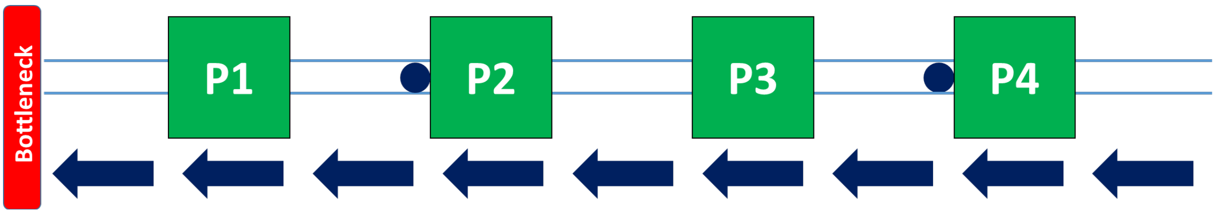

Figure 152: Supply Bottleneck (Image Roser)

You can envision a similar case where the demand is constraining the system. Theoretically you could call it a customer bottleneck, but I usually avoid this term because it may offend the customer. Besides, since any system must have a bottleneck, I prefer to have a (small) bottleneck at the customer rather than facing frequent stock outs (but admittedly there are also industries that have the luxury that they can let their customers wait).

### 27.2.5 Possibility: Bottleneck in an Unobserved Secondary Process

The next and last possibility is, in my view, the most interesting one. The arrows point at a spot where there is no process. What has happened?

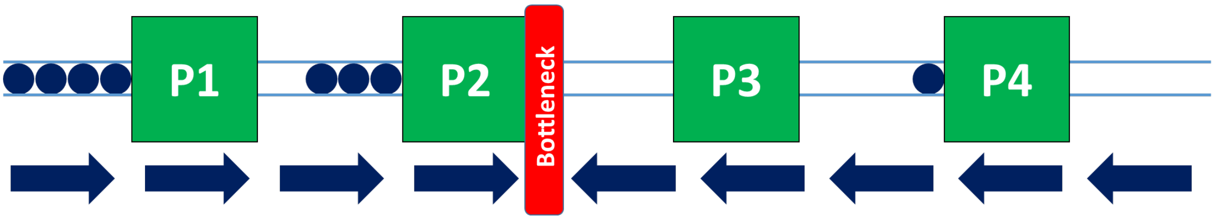


*Figure 153: Secondary Process Bottleneck (Image Roser)*

There are three possibilities:

- The bottlenecks shifted while you walked along the line. In other words, you walked from P2 to P3 while the bottleneck shifted from P3 to P2.
- Measurement Error. Yes, that can happen.
- We missed a process between P2 and P3.

In my experience, the most likely case is situation 3: We missed a process. Somewhere between P2 and P3 is another process, however small, that constrains our system. This may be a small logistic process, the speed of the conveyor belt, or any other secondary process necessary for transport or other things.

In fact, I find about 30% of bottlenecks in such secondary processes. Because nobody is paying attention to these "*minor*" processes, they become the bottleneck very frequently. This is also one of the strengths of the bottleneck walk: **You find the bottlenecks even in locations where you weren't even looking!**

The bottleneck walk above describes how to find the momentary shifting bottleneck in your system. The next post "The Bottleneck Walk – Practical Bottleneck Detection Part 2" will go into more detail on how to establish the big picture, and will give you additional tips and tricks on bottleneck detection and a list of advantages and disadvantages.

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- Roser, Christoph, Kai Lorentzen, and Jochen Deuse. "Reliable Shop Floor Bottleneck Detection for Flow Lines through Process and Inventory Observations." In *Proceedings of the Robust Manufacturing Conference*. Bremen, Germany, 2014.
- Roser, C., Lorentzen, K., Deuse, J., 2015. Reliable shop floor bottleneck detection for flow lines through process and inventory observations: the bottleneck walk. Logistics Research 8.

# 28 The Bottleneck Walk – Practical Bottleneck Detection Part 2

*Christoph Roser, July 13, 2014 Original at https://www.allaboutlean.com/bottleneck-walk2/*

*Figure 154: Six empty green wine bottles (Image Roser)*

The bottleneck walk is far and wide my most favorite method to detect bottlenecks on the shop floor (not only because it was developed by me, but also because it is really good!). You can **detect shifting bottlenecks**, using **no math whatsoever** and **no time measurements**, simply by **walking along the production line** and observing the line. It's almost too easy to believe, but it works like a charm! Due to the length of this topic, I have broken the article into two posts. The first post "The Bottleneck Walk – Practical Bottleneck Detection Part 1" details how to find the current temporary bottleneck. This second post details how to determine the big picture regarding the bottlenecks. See below for a complete list of posts on this series on bottlenecks.

## 28.1 Long-Term Average Bottleneck

In the previous post, we saw an easy approach to determine the momentary bottleneck on the shop floor. We simply walked along the production line and determined the direction of the bottleneck for different processes and inventories. The bottleneck has to be between two directions pointing at each other:

- Process lacking parts (starved) → Bottleneck upstream
- Inventory (rather) empty → Bottleneck upstream
- Process waiting for transport (blocked) → Bottleneck downstream
- Inventory (rather) full → Bottleneck downstream.

Doing such a bottleneck walk once will give you the location of the current temporary bottleneck. However, this may be a random fluke, and the bottleneck may be somewhere else shortly thereafter. Hence it is beneficial to make multiple observations. Below is an example of such multiple observations for our system.

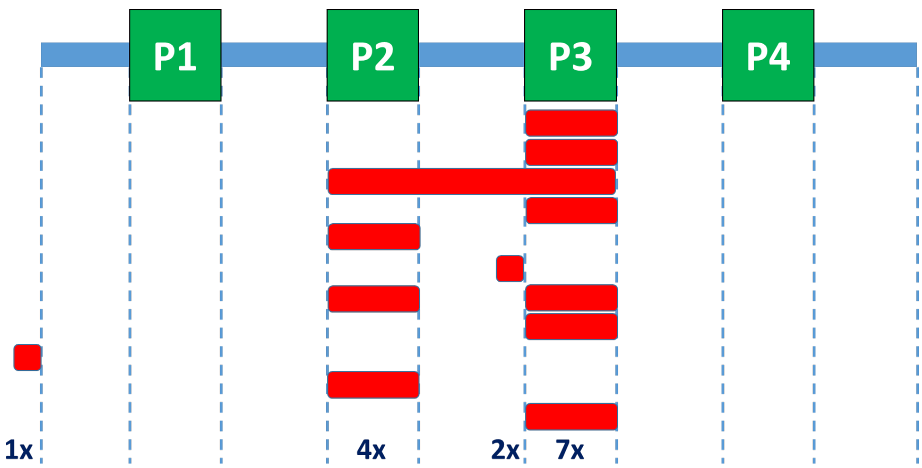

*Figure 155: Summary of bottleneck observations (Image Roser)*

The graph shows the summary of altogether eleven observations. It can be seen that the bottleneck shifts frequently between P3 and P2, with P3 being the bottleneck most frequently. Only once was there a supply bottleneck and only twice a secondary process between P2 and P3. Hence if you want to improve the bottleneck, you should work on P3 or, alternatively, P2.

As for the number of observations: How many observations do you need to find the bottleneck? You could do a statistical analysis and calculate confidence intervals. However, in my experience, this is usually way too much math for the shop floor. Hence I usually recommend making bottleneck observations until you think you understand the situation.

Also, there is the question regarding the time between observations. I usually suggest giving the system some time to change. For example, if you have a cycle time of one hour, doing an observation every five minutes will not help. However, if your cycle time is a few seconds with little inventory, the bottleneck may have changed after less than five minutes.

## 28.2 A Few Tips

Here are a few additional points I find helpful when doing the bottleneck walk:

- If you find the bottleneck, look at the bottleneck right after the observation. Chances are the bottleneck is still there. This helps you to understand the reason why that process became the bottleneck.
- You may also write down not only the direction of the bottleneck, but also the state for processes that could be bottlenecks, or any other observation you think is worthwhile noting down. If you look at the data later, you may for example see that process P3 was always the bottleneck while working, and P2 always when having a breakdown. This also gives you clues on what to do to improve the system.
- There is always the temptation to automatize this data collection and have a computer take the measurements. Don't! While there is the convenience of an automated data retrieval, I am a firm believer in doing the observing yourself. You will see so much more when you look for the bottleneck yourself instead of looking at a computer printout.
- A bottleneck walk does not take much time. However, to make it even faster, you could define the exact locations for the observations, so your observations become even faster. For example, you could mark buffers to quickly see if there is less than 1/3rd or more than 2/3rd of buffer capacity used.
- For very long lines you can also do a first bottleneck walk with few observations to find the section where the bottleneck is and then make a second more detailed bottleneck walk for the relevant section.

Observing right away, not data collection, defines observation points (faster).

## 28.3 Why You Should Use this Method!

*Figure 156: Fast, reliable, easy… (Image Roser)*

The method works very well. I believe there are numerous advantages in using this method:

- **Very fast**: It usually takes less than five minutes to do a bottleneck walk (unless you are doing it for the first time).
- **Accurate**: The method can reliably find shifting bottlenecks in flow lines.
- **No math**: You don't need any calculations for the bottleneck walk, hence it is very shop floor friendly.
- **No measurements**: You don't need any measurements, especially time measurements of processes, hence it is very union friendly.
- **Finds bottlenecks anywhere**: Even finds the bottlenecks in processes that you didn't even consider as part of your bottleneck walk, e.g., conveyor belts, handling robots, etc.
- **Works with branches and parallel processes**: Also finds the bottleneck in systems where the material and information flow has different branches. As long as you can tell what the process/inventory is waiting for, you can find the bottleneck.
- **Supports root cause analysis**: Direct observation of the bottleneck helps to understand the root cause of the bottleneck.

Of course, there are also still some open points:

- Difficulties with job shops, better suited for flow shops.
- Observation not ideal for extremely long cycle times.
- More difficult for multi-machine-handling: Is the machine waiting for parts or for the operator?

Yet overall the method works very well. I have trained hundreds of shop floor operators in this method, and have done myself almost one hundred bottleneck detections using my method. Pretty much all were astonished by how easy it is to find the bottleneck and by the clarity of the bottleneck walk approach. (Note: I also do simulation-based trainings on the bottleneck walk. If you are interested, please contact me.)

In less than half the cases, the bottleneck was not where the management and operators expected it to be. In one third of the cases, it was a previously unobserved minor secondary process.

I hope this post and the previous posts inspired you to go out and determine your bottleneck. Tip: If you are doing this for the first time, I recommend a heavily automated line with clearly defined FIFO lanes and a short cycle time. It is not a requirement, but for learners it works best. In any case, **go out and improve your industry!**

## 28.4 Sources:


- Roser, Christoph, Kai Lorentzen, and Jochen Deuse. "Reliable Shop Floor Bottleneck Detection for Flow Lines through Process and Inventory Observations." In Proceedings of the Robust Manufacturing Conference. Bremen, Germany, 2014.
- Roser, C., Lorentzen, K., Deuse, J., 2015. Reliable shop floor bottleneck detection for flow lines through process and inventory observations: the bottleneck walk. Logistics Research 8.

# 29 Manufacturing – A key stepping stone on the Road to Prosperity

*Christoph Roser, July 20, 2014 Original at [https://www.allaboutlean.com/manufacturing-prosperity/](https://www.allaboutlean.com/manufacturing-prosperity/)*

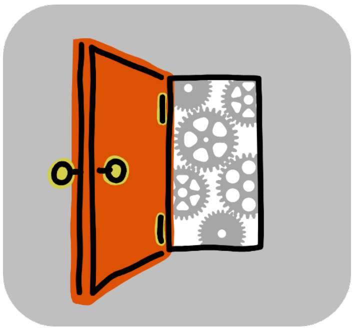

*Figure 157: Open Door to the Future (Image Roser)*

Manufacturing is an important part of most economies. However, during the development of an economy, manufacturing plays different roles at different times. In fact, **manufacturing is a key stepping stone on the road to economic prosperity**. During the development from an agricultural society to a service society, nations must go at one point through a industrial society.

## 29.1 Big Data on Economic Relations

Historically, every nation starts out as an agricultural society. Up to before the industrial revolution, the economy of all nations was based on agriculture. Great Britain was the first nation to industrialize, followed shortly by Europe and North America. Nowadays, however, advanced economies are based mostly on service.

The graph below shows on the Y-axis the ratio of the output of the secondary sector (industry, mining, utilities) to the total value add, i.e. what part of the economy is based on the secondary sector. The X-axis shows the total value add per person, inflation adjusted into 2005 US Dollar. Each dot represents one of 131 countries for each year between 1970 and 2012, for a total of 5302 data points (For Details see Data Source below). The thick black line is the moving 255 value average.

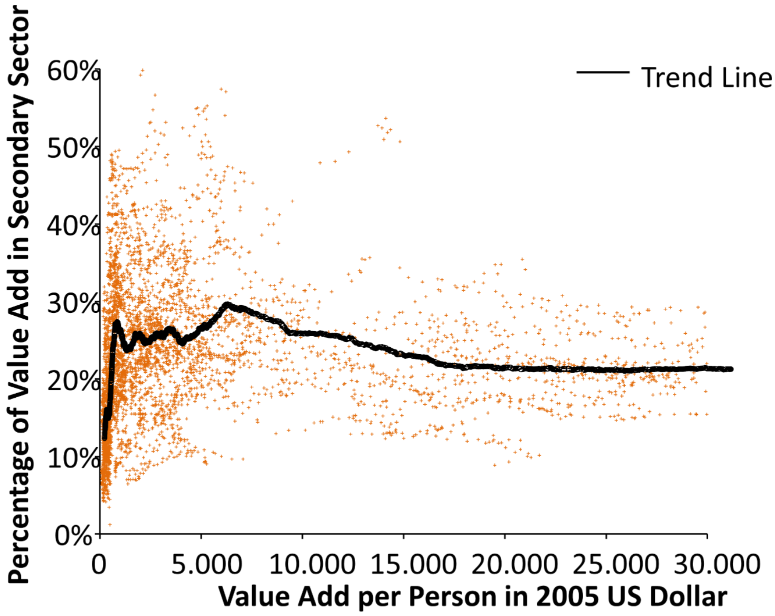


*Figure 158: Part of secondary sector on value add for different countries (Image Roser)*

At first glance, it seems to be a mess of data. However, if you look more closely, you can see a trend. Poor nations with a value add of less than $500 per person have very little industry, often as little as 5% of the total economy. However, industry increases steeply as the wealth of the nation improves. An average country with a value add of only $1000 per person has almost 30% of its economy in manufacturing. From then onward manufacturing holds steady until its peak of 30% for countries with a value add of around $7000 per person. After that **the share of industry shrinks as countries become wealthier**, leveling out at around 22% of the total value add.

There are very few nations with a value add per person of around $7000 that have less than 20% industry. It seems that on the way from agriculture to service, manufacturing is a necessary prerequisite to wealth. While the importance of manufacturing declines for wealthy first world service based nations, **the path to the first world is through industry**.

Below is the same graph, showing also the trend lines for the primary and tertiary sector. Clearly agriculture takes a nose dive while service increases. The steepest increase in relation to the starting point, however, is in industry.

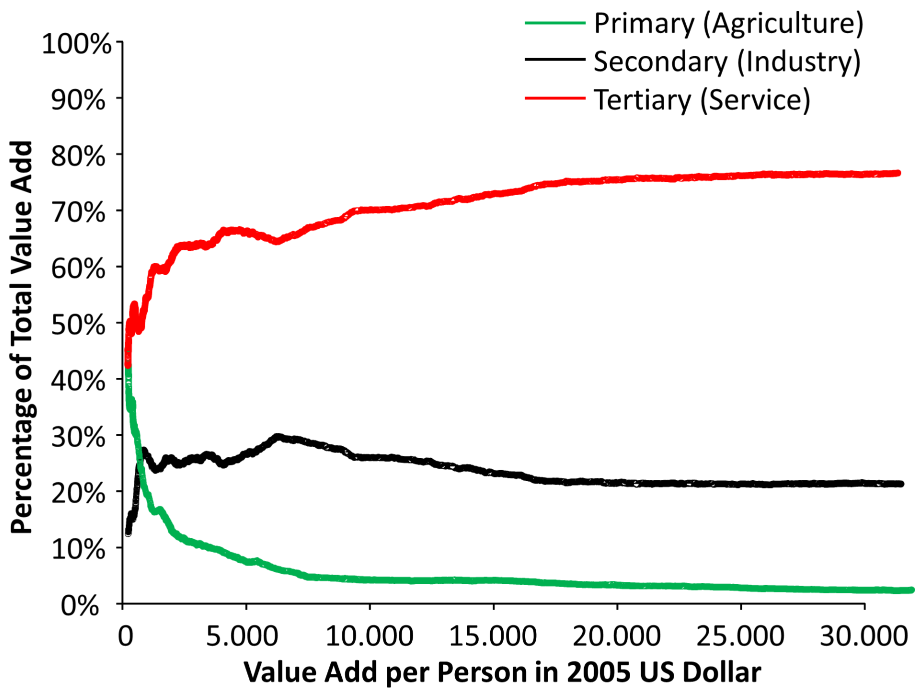

*Figure 159: Development of Primary, Secondary, and Tertiary Sector in relation to per Person value add (Image Roser)*

## 29.2 Different Countries in Detail

Below are charts for selected countries in different continents. Please note that all charts have the same scale, and the data points show the development between 1970 and 2012.

### 29.2.1 Selected American Countries

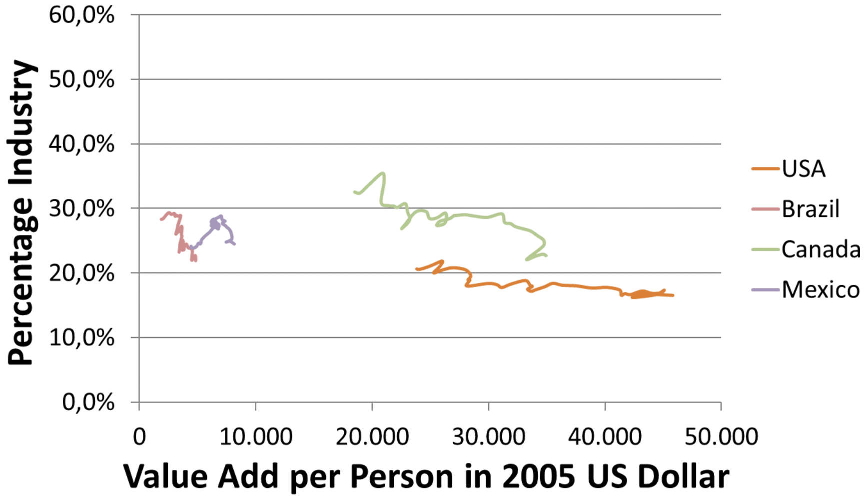


*Figure 160: Percentage Value add of industry for selected American countries (Image Roser)*

Both the USA and Canada are wealthy first world countries with a value add of $45.000 and $35.000 respectively. The share of industry of the total economy is further declining. Mexico and Brazil on the other hand are developing second world countries. Both have a higher level of industrialization, although Brazil is in a decline.

### 29.2.2 Selected Asian Countries

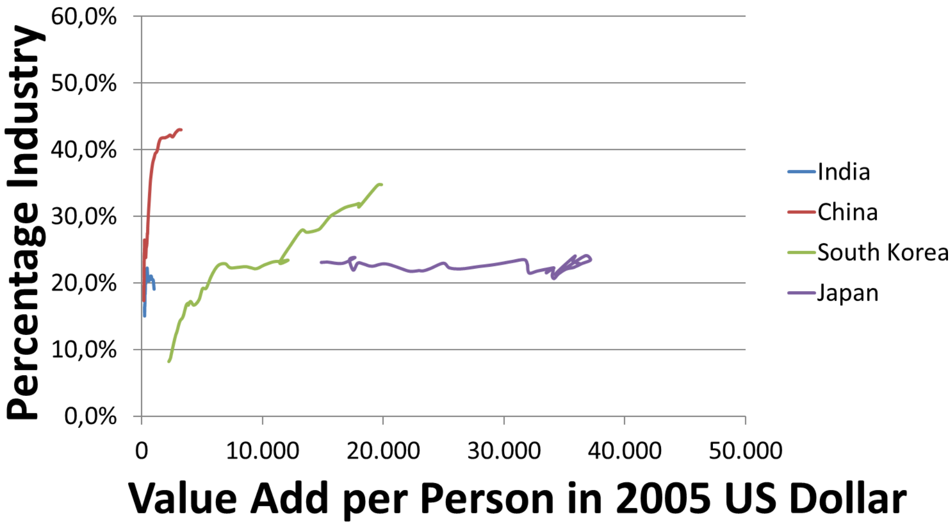


*Figure 161: Percentage Value add of industry for selected Asian countries (Image Roser)*

Japan is a highly developed nation in its post-industrial phase. Industry is steady around 22% of total value add, although the burst real estate bubble in 1990 has stopped its advance. South Korea is a strong Asian tiger that is still jumping into becoming a first world country. The trend looks good, and if there is no war in Asia, South Korea may continue to increase its wealth.

China is still on its way, having over 40% of its economy in industry, while the average value add of a Chinese citizen is still barely on the level of Korea forty years ago. India is a mess. Lack of a political strategy has it standing still for the last forty years.

### 29.2.3 Selected European Countries

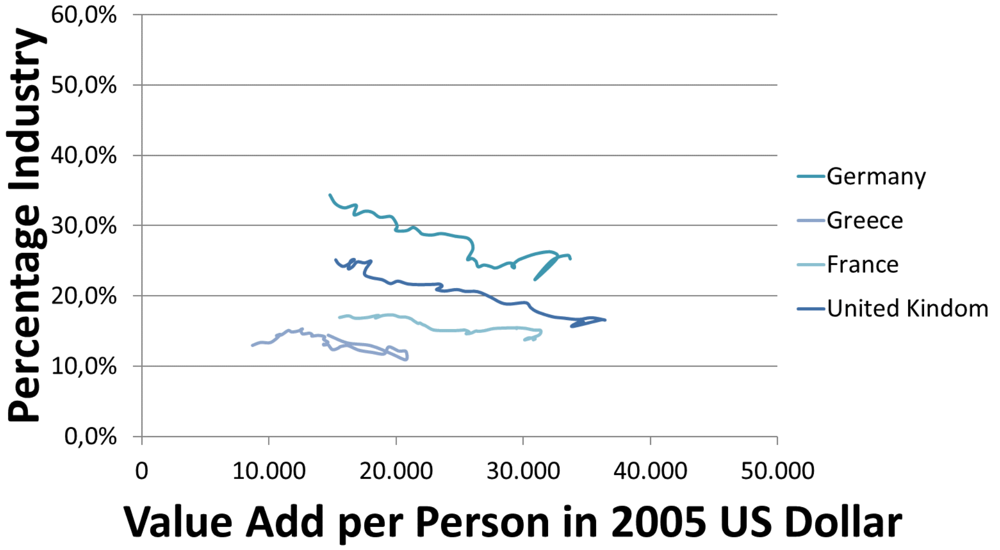


*Figure 162: Percentage Value add of industry for selected European countries (Image Roser)*

Europe is a continent with mostly first world nations. Germany, France, and the United Kingdom are all well in a post-industrial society, although Germany still has a strong manufacturing base. Greece made it over the hill into a post-industrial society, but since then has turned back due to the recession.

### 29.2.4 Selected African Countries


*Figure 163: Percentage Value add of industry for selected African countries (Image Roser)*

Africa is not anywhere close to North America, Europe, or Asia. South Africa is not getting any wealthier, and its share of industry as part of the economy is declining. Egypt is poor but industrialized, although the recent turmoils reduced the industry basis somewhat. Kenia is still a mostly agricultural country, where industrialization increases only very slowly.

## 29.3 Summary

In sum, all countries have to industrialize before they can become a wealthy service based society. As we have seen above, some countries are well industrialized, while others have made significant progress and are well on its way to prosperity. Other countries, however, seem to be stuck in a agricultural or poor early industrial society with little progress in the last 40 years. I hope this post and its big picture view was interesting to you. **Now go out and improve your industry!**

## 29.4 Appendix – Details on Source Data and Analysis

Raw Data courtesy of United Nations Statistic Division. The ratio of the **Mining, Manufacturing, Utilities (ISIC C-E)** to the **Total Value Added** (not the GDP) represents the Y-axis. The X-axis is the **Total Value Added** divided by the population of the country for that year. Data for 138 countries between 1970 and 2012 was considered. These countries were:

Afghanistan, Albania, Argentina, Armenia, Australia, Austria, Bangladesh, Belarus, Belgium, Belize, Benin, Bhutan, Bolivia, Bosnia and Herzegovina, Brazil, Bulgaria, Burundi, Cambodia, Cameroon, Canada, Central African Republic, Chile, China, Colombia, Congo, Democratic Republic of the, Costa Rica, Côte d'Ivoire, Croatia, Cuba, Cyprus, Czech Republic, Czechoslovakia (Former), D.P.R. of Korea, D.R. of the Congo, Denmark, Djibouti, Dominica, Dominican Republic, Ecuador, Egypt, El Salvador, Estonia, Ethiopia, Ethiopia (Former), Finland, France, Gambia, Georgia, Germany, Ghana, Greece, Guatemala, Guinea, Guinea-Bissau, Haiti, Honduras, Hungary, Iceland, India, Indonesia, Ireland, Israel, Italy, Japan, Jordan, Kazakhstan, Kenya, Kosovo, Lao People's DR, Latvia, Lesotho, Liechtenstein, Lithuania, Madagascar, Malawi, Malaysia, Mali, Malta, Mauritius, Mexico, Mongolia, Montenegro, Morocco, Mozambique, Namibia, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Norway, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Republic of Korea, Republic of Moldova, Romania, Russian Federation, Senegal, Serbia, Sierra Leone, Singapore, Slovakia, Slovenia, South Africa, Spain, Sri Lanka, Suriname, Swaziland, Sweden, Switzerland, Syrian Arab Republic, Tajikistan, TFYR of Macedonia, Thailand, Trinidad and Tobago, Tunisia, Turkey, Turkmenistan, U.R. of Tanzania: Mainland, Ukraine, United Kingdom, United States, Uruguay, USSR (Former), Uzbekistan, Venezuela, Viet Nam, World, Yemen Arab Republic (Former), Yemen Democratic (Former), Yugoslavia (Former), Zimbabwe

Additional 84 countries have been excluded from the analysis, based on

- Mining Revenues >50% Value Add, therefore excluding for example oil exporters like Kuwait and Saudi Arabia
- Suspicion of flawed data, especially when the numbers don't add up or the CIA world fact book gave very different values. This applies especially to some African nations like the Sudan or the Kongo
- Very small or fragmented nations like San Marion or the Seychelles due to a handicapped industrial development

The list of excluded states is:

Algeria, Andorra, Angola, Anguilla, Antigua and Barbuda, Aruba, Azerbaijan, Bahamas, Bahrain, Barbados, Bermuda, Botswana, British Virgin Islands, Brunei Darussalam, Burkina Faso, Cabo Verde, Cayman Islands, Chad, China: Hong Kong SAR, China: Macao SAR, Comoros, Congo, Cook Islands, Equatorial Guinea, Eritrea, Fiji, French Polynesia, Gabon, Greenland, Grenada, Guyana, Iran (Islamic Republic of), Iraq, Jamaica, Kiribati, Kuwait, Kyrgyzstan, Lebanon, Liberia, Libya, Luxembourg, Maldives, Marshall Islands, Mauritania, Micronesia, Micronesia (FS of), Monaco, Montserrat, Myanmar, Nauru, Netherlands Antilles, New Caledonia, Nigeria, Oman, Palau, Polynesia, Puerto Rico, Qatar, Rwanda, Saint Kitts and Nevis, Saint Lucia, Samoa, San Marino, Sao Tome and Principe, Saudi Arabia, Seychelles, Solomon Islands, Somalia, South Sudan, St. Vincent and the Grenadines, State of Palestine, Sudan, Sudan (Former), Timor-Leste, Togo, Tonga, Turks and Caicos Islands, Tuvalu, Uganda, United Arab Emirates, Vanuatu, Yemen, Zambia, Zanzibar

The moving average is based on 255 values. This is the average of the percentages, hence the average was not weighted according to the size of the nation.

# 30 The Hidden and not-so-hidden costs of Inventory

*Christoph Roser, July 27, 2014 Original at [https://www.allaboutlean.com/inventory-cost/](https://www.allaboutlean.com/inventory-cost/)*

*Figure 164: 1/3rd to 2/3rd gone every year! (Image Apollo2005 under the CC-BY-SA 3.0 license)*

Inventory is one of the seven types of waste. There is usually quite a significant cost associated with having inventory, usually much more than what traditional bookkeeping accounts for. **Between 30% and 65% of the value of your inventory is spent every year as inventory-related costs!** This post looks into more detail at the cost of this inventory.

## 30.1 Causes of Inventory Cost

### 30.1.1 Cost of Capital

*Figure 165: Money costs Money (Image unknown author in public domain)*

The first expense associated with inventory is the cost of capital. Simply speaking, the inventory you have represents money, either in the form of raw materials or finished goods that are not yet sold. In any case, you paid for the goods already but have not yet received the return by selling the products. Hence, inventory is tied up cash.

The cost of capital is usually the cost to secure financing (both debt and funds). A (somewhat simplified) example is the interest rate you have to pay for a loan. If you have to borrow $1 million to put it into your inventory, the interest rate would be part of the cost of capital.

The exact number for cost of capital depends on your company, but as of 2014 the average is around 8% (See Cost of Capital by Sector). **Typical industry estimates range from 6% to 12% for the cost of capital.**

### 30.1.2 Taxes and Insurance

*Figure 166: Taxes! (Image James Montgomery Flagg in public domain)*

Besides cost of capital, the goods also have to be insured. Furthermore, they will also be taxed. Details again differ from industry to industry and country to country, but it is estimated that **between 3% and 9% are added on top for insurance and taxes.**

### 30.1.3 Storage Cost

*Figure 167: This, too costs money! (Image Peter Craven under the CC-BY 2.0 license)*

The next major cost factor is storage cost. You need to store your goods somewhere. In the simplest case, this may be a stockpile of sand or coal. More sophisticated goods demand protection against the elements, commonly through a warehouse with shelves or storage facilities.

*Figure 168: Storage Cost in Action … (Image Axisadman in public domain)*

These are not free either. You have to pay for the ground, for the building, and for the maintenance of the building. Of course, this also depends on your location and the type of goods. A warehouse in New York City is simply more expensive than a similar warehouse in rural Kansas.

For example, the cost of storing a pallet in a warehouse is around $17 per month or around $200 per year (not including handling – see the next point for that). Of course, the value of the goods on the pallet varies widely, but $10,000 per pallet is a good estimate. **Hence the storage cost in industry is, very roughly, at least 2% of the value of the goods (but it may be up to 5% of the value of the goods) per year.**

### 30.1.4 Handling Cost

*Figure 169: Forklift in Operation (Image U.S. Navy Petty OfficerKatarzyna Kobiljak in public domain)*

Now we know the cost of storing your goods. However, this also requires handling. The goods have to go into storage and get back out again. A common saying in industry is that every time someone touches a package or pallet, it will cost you between $1 and $2.

Of course, there are more people involved in the handling of the pallet. Common industry rates start around $3 to $4 for an incoming pallet, and again the same number for an outgoing pallet. Hence the expense is around $8 per pallet moving through the warehouse. Additionally, the pallet is usually moving not only through one but through multiple warehouses. **In sum, this also adds between 2% and 5% of the cost of the goods for handling.**

### 30.1.5 Administration Cost

*Figure 170: Administration costs money, too! (Image Seattle Municipal Archives under the CC-BY 2.0 license)*

Additionally, there is the administration cost of data entry and bookkeeping. This is also often around $5 per transaction, both for entry and for exit, and again through multiple warehouses.

Now we would need to know how often the pallet moves through the warehouse. This is called turnover (i.e., the average number of times your inventory is exchanged per year). In manufacturing, turnover is usually not so hot, with an average turnover below two, meaning they have between half a year and one year inventory on hand (Source: What Should the Inventory Ratio Be for Manufacturing?). Automotive is much better with a turnover between five and ten (Source: How Do the 7 Largest Auto Companies Stack Up Against Each Other?).

Assuming a turnover of five would mean that there are five incoming and five outgoing pallets per year for every pallet in storage. **As administrative costs are higher than handling, this adds between 3% and 6% of the cost of the goods.**

### 30.1.6 Scrapping and Obsolescence

*Figure 171: Not quite new… (Image IFCAR in public domain)*

Both products and raw materials may become obsolete. With increasing volatility and decreasing product life, new products come around even more frequently. If you still have old goods on hand, you can either update them, sell them below cost, or throw them out. In any case, this costs money.

This is often one of the biggest parts of the cost of inventory. It is estimated that **obsolescence is between 6% and 12% of the value of the goods**. Additionally, this is increasing due to even faster product launches and upgrades.

### 30.1.7 Deterioration and Theft

*Figure 172: A bit aged… (Image Anthony DeLorenzo under the CC-BY-SA 2.0 license)*

Closely related to scrapping cost is deterioration and theft. Products and raw materials may age. This is especially true for perishable goods, but almost every product will deteriorate over time. Glues may get old, metals may rust, electronics may loose their battery life.

Even if they do not deteriorate, they may get dirty. One plant I knew manufactured white panels for housing of electronics and white goods, and then let them sit on the shelves for three months. All of the panels had to be cleaned again by hand since they were so dirty.

Products may also get damaged. Being moved around usually involves the risk of damaging your products. Finally, there is also the issue of theft. Goods may simply go missing. **Both deterioration and theft make between 3% and 6% of the value of the goods.**

### 30.1.8 Value or Cost of Response Time

*Figure 173: I`ll be right with you … (Image Jürgen Schoner under the CC-BY-SA 3.0 license)*

Yet another factor influenced by inventory is the response time. The more inventory you have, the longer your throughput time and the more sluggish your company. Rather than dancing nimbly around your competitors, inventory makes you lag behind. A positive example is Inditex, a Spanish textile manufacturer. Especially for its ZARA brand, they produce in Portugal and Spain. Hence they can deliver the copy of the latest *haute couture* to their European stores while the competition is still loading in Shanghai.

Another example was during the 2008 economic crisis. For some industries, sales dropped dramatically, but there were still five months' worth of goods in the pipeline (or on ships). Slowing down the company had five months of lag. All of these products had to be stored somewhere, since they could not be sold. This increased costs even more. Similarly, when the economy increased again, there was another five months lag due to shipping.

Overall, a leaner supply chain makes your company more responsive. It is very difficult to put a value on your companies responsiveness, but I would estimate **a cost of at least 5% or 10% of the value of your goods for sluggish response times.**

## 30.2 Summary

Overall, the **cost of inventory is between 30% and 65% per year!** While this differs from company to company, it is not to be underestimated. Some instances even had a cost of inventory in excess of 75%. Below is the distribution for an optimistic case with "*only*" 30% of the value of the goods as inventory cost per year.

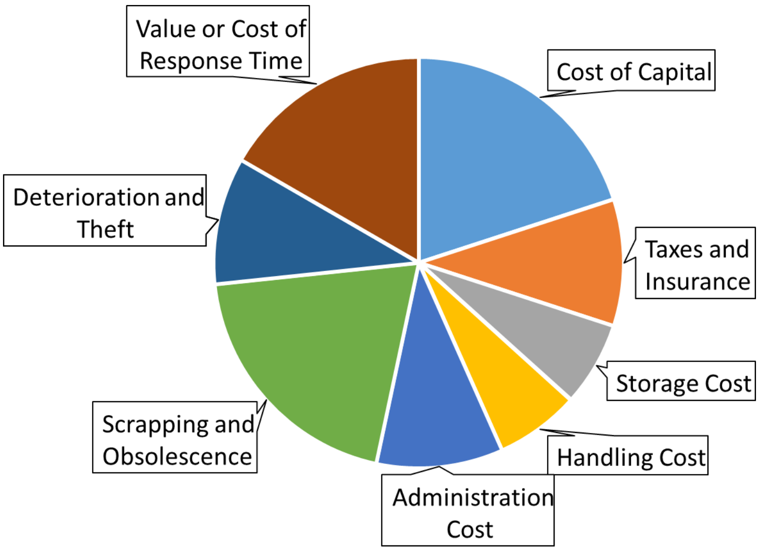


*Figure 174: Cost of Inventory (Image Roser)*

Hence one of the reasons for the success of Toyota in particular and lean manufacturing in general is the realization of the cost of inventory. You are effectively paying between 1/3rd and 2/3rd of your inventory every year! I hope this motivates you to reduce your inventory. **Now go out and improve your Industry!**

## 30.3 Source

(unless linked above):

Richardson, Helen: Control your costs–then cut them. Transportation & Distribution; Dec 1995, Vol. 36 Issue 12, p. 94

# 31 Facing Change in Modern Manufacturing Systems – The Difference between Flexible, Agile, Reconfigurable, Robust, and Adaptable Manufacturing Systems

*Christoph Roser, Augest 03, 2014 Original at https://www.allaboutlean.com/change-in-manufacturing/*

*Figure 175: Four Seasons (Image Roser adapted from Cherubino)*

The speed of modern business is continually increasing. Product life cycles of cars and mobile phones are decreasing, and customer demand is more volatile. Gone are the days of Henry Ford, who produced his Model T for almost 28 years without much change. Modern manufacturing systems need to be prepared for a constantly changing environment. The challenge has been realized for quite some time now, and there are a multitude of expressions related to this problem. This post will discuss many of these terms related to the challenge of change.

## 31.1 Active and Passive Change to the Manufacturing System

Generally speaking, the ability of manufacturing to react to change can be grouped in two parts:

- Active change, where operators and management actively change the manufacturing system. The goal here is to have a system that can be changed easily.
- Passive change, where the system itself has a built-in ability to change. The system automatically reacts even without the operators or management adjusting the system.

Naturally, a passive change is preferable when possible. Examples for a passive system are kanban or CONWIP (i.e., any system that limits the work in progress). Using such an approach, the manufacturing system never gets overloaded but can run much smoother than a system where every order is pushed in immediately.

## 31.2 Sources of Change

Change in a manufacturing system is inevitable. There are different sources of change, requiring different responses to counteract its effect. In short, **everything changes**. Below is a list of possible sources of change in more detail.

- Machines and tools – They may age or break, disrupting the system.
- Man – Your labor force is not static, but will change over time. Are there tasks that only one employee can do? If so, you are at risk. Will you survive a strike?
- Supply – Supplies may be delayed, or a source of supply may dry up completely. Will your business survive if your key supplier goes bankrupt? Many companies use a dual-source strategy to reduce this exposure to risk.

- Customer – Has the habit of always ordering more or less than you expected, ordering different products, or even switching to the competition completely (although sometimes they also switch to you). Also has a reputation for unreasonable demands. But then, you can't live without customers either.
- Competition – Technologies improve, and prices (usually) go down. Are you ahead of the competition, swimming with the bulk, or are you falling behind?
- Management – One of the biggest sources of change in manufacturing. On a large scale, a new boss usually means out with the old and in with the new, whatever that may be. Even on a small scale, management disrupts. It is common wisdom in industry that night shifts are more productive, since there are no managers around to change things. But then, they often have to forward changes that are forced on them by external sources in order for the company to survive.

There are more sources of change, depending on the level of detail you go into. However, the focus of this post is different aspects to face this constant barrage of change.

## 31.3 What the Industry is Talking About (… and What They Mean)

Below is a list of terms used to express different approaches to face change in manufacturing. Unfortunately, these terms are used differently by different researchers and practitioners. My goal is to give you an overview of what is out there:

### 31.3.1 Flexible Manufacturing System

*Flexible /ˈflɛk.sɪ.bəl/: Capable or being easily changed*

**A flexible manufacturing system aims to produce different products on the same system** without excessive changeover cost. At a minimum, this includes different products of the same product family. More advanced flexible systems, however, can also include products of different product families.

One popular example in automotive is Toyota, which was the first automotive company to assemble completely different car models on the same assembly line.

According to Google Ngram viewer, the term was very common and popular around 1990, but since then has lost its luster. The graph shows that the use of the words "flexible manufacturing" started around 1980 and peaked around 1990. Since then the usage of these words fell significantly, yet at its peak it was one of the most important keywords in manufacturing.

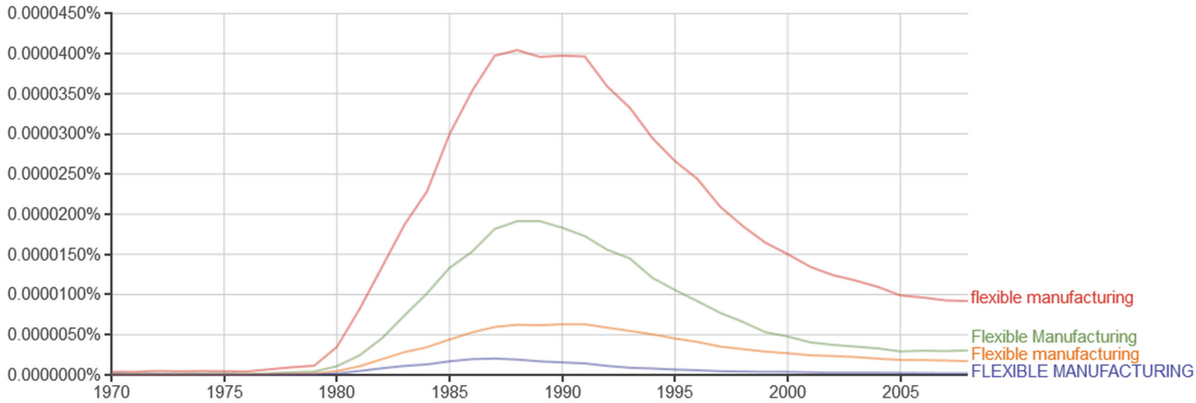


Figure 176: Use of flexible manufacturing in Literature (Image Roser)

### 31.3.2 Agile Manufacturing System

*Agile / ˈædʒ.aɪl: Having the ability of quick motion*

Yet another popular term in industry is "agile manufacturing." Somewhat vague, **agile manufacturing aims for a quick response to changes**.

Below are the Google Ngram results for agile manufacturing. The term was unknown before 1990, but peaked already around 1996, only slightly below the peak of flexible manufacturing.

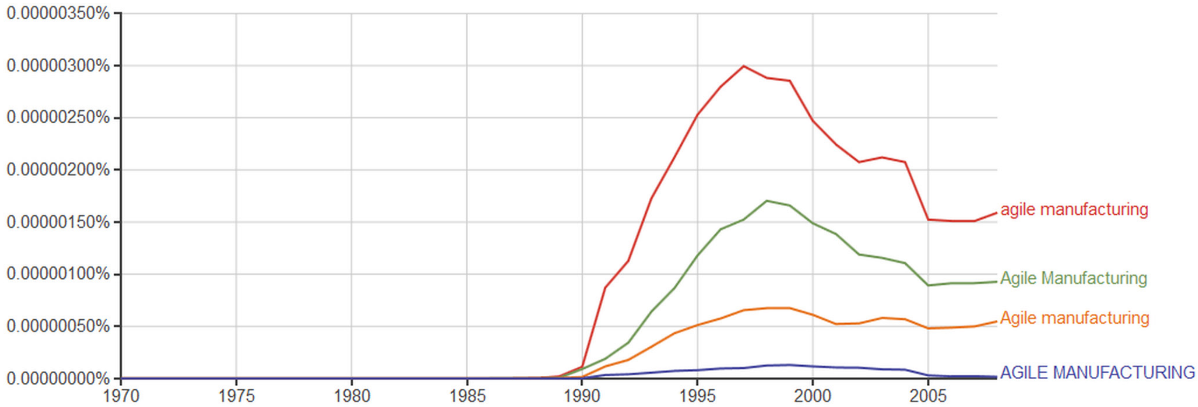


*Figure 177: Use of agile manufacturing in Literature (Image Roser)*

### 31.3.3 Reconfigurable Manufacturing System

> ***Reconfigurable*** *\ˈrēkən-ˈfi-gyərəbəl/: Able to be rearranged or adapted, able to be set up in a particular way*

The expression "reconfigurable manufacturing" is similar to adaptable manufacturing above. The **r**econfigurable manufacturing **system is (supposedly) also able to adjust rapidly to changing circumstances.**

Below are the Google Ngram results for reconfigurable manufacturing. The term was unknown before 1990, but shows strong growth from 2000 onward. It seems that the meaning is identical with agile manufacturing above, only the names have changed.

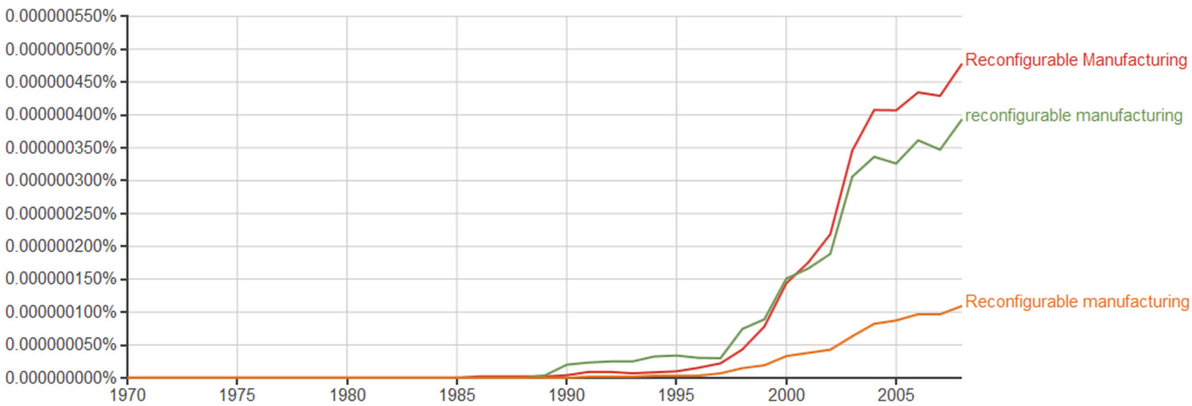


*Figure 178: Use of reconfigurable manufacturing in Literature (Image Roser)*

### 31.3.4 Robust Manufacturing System

> ***Robust*** *\rō-ˈbəst\: Designed or evolved in such a way as to be resistant to total failure despite partial damage*

Robust, by definition, means that the **robust manufacturing system is insensitive to problems** and challenges that arise. This can be achieved, for example, through redundancies. If you have only one machine for a critical process, then your entire system is in danger if the machine breaks. The same applies if you have only one employee able to program or operate this critical machine(s) – and believe me this happens way more often than you would think.

One step up is to not only have more than one machine, but to have more than one location. For example, one of the largest cardboard manufacturers, the Mayr-Melnhof Karton AG, uses a multi-site concept in case one of their plants has to stop operations for whatever reason.

However, in industry and research, the term “robust” is sometimes also used as a synonym for “flexible” or “agile,” even though they are, strictly speaking, not the same.

Below are the Google Ngram results for robust manufacturing. Starting in 1980, the expression shows steady growth. Unfortunately, Ngram data is available only until 2008. However, from my experience, there is still a lot of talk about robust manufacturing in industry.

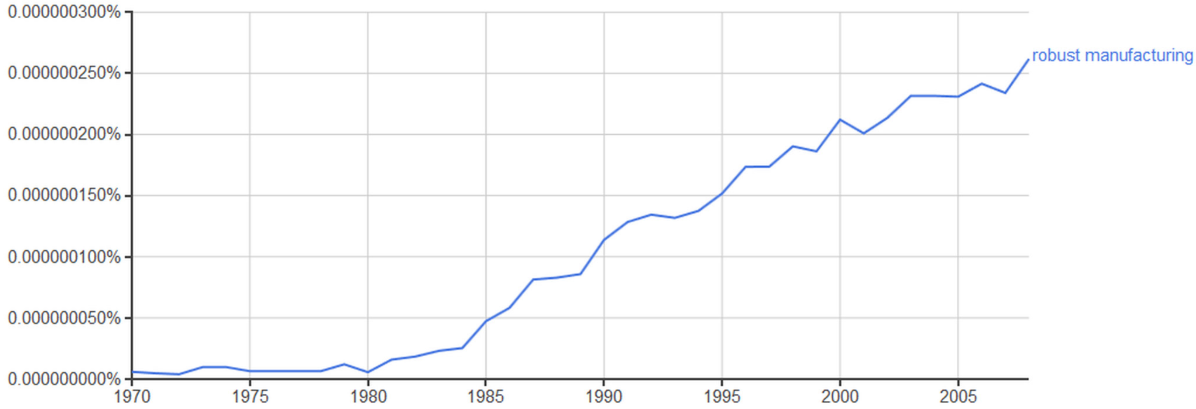


*Figure 179: Use of robust manufacturing in Literature (Image Roser)*

### 31.3.5 Adaptable Manufacturing System

> ***Adaptable*** */əˈdæptəbəl/: Capable of fitting by alteration; capable of modifying or remodeling for a different purpose;*

Another way of saying “agile manufacturing “is “adaptable manufacturing.” However, in research, **adaptable manufacturing considers unforeseen future events during factory planning**. You can already include a lot of flexibility, adaptability, and robustness options when deciding where and when to install new equipment or establish new plants. Do you establish a plant in a country because it is cheap, or do you also consider that political unrest may burn down your plant three years from now? (I was thinking about naming an example country, but then there are too many that are on shaky ground. ☹)

The term “adaptable manufacturing “was used especially around 1990, but due to its specialized meaning even then it was only around 1% of the usage of flexible manufacturing above.

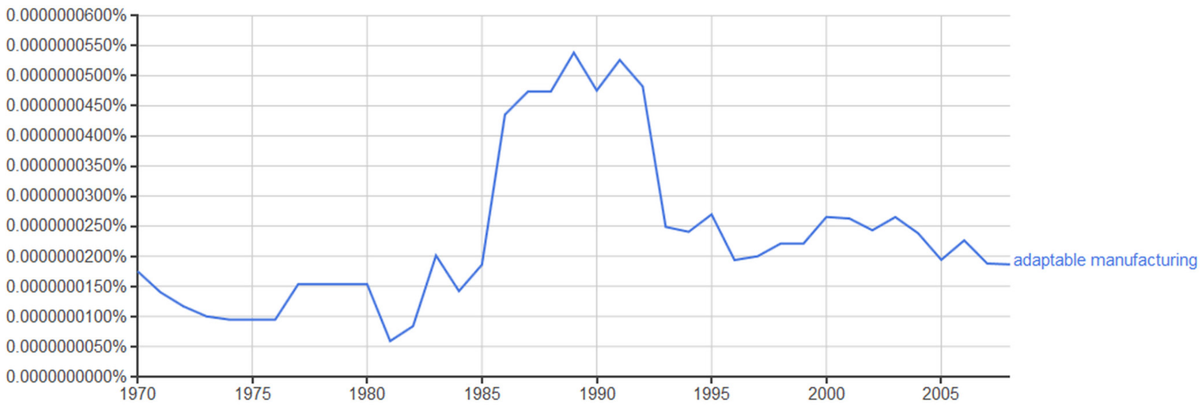


*Figure 180: Use of Adaptable manufacturing in Literature (Image Roser)*

### 31.3.6 Other

There are many other terms and buzzwords flying around in industry and academia. Here is a selection of additional terms in use:

- **Intelligent Manufacturing System** – Sort of a catch-all of everything that is good, beautiful, and trendy. However, this also means that it has no specific meaning. The term peaked in 1995. Around this time, people jumped on the bandwagon and a research institute with the same name was founded. The phrase is still commonly used, but everybody uses it to mean something slightly different.

- **Holonic Manufacturing System** – Holonic stands for autonomous and self-reliant. Initially used in 1990 for systems that can adapt to new products, research now talks about self-adjusting systems.
- **Versatile Manufacturing System** – This term is almost the same as "modern manufacturing," with first uses dating back to 1885. Depending on whom you talk to, this means the same as "flexible manufacturing," or it means "automation and computers," etc. The term is still used, but rather infrequently.

There are even more other but obscure terms like wisdom-enhanced manufacturing, self-organizing manufacturing, resilient manufacturing, or reactive manufacturing, but they are used only rarely.

In any case, I hope this brief overview of flexibility in manufacturing was interesting to you. Now go out and improve your Industry!

## 31.4 Sources

Ngram graphs are from the Google NGram viewer, using English language case-insensitive searches.

# 32 Corporate Culture on Quality Starts at the Top – A Small Anecdote on Organizational Blindness

*Christoph Roser, Augest 10, 2014 Original at https://www.allaboutlean.com/corporate-culture-quality/*

*Figure 181: Notice something? (Image ArnoldReinhold adapted by Roser under the CC-BY-SA 3.0 license)*

Quality starts at the top with management. Top executives like to talk about quality, but employees below usually know very well if the manager only talks the talk or also walks the walk. Words are cheap. Quality (and pretty much everything else that is important) requires attention by management.

Of course, the CEO cannot check everything himself. However, he surely can observe and sample. Many managers seem to have forgotten how to look, and instead rely purely on whatever their subordinates tell them. They need to know how to look and how to see. I wrote a sarcastic post on this topic before (How to Misguide Your Visitor – or What Not to Pay Attention to During a Plant Visit!), but this topic is far from exhausted. This post now focuses on quality, based on a small anecdote of mine.

## 32.1 Small Anecdote on Quality

A few months back, I wandered into Elbenwald (literally *Elfen Grove*), a German store specializing in geeky t-shirts and accessories. I admit, I do have a fable for such geeky things, even though my current position as a professor does not really allow me to wear t-shirts (especially not the one with Gandalf saying *"You shall not pass!"* during exam periods).

### 32.1.1 Noticing a Flawed Product on Display

*Image of Harry Potter T-Shirt with misaligned printing removed due to copyright concerns.*

In any case I noticed that one of the Harry Potter t-shirts had a misprint. The t-shirt was printed more than once at an offset, leading to a blurred double picture – just like after having too many pints of *Hog's Head Brew*.

Defects do happen. It should have been sorted out by quality control, but this one made it into the stores. However, it not only made it into the stores, it made it into the display of the store! The store was advertising its products using defective products. That should not have happened!

In any case, me being a nice geek, I indicated the problem to the sales staff. My expectation was that they would fix the mistake post haste.

Yeah, right.

### 32.1.2 Still Noticing the Flawed Product on Display Two Months Later …

Two moths later, I walked past the store again and decided to have a look. There was the very same t-shirt, with the very same misprint, in the very same spot as before. **Nothing had happened! In two months!** The store staff did not notice, the store manager did not notice, and upper management did not notice or did not visit either. In two months! Even me pointing it out made no difference.

Clearly, this needed to be escalated. While it was not my business, as a lean expert I cannot help but to poke my finger at such things. Hence I looked up the CEO on the web and sent him an email describing the problem with the t-shirt in particular and the corporate culture on quality in general.

### 32.1.3 Escalation to the CEO Works …

I received a very nice email back, grateful for the help. The CEO also talked about the difficulties in changing the corporate culture. I can only imagine the events behind the scene that my email started. (Actually, I have seen the action following similar customers' emails to the CEOs in other companies. If you want to get things done quickly, an email to the CEO is not the worst thing you can do.)

*Image of Harry Potter T-Shirt with no longer misaligned printing removed due to copyright concerns.*

In any case, after visiting the store again a few days later, the problem was fixed. The flawed t-shirt was exchanged with a proper one.

The question remains: Why does it need the repeated input of an external customer over many months (even if it is a nagging lean geek like me) to fix something that should have been bleeding obvious to everybody in the store?

## 32.2 Quality Starts at the Top

The CEO pointed out how they did trainings, how they tried to get their employees to also see the *store as a customer*, and their **fight against organizational blindness**.

He did not point out why he or his other top executives did not see it. So why did they not see it? There are two reasons I can imagine:

- The top executives did not visit the store within two months.
- (One of) the top executives visited, but did not see the problem in plain sight.

It was a small chain with approximately ten stores, hence we can assume (or hope) that at least one of the top executives would visit the store within a two-month period. I believe that one of the top executives visited but failed to see the problem. If they did not see it, then it was a clear message to the employees that this was not important. The problem of organizational blindness usually starts at the top.

To be fair, **it is difficult not to succumb to organizational blindness**. If you are new in a job, you see all the problems. The longer you stay, the more *normal* all the problems become. I find that the first six months are the easiest to spot problems. After that, the vision becomes more cloudy, and after three years everything is just as normal as it has always been.

In this particular case, the CEO was in his position for more than ten years. It seems he overall did well, as the business not only prospered but also expanded significantly throughout this time. Yet, after ten years in the job, it is hard not to succumb to organizational blindness.

## 32.3 How to Fight Organizational Blindness – Especially on Quality – Especially for Top Executives

Organizational blindness is habit taking over awareness. The key against organizational blindness is to break these habits.I believe there are a few simple steps that can help.

### 32.3.1 Go and See!

Go to the shop floor/sales floor/warehouse or wherever your action is. As we say in lean lingo: *Genchi Genbutsu*, Japanese for "g*o and see.*" Do not simply rely on reports and numbers, since your subordinates will tell you only what makes them look good. Rarely is a CEO told what went wrong. Instead, go to see the real action.

### 32.3.2 When You are There, Focus and Actually See!

Once you are at the site of the action, you actually have to see. This is easier said than done. Of course, you should also see your people, but the purpose of your visit is not only to socialize. Also look at the goods, equipment, tools, etc.

Frankly, a plant tour (or site tour) is usually not helpful, since there is too much to see and you end up seeing nothing. (This is sometimes done intentionally by middle management, see How to Misguide Your Visitor – or What Not to Pay Attention to During a Plant Visit! for details.)

Instead, focus on a few core points. I have developed a Lean Shop Floor Visit Checklist – Top 4 Things to Watch in the Factory for general visits. If you are particularly interested in quality, there are some other things you can focus on. Again, do not try to see everything, but focus on your point of interest (i.e., if you look at quality, do not look at productivity and inventory at the same time). If possible, also spend more time in one spot rather than a little time everywhere. Related to quality here are a few suggestions you could watch:

- General quality of the goods – Do they look good, are they in proper order, etc.?
- Storage of the goods – Are they stored properly, are they dirty, do the storage facilities look clean, etc.?
- Handling – Are the goods treated carefully, or are they kicked around? Do the employees respect the products for the customer?
- Machines and equipment – Is everything in order, are the machines maintained? Is oil dripping, are the machines dirty, or out of alignment, etc.?
- Overall Cleanliness – While overall cleanliness by itself is not the most important thing to watch, a messy area hints at more problems that are harder to see.

### 32.3.3 When You Have Seen Something, Use the Chain of Command!

If you have seen something (and chances are you will if you look close enough), you have to decide if you tell the next best employee to fix it, or if you use the chain of command. (In fact, if you are particularly bent on educating your employees, you may even tell them that you have seen *something* in a particular area and ask them if they see it too. They may end up seeing more things than you.) If it is a critical problem that needs fixing right away, tell the closes employee or supervisor. However, this is probably only a temporary quick fix.

In any case, you need to use your hierarchy. Using the chain of command helps you to achieve a faster change of the corporate culture. So get your direct subordinate responsible for the area and inform him of the problem (chewing out optional depending on your personality and the frequency of such problems).

### 32.3.4 Go for Permanent Solutions – But Don't Solve It Yourself!

Important: Do not simply tell him to fix it! A fix is usually a quick fix, and the problem will pop up again soon. Go for a long-term solution. **Do not give specific solutions! Your time and capacity is too valuable for this. Besides, it will train your employees to let you do all the thinking, a sure receipt for failure. This is not because you can't think but because there is simply too much to think about. Plus, you may be good, but you are not an expert in everything, and your well-intended solution may just make things worse.**

Hence demand a permanent solution, but let your employees decide how. If you have multiple levels of management below you, make sure that the appropriate level finds the solution. Your direct subordinate may also be the wrong person to fix the problem, for the same reasons you are. Have the chain of command report back to you after an appropriate time. If possible, check the same issue again next time you are around (and have a serious chewing out ready if the same problem happens again).

Doing this frequently in many different locations and departments will help you to achieve a corporate culture for quality, even though it is still a enormous task especially for larger corporations. **Again, use your chain of command!** Ideally, your subordinate managers will also adapt a similar approach to quality. Keep up the pressure, and good luck! **Now go out and Improve your Industry!**

## 32.4 Note:

I informed the CEO about this post, and got a very positive reaction. He also asked me to add the links to his website Elbenwald, which are now included in the post.

# 33 Theory and Practice on FiFo Lanes – How Does FiFo Work in Lean Manufacturing?

*Christoph Roser, Augest 17, 2014 Original at https://www.allaboutlean.com/fifo-lane/*

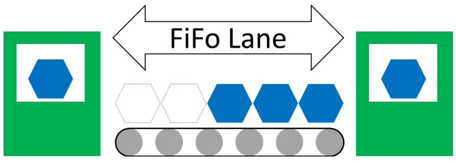


*Figure 182: FiFo Lane (Image Roser)*

FiFo lanes are an important part of any lean material flow. They are a very simple way to define both the material flow and the information flow. In this post I want to tell you why to use FiFo, how to use FiFo, and the advantages of FiFo, as well as show you a few examples of FiFo lanes.

## 33.1 The Reason for FiFo – Decoupling of Processes

Processes usually have different cycle times needed to process one part. Hence processes have to wait for slower processes. In a static world with no fluctuations or variations, this would never change, and the processes would always have to wait on the slowest process, (i.e., the bottleneck). No amount of inventory in between will change that.

Imagine three processes as shown below, where the middle process is always the slowest one. All inventories before are always full, and all the upstream processes are blocked. Similarly, all the inventory afterward is empty, and all processes downstream are starved for material. Again, no amount of inventory in between will change that.

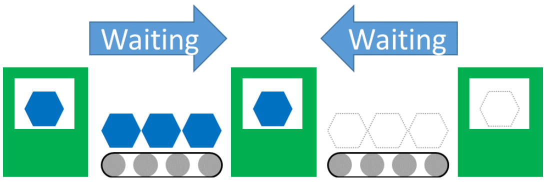


*Figure 183: Waiting on Bottleneck (Image Roser)*

However, in the real world, processes are not static but dynamic. Sometimes a process will take longer or shorter time than average. In this case, a FiFo lane can improve utilization and throughput of the system. For that matter, any type of buffer can improve the system, although the FiFo lane has quite some advantages as we will see below.

Ideally, the process with the slowest average speed should never have to wait on another process (either from lack of material or from being blocked). However, due to such fluctuations, the process may have to wait because another process is temporarily slower. This waiting can be avoided by having inventory, with the long-term slowest process working with material from a buffer inventory (if the temporary slower process is before), or filling into a buffer (if the temporary slower process is afterward).

The picture below shows you the examples, where the last process is temporarily slower and the middle process works into the empty inventory, and where the first process is temporary slower and the middle process works out of a full inventory.

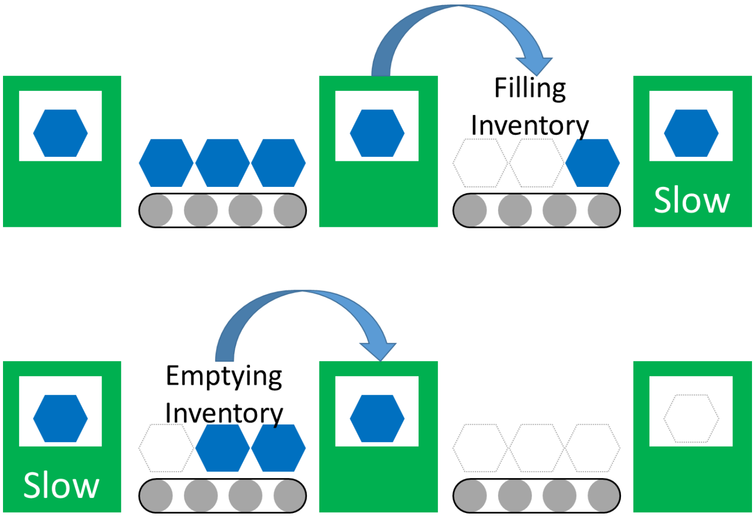

Figure 184: Filling and emptying inventory (Image Roser)

Again, this works for any kind of buffer. A FiFo lane, however, does have some advantages. But first I would like to talk about what makes a FiFo lane a very special type of inventory storage.

## 33.2 The Rules for FiFo

There are basically two rules that are important for FiFo lanes:

No part can overtake another part

The first part that goes into the buffer is also the first part that comes out, hence the name FiFo for *First-In-First-Out*. **The sequence of parts has to be maintained**. No part can overtake another part in the lane. No part can squeeze in from the outside either.

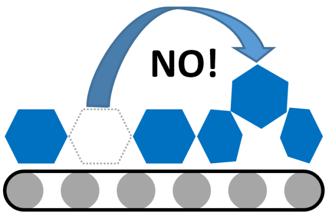

Figure 185: Breaking Sequence in FiFo (Image Roser)

This rule is important to avoid fluctuations in throughput time. One of the goals of lean manufacturing is to have a smooth material flow. If parts overtake each other, then the waiting time for the other parts will be longer, and can potentially be *much* longer. Eventually the delayed parts will be too late too.


Figure 186: grocery store market supermarket retail shop (Image ed_davad in public domain)

Imagine you're standing at the supermarket checkout, with ten people in line in front of you. While it may take some time, you can estimate how long it will take you to pay and leave. Now imagine someone cutting in line in front of you. Certainly, you will have to wait longer. Now imagine every third person cutting in line in front of you. Your waiting time can be very unpleasant.

While in manufacturing parts won't get upset if they wait in line longer, the customers waiting for the parts certainly will (as will your friends and family if you do not show up with the groceries).

There must be a clearly defined maximum capacity

The second rule requires the FiFo lane to have a clearly defined maximum capacity. There must be an upper limit, after which the preceding processes have no more space in the lane to put parts and must stop. **When the FiFo is full, the preceding process must stop**.

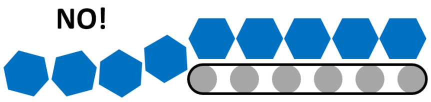


*Figure 187: Overfilling FiFo Lane (Image Roser)*

By the way, there is no explicit rule for a minimum capacity. The minimum capacity of a FiFo lane is zero. Since it is impossible to have less than zero parts in the lane, we need no extra rule to cover impossible cases. If there are no parts, the next downstream process has to stop.

The reason for this rule is to avoid overproduction. Overproduction is one of the seven types of waste (Japanese: *muda*), and according to common wisdom it is the worst type of waste. If you produce too much, your system will be clogging up. Everything will be slower, waste increases, throughput time increases, and your system will be anything but lean.

### 33.2.1 Breaking the Rules

As always, **some rules can be bent and others can be broken**. The two rules above are what turns a buffer into a FiFo lane. These rules make a lot of sense and should be followed. However, there may be rare cases where it may make sense to break the rules. Just be fully aware that by breaking these rules you will create some problems elsewhere that you can not yet even see. The question is, is it worth it?

For example, assume you have different products on your FiFo lane and you are missing parts to process the next two products on the lane (they won't arrive until three days later). Now you have two options:

- Wait until the missing parts arrive three days later.
- Take the products off the FiFo lane (and hence change the sequence).

Purists would say that you must not break the rules. Practice has taught me that sometimes it may be necessary to break the rules. In the example above I would break sequence and take the two products that I cannot process off the line and continue with other products. After the missing parts arrive, I would put the products back in the FiFo, possibly even jumping ahead in the line.

Let's be clear: I don't like it. However, I would like it even less to stop production for three days until the parts arrive.

At the same time, be careful not to make too many exceptions. You mess up your system, you teach your employees that rules in general are only optional, and worst of all you take pressure off the system to improve. Hence avoid breaking the rules as much as you can.

## 33.3 Advantages of FiFo Lanes

A FiFo lane has quite some advantages. First of all, it is a **clearly defined material flow**. You avoid overproduction and stuffing your system since the upstream process must stop if a certain inventory limit is reached (the downstream process stops anyway if the buffer is empty). Fluctuations on throughput time are reduced, and it is more likely that your parts will be completed on time. No part will be forgotten in the system until it is too late, with either the customer complaining or the part becoming old or obsolete.

It is a **lean material flow**. Due to the upper limit on FiFo lanes, it is not possible to overfill the system. Your system will still be able to react (relatively quickly) to changes in demand. Your total work in progress and inventory is capped. All seven types of waste (of which overproduction is the worst) will be reduced. Overall it is more efficient.

It is also a **clearly defined information flow**. You do not need to tell the processes at the end of the FiFo line what to do. They simply process whatever part comes down the lane. This takes a lot of management overhead off your chest. You only need to control the first process in a FiFo system; all the others manage themselves (at this point, Kanban are very useful to control the first process).

FiFo also helps **visual management**. It is usually easy to see if a FiFo lane is full or empty, giving you lots of clues on the status of the system, as for example the bottleneck. If you or your employees notice the FiFO getting rather full or unusually empty, they may investigate why and may be able to fix a problem before it becomes critical. Never underestimate the ability to go and see directly what is going on in your system.

## 33.4 Examples of FiFo Lanes

Finally, I have a few examples on FiFo lanes. One example that probably all of you have experienced at one point or another is waiting with other people for a process. This may be at the supermarket checkout, airplane check-in, the ticket window, the toilet, a fast food counter, or any kind of one-person-at-a-time service. Hopefully for you, the system utilized a FiFo lane. This is probably the most fair approach. Which of the two queues below would you rather be in?

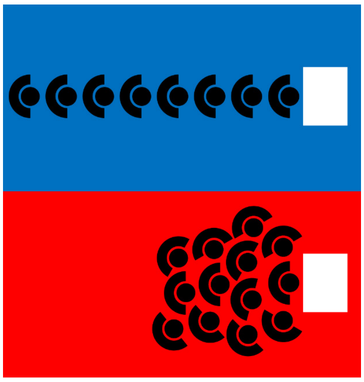

*Figure 188: Inspired by "How to stand in line" by artist Yang Liu in her book East meets West. (Image Roser)*

Below is another example, the assembly line. The number of parts in the line is limited, and the parts – in this case the cars – don't overtake each other.

*Figure 189: Volkswagen Beetle Assembly Line (Image Schaack, Lothar under the CC-BY-SA 3.0 Germany license)*

Below is one of the first assembly lines in the world: the line of Henry Ford producing his model T, or in the image below the magneto line.

*Figure 190: Ford assembly line 1913 (Image Ford in public domain)*

I hope this post on the FiFo lane was interesting to you. The mathematical details are in my next post Determining the Size of Your FiFo Lane – The FiFo Formula, and there is also a FiFo Calculator – Determining the Size of your Buffers. Now go out and organize your industry!

# 34 Determining the Size of Your FiFo Lane – The FiFo Formula

*Christoph Roser, Augest 24, 2014 Original at https://www.allaboutlean.com/fifo-size/*

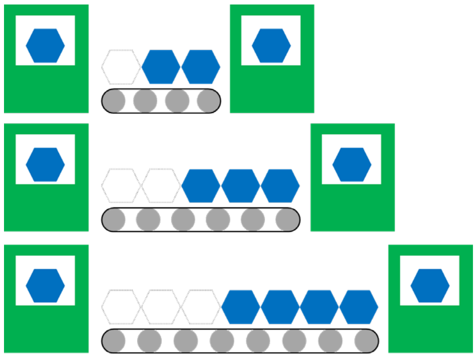

*Figure 191: How long should it be? (Image Roser)*

FiFo lanes are an important tool to establish a pull system. They are often combined with kanban. However, while there is a lot of information on how to calculate the number of kanban (the Kanban Formula), there is very little information available on how large a FiFo should be. In my last post I talked about why we need FiFo lanes. In this post I want to discuss how large a FiFo should be. The first part is a lot of mathematical theory, but you can easily skip ahead to the practical advice**.** In another post I have programmed a small FIFO calculator that does exactly these calculations.

## 34.1 The Mathematically Correct (and Practically Completely Useless) Solution

[*Note: I have programmed a small tool that does the math for you:* The FiFo Calculator – Determining the Size of your Buffers at https://www.allaboutlean.com/fifo-calculator/]

First, I would like to show you the mathematically rigorous approach – which turns out to be completely useless in practice. (For a practical approach, see below). The mathematical approach uses probability functions. Assume you have two processes, A and B, that are randomly distributed as shown below.

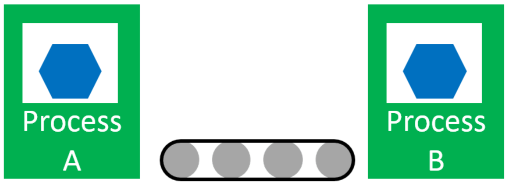


*Figure 192: Two Processes (Image Roser)*

Below are two example probability distributions for these processes. These are standard normal distributions. These are, in fact, not good assumptions for processing times, since they start at minus infinity and hence can have negative values too. Nevertheless, these functions are probably the best known and are also illustrative, hence I use them here.

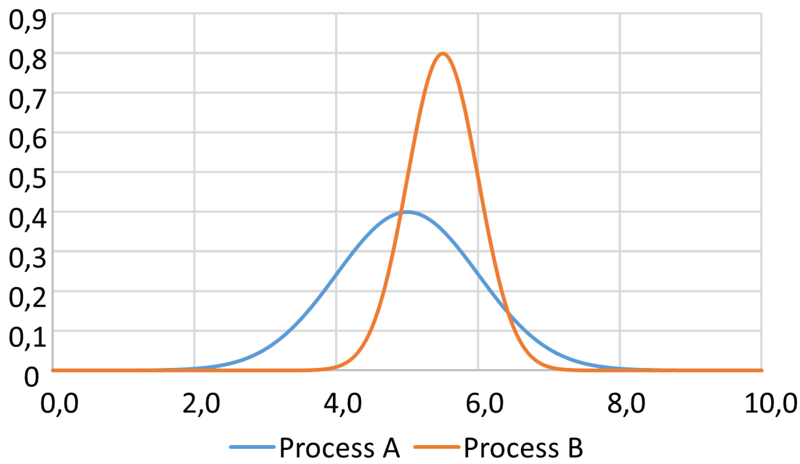

*Figure 193: Two normal distributions (Image Roser)*

This can also be expressed mathematically as two probability density functions, given here for normal distributions:

$$f_A(x) = f(x, \mu_A, \sigma_A) = \frac{1}{\sigma_A\sqrt{2\pi}} e^{-\frac{(x-\mu_A)^2}{2\sigma_A^2}}$$

$$f_B(x) = f(x, \mu_B, \sigma_B) = \frac{1}{\sigma_B\sqrt{2\pi}} e^{-\frac{(x-\mu_B)^2}{2\sigma_B^2}}$$

The first process, A, has a mean of 5 and a standard deviation of 1. The second process is a bit slower with a mean of 5.5, but has a tighter standard deviation of 0.5. This means that in average process, B is the bottleneck with a mean cycle time of 5.5. However, sometimes by chance process A will be slower than process B and may become a temporary bottleneck.

Inventory (as, for example, a FiFo) tries to prevent the slow down of process B. The more inventory you have, the less likely it is that process B will be slowed down by process A. This will increase the overall system output. Please note that no matter what you do with your inventory, the system cannot become faster than process B.

### 34.1.1 The “Simple” Case – No Inventory

In the most simple case, we have no inventory between two processes. In this case, the likelihood of the slower process B being temporarily slowed down by process A. Mathematically speaking, this is the probability of process A being slower than process B. This can be calculated by integrating as shown in the formula below, which gives us the probability of process A being slower than process B:

$$P(A > B) = \int_{-\infty}^{+\infty} f_A(x) \cdot \left( \int_{-\infty}^{x} f_B(x)dx \cdot \right) dx$$

As any sum or difference of independent random variables will in almost all cases result in a normal distribution, the above can be also expressed as a normal distribution, where the mean and standard deviation can be calculated quite easily:

$$\mu_{A-B} = \mu_A - \mu_B$$

$$\sigma_{A-B} = \sqrt{\sigma_A^2 + \sigma_B^2}$$

This can be visualized as in the graph below. We see again our two initial distributions as above. The third gray curve is the distribution of the difference A–B. The likelihood of process A being faster than process B is the likelihood of the difference being larger than zero, represented by the shaded area.

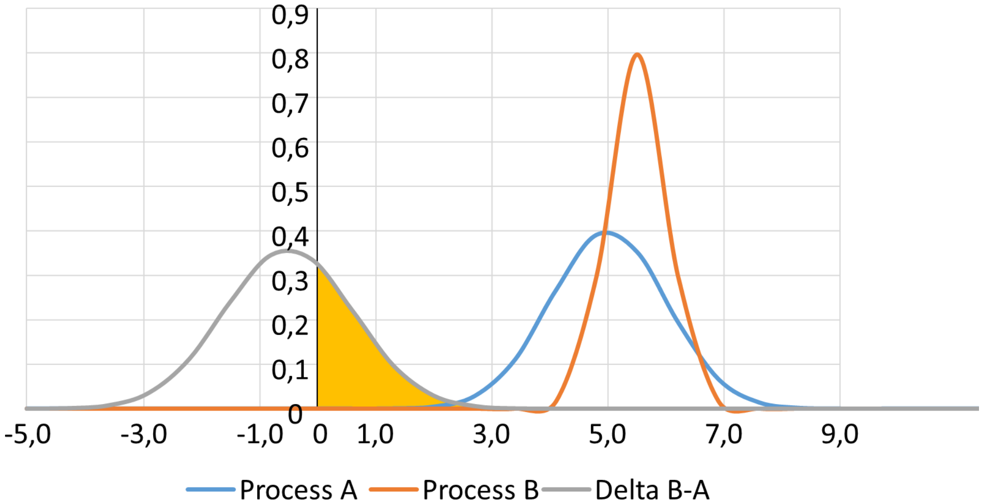


*Figure 194: Graph of difference between two distributions (Image Roser)*

In our example with a mean of 5 and 5.5 and a standard deviation of 1 and 0.5 for process A and B respectively, this gives us a likelihood of process A being slower of 32.7%. **In about 1/3rd of the cases, process B is slowed down by process A even though process B is on average the slowest process.** Of course, this means that our system slows down. Instead of the maximum possible part every 5.5 time units, it is now a part every 5.75 time units. This gets worse with increasing standard deviations too.

### 34.1.2 Including Buffer to Increase Speed

Adding buffer between the processes reduces the likelihood of the normally faster process A slowing down the normal bottleneck process B. This means that the sum of two random times from process A has to be larger than the sum of two random times of process B. The distribution can be calculated as follows:

$$f_{2\cdot A}(z) = \int_{-\infty}^{+\infty} f_A(z-x) \cdot f_A(x) dx$$

Luckily, this too can be simplified to calculate the mean and standard deviation of a normal distribution as shown below:

$$\mu_{2\cdot A} = 2 \cdot \mu_A$$

$$\sigma_{2\cdot A} = \sqrt{2 \cdot \sigma_A^2} = \sqrt{2} \cdot \sigma_A$$

Even more general, this can be calculated for the sum of any number of random times:

$$\mu_{n\cdot A} = n \cdot \mu_A$$

$$\sigma_{n\cdot A} = \sqrt{n \cdot \sigma_A^2} = \sqrt{n} \cdot \sigma_A$$

The means of these sum go up linear with the number of times included. The standard deviation, however, increases only with the square root of the number of times! Hence, while the relative distance between the sums for the process times stays equal, the with of the distribution becomes smaller.

Below are the distributions for the sum of ten times process A and ten times process B. In comparison with the images above, the relative distance between the means did not change much. Process B is still 10% slower than process A. The width, however, has significantly decreased. For example, process A has a standard deviation of 1 for a cycle time of 5. Multiplying by 10 increases the sum of the cycle times to 50, but the standard deviation only to 3.16.

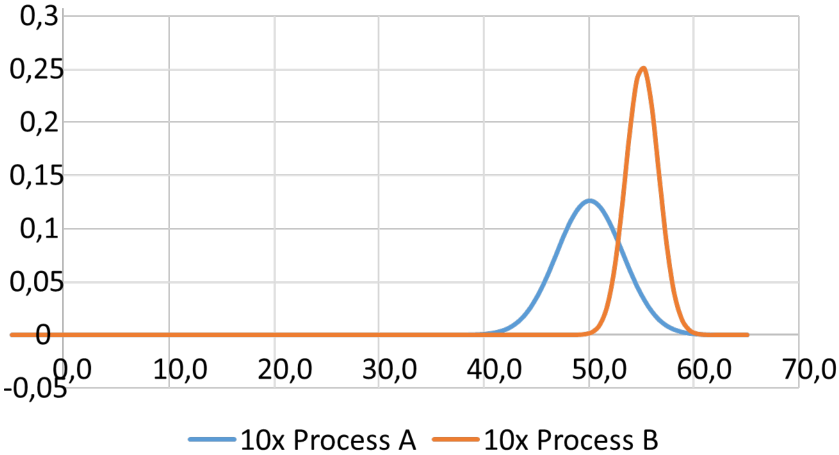


*Figure 195: Graph with sum of ten distributions (Image Roser)*

### 34.1.3 Relation between Buffer Size and Slowing Down Primary Bottleneck

With these mathematical relations, it is easy to calculate the influence of process A on the nominally slower process B in dependence to its buffer size. The graph below shows the likelihood of process A slowing down process B in dependence on the buffer size in between.

Clearly, having no buffer at all is pretty bad, and around 33% of the time process B is slowed down by process A. Even increasing buffer a little bit will help enormously. However, the improvement will slow down eventually. Having a buffer size of 20 or of 50 makes little difference.

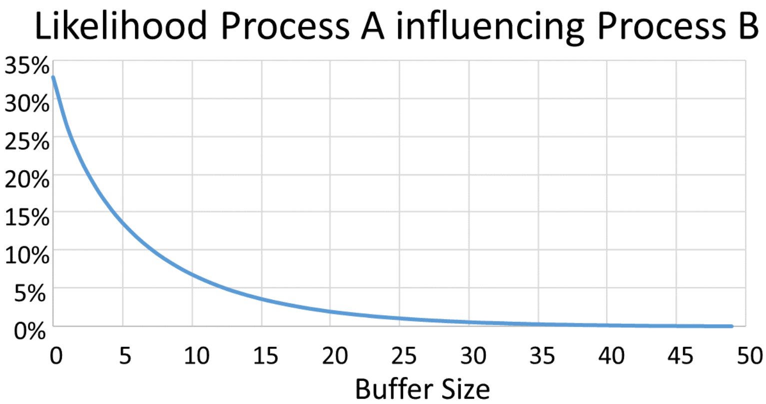


*Figure 196: Likelihood of one process slowing down other process in relation to buffer size (Image Roser)*

Please be aware that the detailed numbers in above graph are only valid for the above example, and if you have different means and standard deviations, your graph may look different. The general trend is true, however. **A small buffer makes a big difference, whereas a larger buffer will not give you as much improvement.**

Now, in theory you could do a cost benefit analysis to find your sweet spot between the cost and effort of a buffer size and its benefit for the overall system performance.

### 34.1.4 Fancy Math, But How Does This Help You on the Shop Floor?

**Well, unfortunately it doesn't help you on the shop floor!** I have included the math above for two reasons. First, I wanted to show you that I can do math ☺. The second and more important reason was to show you that the relation between buffer size and decoupling of processes is nonlinear. A small buffer is almost always sensible. However, making a large buffer even larger will not yield much additional benefit.

In practice, however, these theoretical calculations will not help you much. You rarely know the distributions of your processes well. Real world is also likely more complex, having more than two processes influencing each other. The above calculations are also rather complex, and not everybody can do these. **In sum, the benefit of doing such detailed calculations are usually not worth the effort**. However, if you really want to but don't care about the math, then see my FIFO calculator.

## 34.2 FiFo Sizing on the Shop Floor

### 34.2.1 A Few Practical Suggestions

So how do you determine the size of a FiFo? In truth, there is not really any rule of thumb. As consultants we would have used an *expert estimate* – which are nothing but fancy words for the gut feeling of somebody familiar with the system. Hence:

To determine the FiFo size, ask somebody familiar with the system about his opinion. The FiFo should be able to cover failures, change-overs, or other downtimes of the processes, while at the same time be not too big and cumbersome. Adjust if the real behavior does not meet your expectations.

**Disappointing, isn't it? After all this math, I just tell you to pull it out of somebody's a**.** Yet that is current industry practice. However, there are a few more words of wisdom going around that I found helpful. The first one is:

Buffers are more important before and after the bottleneck(s) than they are around non-bottlenecks.

Buffering the bottleneck is sensible, since you don't want your bottleneck to wait for other processes. Buffering non-bottlenecks is less useful, since they usually have to wait for the bottleneck anyway.

Add at least a buffer of one between processes when possible (if the cycle time of your processes is not linked, e.g., as with a conveyor belt).

One buffer will make the largest difference. Having one buffer between all processes will make the material flow much smoother. The exception is for systems with a identical tact time for the entire system (e.g., conveyor belts). The belt moves with the same speed everywhere, hence a buffer on the same belt is not needed. This also gives a rule for systems with linked cycle times:

If the cycle time of your processes is linked (e.g., as with a single conveyor belt), usually no buffers are needed.

### 34.2.2 Some Not-So-Useful Rules – Don't Use!

There are some more rules out there, but many of them are pseudo-math. They calculate something and you get a result, but it bears little to no relation to the original problem you tried to solve.

For example, one rule defines the FiFo lane based on the desired lead time. If you want a long lead time, simply make your FiFo larger. But then, who would want a long lead time?!?!

Another rule defines the FiFo size for processes that require curing (i.e., a glue drying or a part cooling, etc.). The FiFo lane should be long enough so that the part can finish its curing process (including some safety time). Yes and no. Of course, there should be enough space so that all the parts fit, but curing is also an activity, not just a buffer. If you just put a FiFo there and hope it works, you will almost certainly end up with not-yet-cured parts downstream. For the sake of your quality, install a timer or something that makes sure all parts are fully cured before they move on.

Yet another rule looks at the shelf life. The FiFo should not be so long as for products to expire while in the FiFo. Theoretically absolute correct, practically totally useless advice. Or have you ever seen a FiFo longer than the shelf life?

Overall, FiFo sizing is still based much on experience. As always, I hope this post was interesting to you. Feel free to leave a comment below. Now go out and improve your industry!

# 35 Happy 1st Birthday AllAboutLean.com

*Christoph Roser, September 1, 2014, Original at https://www.allaboutlean.com/1st-birthday/*

*Figure 197: Happy 1st Birthday (Image Ardfern under the CC-BY-SA 3.0 license)*

AllAboutLean.com is one year old. Exactly twelve months ago I started this blog on September 1st with my first post, New Professor, New Blog. Since then I have published fifty-six posts. Time to have a look back. What were the most popular posts? How did visits to my blog develop? What is the outlook for the future? And what is there already in the pipeline that will appear soon on AllAboutLean.com?

## 35.1 Most Popular Posts

Since its beginning one year ago, AllAboutLean.com published one post every week every Sunday, for a total of fifty-six posts (during the first week I posted almost daily, since a blog with only one post looks so … empty).

I try to have all of my posts in excess of one thousand words, and they are all completely written by me rather than short repostings of what is found elsewhere with two sentences as a comment. **I want to add to the knowledge on the web, not just repeat it!** Many of these posts are original research, and most have been very well received. Some even made it to the top of Google search results for selected keywords.

### 35.1.1 To 10 Posts of All Time


*Figure 198: Top 10 (Image Roser)*

Below are the top ten posts of AllAboutLean.com, based on the number of page views. Most of them are posts that help you with your daily work on the shop floor, with focus on practicability and usability. I try to cut through the pure theory and tell you how it really is. **Because on the shop floor you need something that works!**

Other popular posts are related to training and education, how to teach yourself and others some fundamentals of lean. Some of the Top 10 below are actually split into two posts, since otherwise one post would have been too long.

- The Difference Between Lean and Six Sigma: The term Six Sigma is widely used in industry, and often used synonymously with lean production. However, Six Sigma originally came from a quality control direction using a technique that does not work. Only later have they taken over the lean approach. They do have fancy degree titles, though! This post seems to also be my most shared post on LinkedIn at the moment.
- Japanese Standard Pointing and Calling (Video): My first video on YouTube, based on lots of recordings during a trip to Japan. Great visualization of the Japanese Pointing and Calling technique to reduce errors.
- How Many Kanban? – The Kanban Formula, Part 1 and How Many Kanbans? – The Kanban Formula, Part 2: A two-post series on how to calculate the number of kanban. Getting the kanban right (or at least not too few) is important for your system to function. Yet the kanban calculation is not easy. These posts explain the theory of the kanban calculation.
- Simple Kanban System for Office Supplies: Kanban can be mightily fancy, but they don't have to. Especially if you are ordering low quantities of low-value items like office equipment, you need a system that is easy and foolproof.
- Poka Yoke Training – Simple Mistake Proofing Game: Quick and easy game to teach mistake proofing (*poka yoke*) to people of all ages in a few minutes. And it has chocolate too! I often start my lean trainings with this game to get a positive mood. Few people are unhappy if they get chocolate! ☺
- Seven Gadgets for the Basic Lean Toolkit: Whenever I have a lean project on the shop floor, there are a few items that really helped me do my work. If you have never used a flashlight with a narrow focus, you cannot imagine how useful one is on the shop floor.
- SMED – Creative Quick Changeover Exercises and Training: A list of four easy exercises and games to teach quick changeover methods. From cocktails to coffee, from firefighters to Formula 1, there is something for everybody.
- Top Three Methods on How to Fudge Your OEE: The third most popular post on AllAboutLean.com. The OEE is a measure of machine performance, and I have seen far

too many OEE's that were unintentionally-or-not just plain wrong. Usually the error is in a way that tends to make the plant look better than it really is. Hence I wrote this rather sarcastic post on how to fudge your OEE – of course with the goal of helping you determine if you get fudged numbers rather than teaching you how to fudge them yourself.
- Make Your Plant Tour a Success! and Lean Shop Floor Visit Checklist – Top 4 Things to Watch in the Factory: The second most popular post on AllAboutlean.com. When visiting a factory, the host does not always want you to see what really is going on. However, there are a few easy-to-use metrics to estimate the performance of the plant. These two posts are a guide and a checklist on what to watch and observe to determine if the plant is performing well, or merely pretending to do so.

**Finally, the absolute number one in popularity on AllAboutLean.com:** Ten Rules When to Use a FIFO, When a Supermarket – Introduction **and** Ten Rules When to Use a FIFO, When to Use a Supermarket – The Rules: These two posts help you to decide if you should use a supermarket or a FiFo between processes. Few fixed rules exist, but there are a number of useful guidelines that I have summarized here for your convenience. Based on my original research (like many other of my posts), hence there is no other page on the web out there yet that tells you when to use a FiFo or a supermarket.

### 35.1.2 Top 5 Posts by Views per Day

Of course, this list favors posts that have been around for longer time. A post that appeared five weeks ago rarely has the number of page views of a post that appeared twelve months ago. Below are the Top 5 ranked by average page views per day. I have excluded posts from August (last month), as new posts always get more views on the front page. However, all of the Top Five by views per day are also included in the Top Ten of the total views above.

- The Difference Between Lean and Six Sigma: See #9 above.
- How Many Kanban? – The Kanban Formula, Part 1 and How Many Kanbans? – The Kanban Formula, Part 2: See #10 above.
- Poka Yoke Training – Simple Mistake Proofing Game: See #6 above.
- Ten Rules When to Use a FIFO, When a Supermarket – Introduction and Ten Rules When to Use a FIFO, When to Use a Supermarket – The Rules: No surprise, the #1 from above is here too.
- SMED – Creative Quick Changeover Exercises and Training: See #4 above.

### 35.1.3 Some Observations

Some of my posts made it to the top of the Google page search. If you search for fifo supermarket on Google, my Ten Rules When to Use a FIFO, When a Supermarket – Introduction and Ten Rules When to Use a FIFO, When to Use a Supermarket – The Rules occupy the top spots (at the time of writing). Similarly, OEE fudging will return the Top Three Methods on how to Fudge Your OEE and my tag category OEE. With kanban formula I am only in the second spot with How Many Kanban? – The Kanban Formula, Part 1. In any case this is very promising for a rather new website. (Actual Google results may vary, depending on your location, language, and search history)

Also, Facebook likes, LinkedIn shares, Twitter Tweets, and so on are also increasing – although I enabled this option only a few months ago. So, if you like my posts, go ahead and like/share/Tweet, etc.

## 35.2 Some Statistics

The number of visitors and number of views per day is also increasing nicely. Below is the development of the page views (not counting bots and administrators) from October 2013 to August 2014. As you can see, there is a strong growth, and I am looking forward to reaching even more readers in the future. The graph shows the average number of page views per day and the exponential trend.

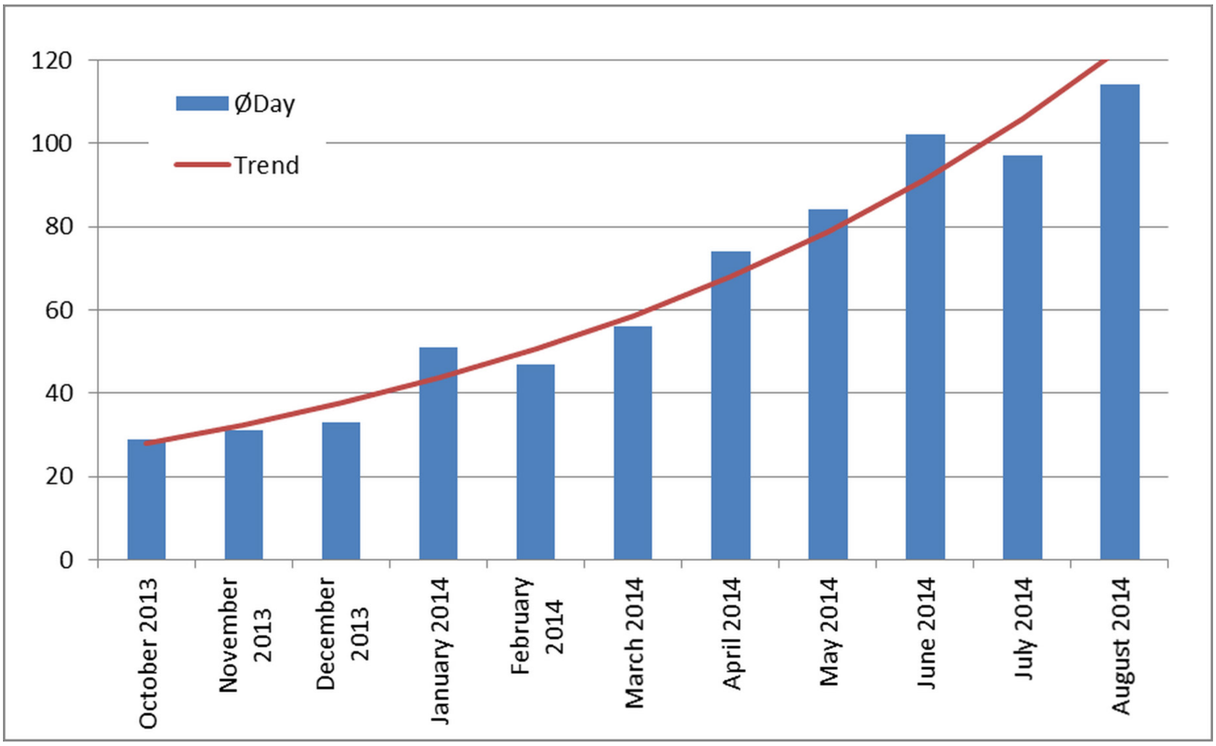


*Figure 199: Average Number of Page Views per Day and its Trend during the 1st Year (Image Roser)*

Of course, we all know that an exponential trend must hold for forever. Hence, I took the liberty of extrapolating this trend for the next 30 years based on one year of data.

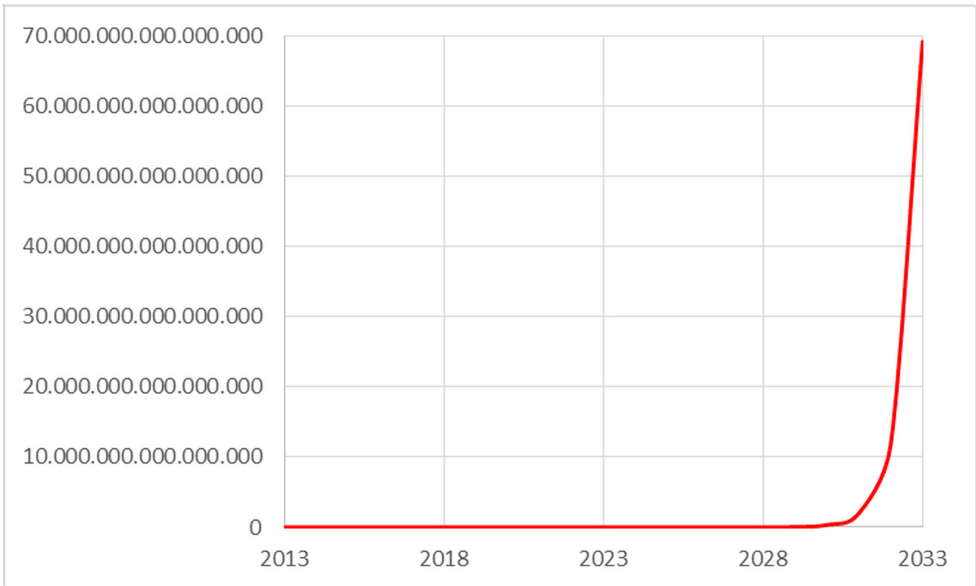


*Figure 200: Absolutely realistic exponential trend curve of my page views for the next 30 years. (Image Roser)*

*Figure 201: World Domination by 2030 … Muhahaha (Image J.J. under the CC-BY-SA 3.0 license)*

Based on this highly realistic data (the numbers are very precise!), I can estimate that by 2019 my site will be bigger than Wikipedia (for all languages combined). By 2024 AllAboutLean.com will have eclipsed Facebook and Google. Finally, by around 2026, all hits on the Internet will be on my page and my page alone. **At the latest by 2030, I will rule the world based on this exponential extrapolation!**

Or maybe not. But the numbers are accurate!

## 35.3 Things to Come

Before I reach world domination, however, there is more work to do. The following items are in the pipeline and will appear on AllAboutLean.com during the next months.

- Another video is in the making. The 40-minute video is my "first lecture" on the history of manufacturing. The German version is already online on YouTube (Geschichte der Produktion). English subtitles and transcripts are in the works.
- A FiFo calculator related to estimating the size of a FiFo based on means and standard deviations. During my last holiday I spent an hour or so every now and then programming JavaScript. A friend of mine called me crazy for not hanging out on the beach with a cocktail during my holiday. He probably is right, but I love this stuff too much.
- A book project related to manufacturing is almost completed. After five years of hard work the draft is completed, and I am in the process of getting it published. Of course, I will keep you updated on AllAboutLean.com as soon as there is more news.

In any case, I hope that my work is helpful for you and you will continue reading AllAboutLean.com.

All the best,

Chris

# 36 Visual Management during World War II – A Visit to the Lascaris War Rooms in Malta

*Christoph Roser, September 7, 2014, Original at [https://www.allaboutlean.com/lascaris-war-room/](https://www.allaboutlean.com/lascaris-war-room/)*

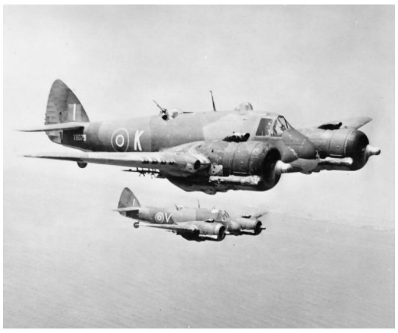

*Figure 202: Royal Air Force Operations in Malta, Gibraltar and the Mediterranean, 1939-1945. (Image Royal Air Force official photographer in public domain)*

For larger improvement projects with a dedicated project team, there is frequently a "war room," a conference room where all the project-related information and performance measures are kept. The name sounds cool and gives a certain air of focus to the project.

The name, however, comes from war rooms for **real wars**. Recently I had the chance to visit the Lascaris War Rooms in Malta, where I was able to see many tools and practices that are still common nowadays in manufacturing and project management.

## 36.1 Malta during World War II

During World War II, Malta was the only Allied land between Gibraltar and Egypt. As an air and naval base, it was able to seriously disrupt the supply lines from Italy to Africa, with Desert Fox Field Marshal Rommel eventually running out of gas during his African campaign. Similarly, it was a (relatively) safe haven for allied supplies going to and from Middle East.

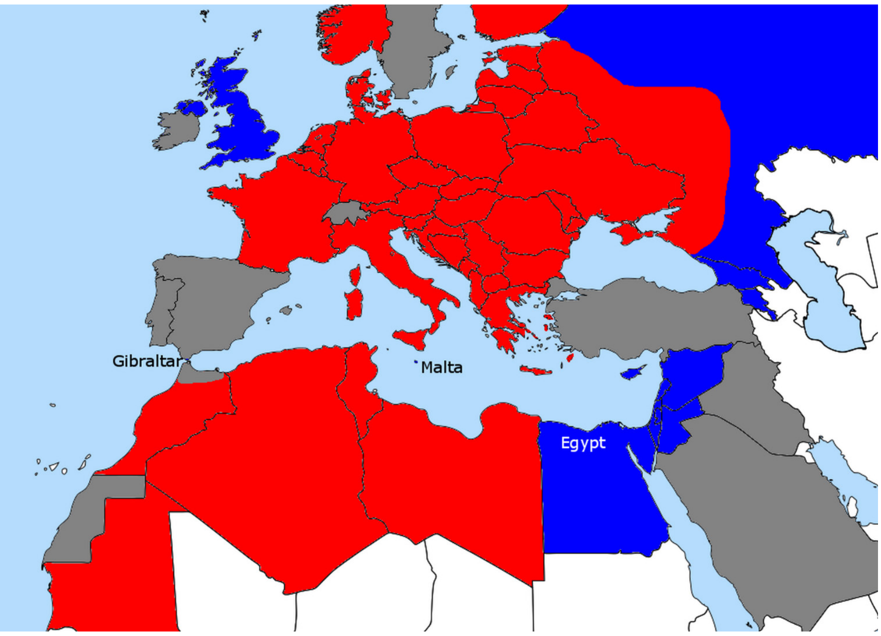


*Figure 203: Significance of Malta for the Allied Forces. Red are Axis territories, blue (including Gibraltar and Malta) are Allied, and gray are neutral. Map shows the situation around 1943. The political boundaries are modern. (Image Roser)*

Significance of Malta for the Allied Forces. Red are Axis territories, blue (including Gibraltar and Malta) are Allied, and gray are neutral. Map shows the situation around 1943. The political boundaries are modern.

The Germans understood the strategic value of Malta, dropping over 15,000 tons of bombs on Malta during 3,343 air raids. More bombs were dropped on Malta in six months than were dropped on London during the entire war, all in preparation for an invasion of Malta.

During this **Siege of Malta**, the Maltese defense forces were faced with a chronic shortage on fuel, ammunition, planes, ships, food, and pretty much anything else needed to fight a war. British high command was preoccupied with the German attacks on the homeland. In any case, the entire population of Malta was awarded the George's Cross, the highest British gallantry award for civilians to "*bear witness to the heroism and devotion of its people.*"

However, after turning the tide in Britain, British high command also eventually saw the strategic value of Malta, and increased supplies. With America joining the war, Malta was not only able to take a beating, but also to dish one out.

This eventually culminated in **Operation Husky, the successful Allied invasion of Sicily** on July 9,1943, and sort of a training for D-Day in Normandy that eventually put an end to Hitler's madness.

## 36.2 The Lascaris War Rooms

*Figure 204: The Entrance (Image Roser)*

These combat operations were controlled and organized from a number of top-secret war rooms in tunnels deep underneath the old Lascaris Battery in Valletta, the capital of Malta. It was used not only during World War II, but also as the NATO Naval Headquarters during the Cold War thereafter, and was a top secret site for decades (even some policemen nowadays don't know where it is ☹). As such, there were actually multiple war rooms in these tunnels.

### 36.2.1 The First War Room during the Siege of Malta

*Figure 205: Fighter Control Room Gallery 1943 (Image unknown author in public domain)*

The heart of the Lascaris complex during the Siege of Malta was the RAF Sector Fighter Control Room. This room coordinated the aerial defenses of Malta. It tried to keep on top of such important information as the number of fighters and bombers, where they were, how many made it back, and similar information on the enemies forces.

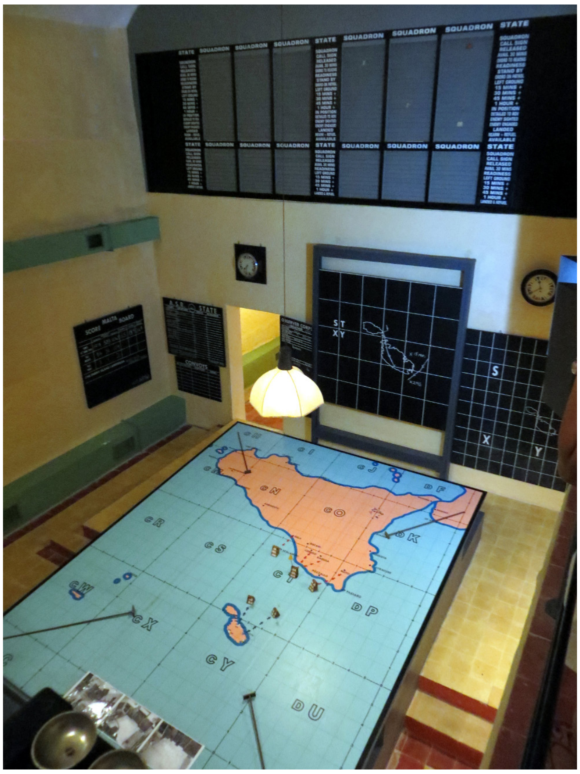

*Figure 206: The View (Image Roser)*

The Fighter Control Room looked like a big opera theater. There was a large gallery on one end with the decision makers, having around twelve seats. They looked at a set of maps and information boards with the latest available information. In this they used a number of tricks that are still popular with lean production nowadays.

One of the important tricks for a successful project (as for example the defense of Malta) is to have all people involved in the same room. Separate offices hinder communication. Sitting in the same room makes sharing information much easier. This room should also have all information relevant to the project. The Lascaris War room is a good example here.

#### *36.2.1.1 The Fighter Operations Board*


*Figure 207: Fighter Information Board (Image Roser)*

On the very top of the room is a large board, the Fighter Operations Board. Such a board is very similar to what is still commonly used in lean manufacturing nowadays.


*Figure 208: Close Up (Image Roser)*

This board captured the status of the available fighters. As shown in the close up, a squadron could be in preparation (released), ready, off the ground, 15/30/45/60 minutes in the air, engaging the enemy, on its way back, or landed.


*Figure 209: Fighter Information Board Signs (Image Roser)*

Different cards that hung from these railings indicated the position on a grid, indicating the squadron number, number of planes, if they were orbiting or had landed. In not-so-lucky situations, an SOS was shown, or it stated that the plane vanished from radar (faded), meaning it most likely crashed into the ocean.

*Figure 210: Behind the Fighter Operations Board (Image unknown author in public domain)*

You may have noticed that the board in the RAF Sector Fighter Control Room is very high up on the wall. How did they change the information on the board if it is so far out of reach? The secret is that behind the board was a second room where the cards were hung. This enabled a quick change of the signs and hence an up-to-date status of the available information.

### 36.2.1.2 The Plotting Table

*Figure 211: RAF Sector Fighter Control Room of the Lascaris War Rooms (Image unknown author in public domain)*

Beneath the gallery was the plotting table, and a large map of Sicily, Malta, and Lampedusa. Assistants moved information about friendly and enemy aircraft and vessels on small movable information makers using croupier sticks.

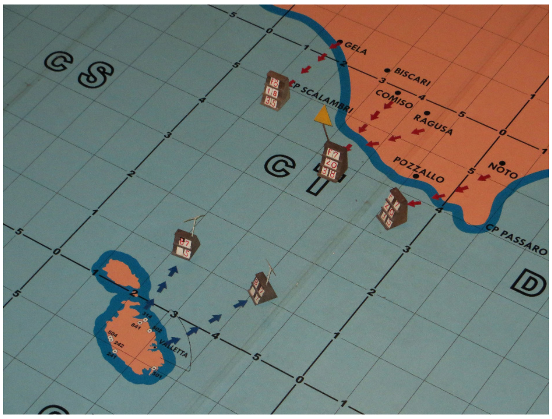

*Figure 212: Lascaris Map Detail (Image Roser)*

By moving these markers, information on the Fighter Operations Board was correlated to their position. The Fighter Operations Board also had some small signs indicating which sector on the map the aircraft were in.

### *36.2.1.3 Different Status Information Boards*

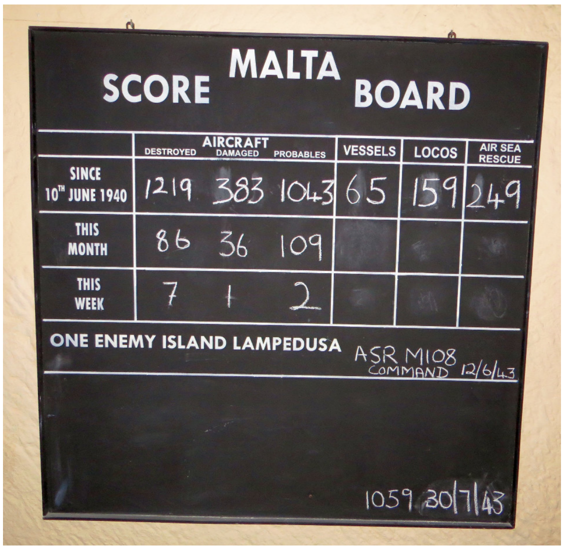

*Figure 213::Lascaris score board (Image Roser)*

The most important board in Lascaris was the scoreboard. The key performance indicator of any air defense was the number of enemy aircraft shot down. Also, in modern project war rooms, the key performance indicators for the project should be displayed prominently (i.e., which subtasks are on time or delayed, total savings, overall speed, etc.).

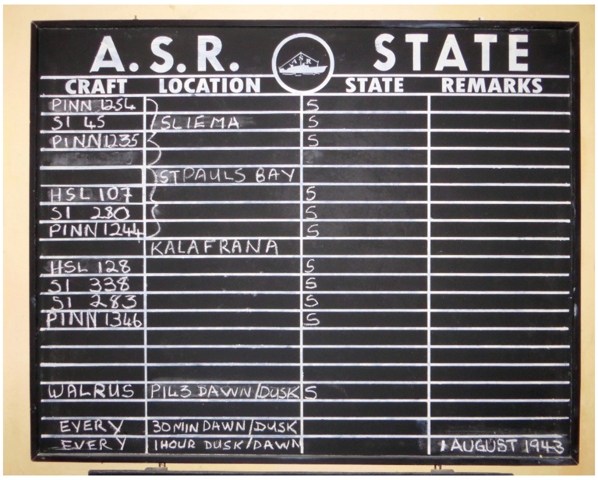


*Figure 214: Air Sea Rescue Board (Image Roser)*

Probably the second most important was the status of the ASR, the Air-Sea-Rescue. Malta lost many more planes than pilots, and many pilots were able to successfully bail out their destroyed aircraft. With the help of the ASR, many of them also made it home.

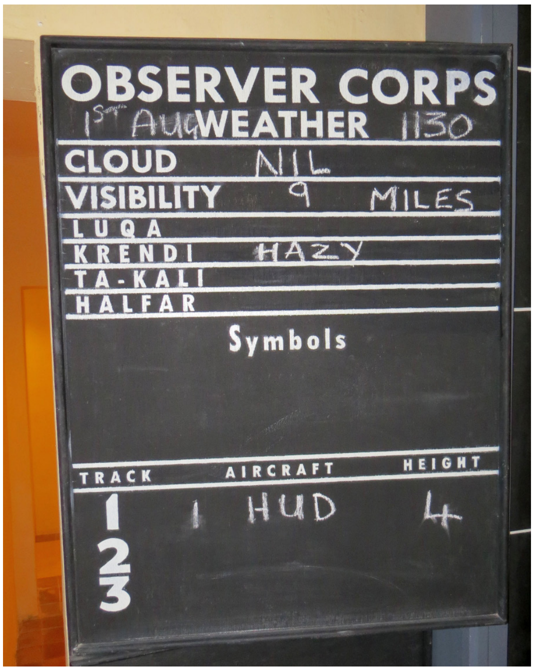


*Figure 215: Lascaris Weather Info (Image Roser)*

Also important was the weather on Malta, in particular the conditions on its different airports. Back then the planes did not yet have an all-weather capability. Another board was tracking the list of convoys, and another board showed the radar station status.

*36.2.1.4 The Clock*

*Figure 216: Lascaris War Room Clock (Image Roser)*

Interesting is also the clock they used in the war room. At first glance it merely looks like a normal clock with some fancy coloring. The color, however, was also used for incoming messages. Whenever the status of the map was updated, the current color was used. At a glance you could see if the message was current, older, or already 15 minutes old – which in aerial combat terms is an eternity. This is another good example of visual management.

### 36.2.2 The Second War Room for the Invasion of Sicily

*Figure 217: Operation Husky War Room Lascaris (Image Roser)*

As the war progressed and the Allied forces got the upper hand around Malta, an invasion of Sicily was planned, code-named Operation Husky. For this a new set of war rooms adjacent to the first were dug. Operation started shortly before the invasion, and the room was used by General Dwight Eisenhower and Field Marshal Bernard Law Montgomery, along with the heads of the Army General Sir Harold Alexander, Air Force Air Chief Marshal Sir Arthur Tedder, and Navy Admiral Sir Andrew Cunningham.

*Figure 218: Operation Husky High Command Room Lascaris (Image Roser)*

In this war room the different heads of the army, navy, and air force as well as the overall commanders Montgomery and Eisenhower had different rooms (in my view a disadvantage for communication).


*Figure 219: Detail of Operation Husky War Room Lascaris Map (Image Roser)*

The operation was planned using small bands with pins. I have used such a system before too. The results look very nice – but it is a hell of a work to create and maintain. In my lean projects nowadays I try to avoid it, opting for text markers on white board or on paper instead. However, it does work well if you are willing to invest the manpower.

### 36.2.3 The Third War Room during the Cold War and Afterward

After the war, the Lascaris War Rooms continued to be used as the headquarters of the Royal Navy's Mediterranean Fleet and later as one of the NATO naval headquarters. These rooms are currently in restoration and should be opened soon.

Nowadays the formerly top-secret Lascaris War Rooms are open to the public thanks to the efforts of the Malta Heritage Trust. If you happen to be in Malta, I can definitely recommend a visit. In this case I can also recommend to visit Fort Rinella, home to the largest muzzle-loading canon ever made. This is also one of the few places in the world where you can shoot with a historic muzzle loader rifle and even fire an antique 24-pounder cannon.

## 36.3 Other War Rooms

*Figure 220: Dr. Strangelove – The War Room (Image Stanley Kubrick, Columbia Pictures in public domain)*

Of course, there are many other war rooms in the world. You can also visit the Churchill War Rooms in London, although I have to say the Lascaris War Rooms in Malta are more impressive. Fictional war rooms are also used in films, the most famous example being in Stanley Kubrick's *Dr. Strangelove*.

*Figure 221: Apollo 11 Mission Control (Image NASA in public domain)*

Yet another war room, so to speak, is NASA's mission control rooms. Decisions based on the available information are also made in these rooms. This is, for example, very nice to see in the movie *Apollo 13.*

In any case, I hope this post gave you some inspiration on how to manage your own projects. Now go out and **improve your industry!**

# 37 The FiFo Calculator – Determining the Size of your Buffers

*Christoph Roser, September 14, 2014, Original at https://www.allaboutlean.com/fifo-calculator/*

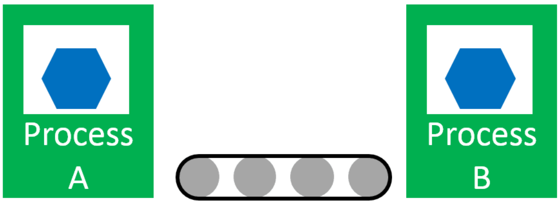


*Figure 222: Two Processes with a FIFO in between (Image Roser)*

In my previous post, I discussed how to Determine the Size of Your FiFo Lane – The FiFo Formula. My preferred method is still an expert estimate. However, if you are interested in the math, here is a small JavaScript calculator that estimates a FiFo size for two processes. For instructions on how to use it and some background, see below. The calculator requires JavaScript, and it may not work with some older web browsers. If you see no graphs below, then try a different browser.

## 37.1 Information About the Two Processes

Please enter the information about the mean and standard deviation of the two processes in the fields below, using a time unit of your choice. You can hover over input fields for additional information.

*You would need to go to the input mask of the calculator at my website at https://www.allaboutlean.com/fifo-calculator/ to do the calculations. Sorry, this does not work in a book.*

## 37.2 Expected System Time

Shows the relation between the FiFo length and the expected overall time between parts for the system.

*The results of the calculations with the effect of the buffer size would also be shown at my website at https://www.allaboutlean.com/fifo-calculator/.*

## 37.3 FiFo Size Recommendation

- Overall Recommended FiFo capacity is no more than 8, based on the larger of the two FiFo sizes given below
- FiFo capacity of 8 needed based on the standard deviations. Any additional FiFo capacity has only a small influence on the overall performance.
- FiFo capacity of 2 needed to cover breakdowns of the faster process up to a duration of 10

## 37.4 Some Additional Observations

- Long Term Bottleneck (in average slowest Process) is Process 1.
- Probability of Process 1 being the short term bottleneck for a FiFo length of Zero is 55.515%
- Probability of Process 2 being the short term bottleneck for a FiFo length of Zero is 44.485%
- The Mean and Standard Deviation you entered was 8 and 4 for Process 1 and 7 and 6 for Process 2.
- FiFo Calculator Version Number: 1.0

## 37.5 Bottleneck Probabilities

Shows the likelihood of one of these two processes being the temporary bottleneck. The larger the FiFo, the more likely that the overall slower process will be the bottleneck.

*The likelihood of one process being the bottleneck would also be shown at my website at https://www.allaboutlean.com/fifo-calculator/.*

## 37.6 Normal Distributions

Shows the normal distributions of the two processes. The closer the distributions are and the more these distributions overlap, the more FiFo capacity is needed to achieve the same performance.

*The normal distributions would also be shown at my website at https://www.allaboutlean.com/fifo-calculator/.*

## 37.7 How to Use the FiFo Calculator

The program below will calculate the effect of the capacity of a FiFo lane (or for that matter, also a random buffer) on these two processes. This program is most useful to calculate the FiFo length before and after the bottlenecks. For more on bottlenecks, see my posts related to bottlenecks, especially the Bottleneck Walk. For a general discussion on how FiFo works, please see Theory and Practice on FiFo Lanes. For some background into the calculations, see Determining the size of your FiFo lane – The FiFo Formula.

You would need information about the time between parts for each of the individual processes, both the mean and the standard deviation. This means collecting data directly from your processes (or making really good assumptions ☺). You have two options here:

Collect data including every disturbance, breakdown, changeover, etc. during regular working hours. Your standard deviation may be quite large. In this case, such breakdowns, etc. are included in the assumptions about the effect of the FiFo. In this case, you can ignore the minimum time to cover for breakdowns by setting it to zero below if you wish.

Collect data without major disturbances, breakdowns, changeovers, etc. during regular working hours. Your standard deviation will be smaller. In this case, such breakdowns, etc. are not included in the assumptions about the effect of the FiFo. In this case, I recommend to also fill out the minimum time to cover for breakdowns below. How long do your want your FiFo to last in case the slower process breaks down completely?

You will see that the larger the FiFo capacity is, the faster your system will be. However, a too-long FiFo will make your system less agile, hence you need a trade-off. The calculator will also suggest a trade-off. In any case, all the calculations below are only estimations. If you think the results to be strange, use your common sense or the common sense of someone familiar with the system.

## 37.8 About the Calculator

The calculator uses the equations in Determining the Size of Your FiFo Lane – The FiFo Formula to estimate the bottleneck probability. Similar equations were used to estimate the expected joint speed of the system, where the probability of process A having a certain cycle time was combined with the probability of process B being larger than this cycle time and the corresponding expected value of process B. The latter part is a bit complex and involves double integrals.

Calculating the error function necessary for the normal distribution is difficult, but luckily different programming approximations are available for calculating the integral of the normal distribution.

However, joint integrals are trickier. The above calculator estimates a numerical integral, (i.e., the probabilities and means for different X are summed up). Hence the approach is not mathematically perfect, but by far exceeds the accuracy of a Monte Carlo simulation for similar calculation times. For any practical purposes, this calculator is probably much more accurate than the data you are entering in the first place. (How accurately do you know the standard deviation of your processes?)

As for the graphs, Google provides a pretty nifty and free JavaScript library for such graphs (and many other things).

Of course, use all results at your own risk!. In any case, I hope this tool helps you to get a better understanding about your system. Now go out and Improve your Industry!.

# 38 The Advantage of Handwritten Data on the Shop Floor

*Christoph Roser, September 21, 2014, Original at [https://www.allaboutlean.com/hand-written-shop-floor/](https://www.allaboutlean.com/hand-written-shop-floor/)*

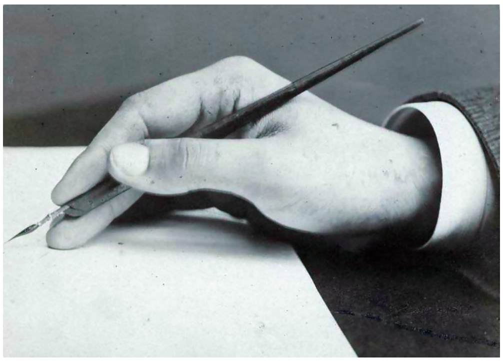

*Figure 223: Hand with Pen (Image Josef Löwy in public domain)*

On a modern shop floor, you will find lots of data and documentation. These are quite useful to track and improve the situation in the operations. Many of them are quite nicely printed charts, diagrams, and tables of key performance indicators (KPIs). However, when I look closer at them, I often find that they were last updated six months ago, or even more than one year ago. **That is useless in practical terms!** You need up-to-date information if you want to manage a process. For this, **entering data by hand is most useful**. In this post I will discuss different advantages of tracking data by hand on the shop floor.

## 38.1 The Uselessness of Pretty But Obsolete Data

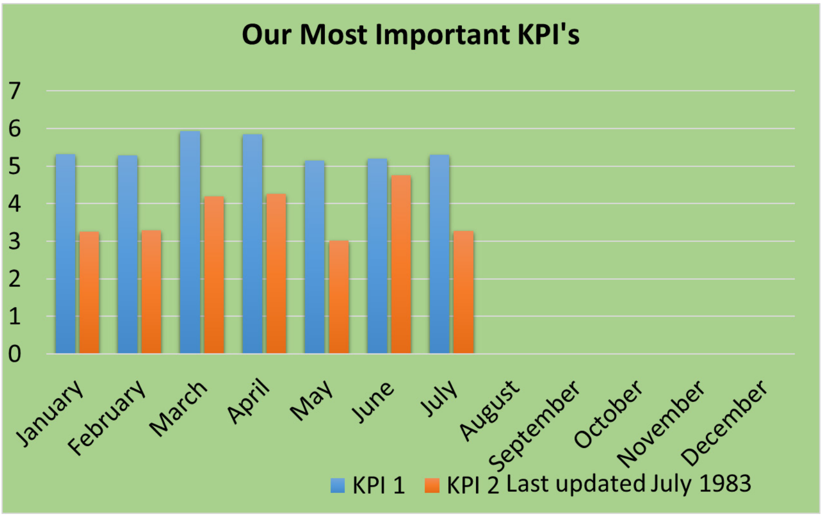


*Figure 224: Pretty … but last updated in 1983 (Image Roser)*

On many shop floors, lower and middle management opts for printed data. Modern computers make it easy to create beautiful and colorful graphics. Often, this is what the next level of management wants: pretty and good-looking charts that are easy to read – **except that nobody really reads them!**

The operators on the shop floor are too busy to bother with such data. Higher management is equally to busy. The latter case may actually be intentional, as befuddling higher management with data it is one of the [top strategies to keep higher management in the dark](#) about what is really going on. Hence, for shop floor management it is easier to look good without actually being good.

Yet, even with computer assistance, creating such drawings costs time. The actual act of creating the graphic may take only five minutes. However, humans are not good at working tasks back to back. We need some time to mentally prepare for the task, get our thoughts organized, maybe have a cup of coffee, etc., and in no time this five-minute task has used up thirty minutes of our time. Even then the chart still sits on the desk and is not yet on the shop floor.

Additionally, creating the chart by computer is usually not done by shop floor operators. Often they do not have access to computers. In effect, the charts are created by more educated (and hence more expensive) workers like foremen, shop floor supervisors, or managers. Overall, this will eat up a lot of time of people who are chronically short on time.

## 38.2 Draw It by Hand

The solution to all these and more problems: **Draw the charts by hand!** Or, to be more precise, enter the data in a pre-printed form by hand. This has quite a lot of advantages.

### 38.2.1 Shop Floor Involvement

*Figure 225: Factory Workers (Image Cherie A. Thurlby in public domain)*

First and possibly most important, this can be done by the shop floor. Rather than having management add the data, have the shop floor operators add a point to a chart, or a number to a table, or a text marker for a red/yellow/green process.

Since the shop floor operators have a huge influence on your performance measures, they need to be aware of these measures and their performance. With sheets printed by someone else, there is an additional effort to make your employees aware of the status of KPIs that are important to you. If they have to fill it out themselves, they automatically have to deal with this number.

Just to be sure: Of course you should pre-print an empty data sheet. It is not the task of the workers to draw x and y axes and write headlines, but rather to fill in the latest data points.

### 38.2.2 More Likely to be Up-to-Date, Hence More Likely to be Effective


*Figure 226: Updated Today (Image Roser)*

With the workers adding the data, your data will also be more up-to-date. It does not matter if it is normal office working hours or 3:00 AM on the night shift, the data can be updated whenever there are people working. Hence, whenever you visit the shop floor (hopefully often!), you can see the current state of your KPIs (in addition to all the things you can see just by being on the shop floor!)

However, with all due respect, when you are seeing them, it is already too late to do something about these KPIs. The workers, however, can influence these KPIs. By adding these KPIs by hand, the workers are involved. They will be able to influence these KPIs, and most likely even before they are written down.

#### 38.2.3 It Forces You to Make It Simple

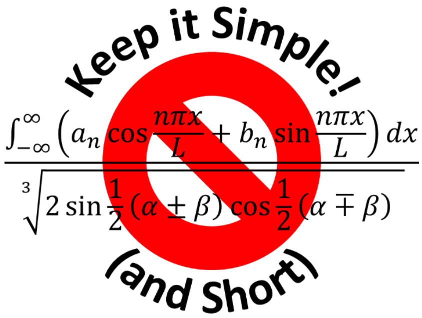


*Figure 227: Keep It Simple! (Image Roser)*

Yet another advantage of adding the KPIs by hand is simplicity! I have seen too many KPIs that required lengthy and complex calculations, resulting in a KPI that was no longer understood and also easily fudged (see for example my post Top Three Methods on how to Fudge Your OEE). In my experience, the more complicated a performance measure is, the less useful is it for actual measuring performance. Usually there are too many exceptions and loopholes to make the KPI look good.

For example, I routinely don't believe OEEs, delivery performance measures, cost calculations, and many more. Don't get me wrong, it would be nice to have these numbers. I sometimes also calculate them myself if I need them for a project. But I do not use complicated KPIs without knowing in detail how they are calculated.

However, if the operators on the shop floor have to add the numbers, it forces you to keep it simple. Any complex math is usually lost on the shop floor. Instead, your KPIs have to be based on simple things that, for example, can be counted. On the shop floor I (usually) do believe quantities produced, time worked, workers present, and other such measures that are simple and easy.

#### 38.2.4 No Lost Time for "Prettifying"

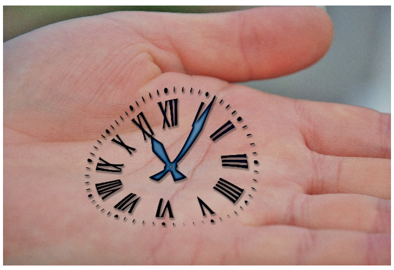

*Figure 228: Time on Hand (Image unknown author in public domain)*

Finally, it saves time for management or office workers. You do not have to print the same charts over and over again with one additional data point every week (bad) or every day (worse).

As mentioned above, the updating and printing may be actually not too bad, but it will interrupt your other and possibly more important tasks. Overall, a simple five-minute print out can turn into thirty lost minutes. Hence, giving the task to the shop floor enables you to work more distraction free (assuming that you may have enough distractions coming in from other sources already ☺).

### 38.3 Occasions Where Printed Data May Be More Useful

In sum, try to use hand written KPIs on the shop floor whenever you can. However, there are a few instances where printing may be better. Most of them are pretty obvious:

**Your superior wants pretty printed charts**: Or, to phrase it differently, your superior does not promote or give raises to people that do not have pretty printed charts. If you have to choose between useful handwritten data and your career, by all means go for your career. You would be surprised how often such mundane details make or break a career, unfortunately.

**Information that is needed frequently**, and is needed for the process to work. For example when storing material on a shelf, the location should not be written by hand. Mistakes happen, and with a lot of locations, you will be searching for material frequently. In such instances scanning or RFID tags are a much more reliable method.

**Information that changes only rarely**, as, for example, work instructions. Of course they do change – in fact they should change, but not every day.

**Legally required data**: If the laws applicable to your plant require certain data or information posted on site, it may be better to print them.

**Safety or quality instructions and warnings** (but not KPIs about safety): Warning labels need to be visible. For obvious reasons, please do not use handwritten Emergency Exit signs or Toxicity warning labels. Similar is true, for example, if you have blocked stock, although the reason can be written by hand on a visible (usually red) tag. KPIs about safety and quality, on the other hand, can be written by hand again. This includes, for example, accidents per month (hopefully none) or defects per day (also hopefully none, but if I could choose I'd rather go for no accidents).

In any case, try to use handwritten data filled in by the shop floor wherever you can. I hope this post was useful for you. Now go out and **improve your Industry!**

# 39 A Successful Example of Lean Implementation – Trumpf and its Synchro Manufacturing System (Part 1)

*Christoph Roser, September 28, 2014, Original at https://www.allaboutlean.com/trumpf-synchro-1/*

*Figure 229: Trumpf Logo (Image Trumpf for editorial use)*

Almost a century ago, Toyota started to develop its Toyota Production System, the archetype of every lean manufacturing system. Almost every manufacturing company nowadays seems to try to implement lean manufacturing. At the same time, most also seem to fail miserably, creating a lot of huff and puff with little benefit. However, occasionally there are (very) few companies that have implemented lean manufacturing successfully. Trumpf **and its Synchro production system is such a successful example of Lean manufacturing,** and one of the finest production system for machine tool builders. Due to the length I have split this post into two parts, the second part being available here.

Usually I am very skeptical when companies claim how excellent and lean they are (because usually they are not!). However, many credible sources praised Trumpf for its outstanding production system called **Synchro**. Hence I was more than excited when I got the opportunity to go and see for myself to find out if it really is that good. Now I can fully confirm that Trumpf indeed is an outstanding example of lean manufacturing. Furthermore, it did not simply copy whatever Toyota does (a common mistake), but adapted its system to the needs of a high variety low volume machine tool builder.

## 39.1 The Company

*Figure 230: TRUMPF Sales and Service Center (Image Trumpf under the CC-BY-SA 3.0 license)*

Trumpf, founded 1923, is the world market leader for sheet metal processing machines. With more than 10.000 employees in all continents, the family owned company is also one of the largest machine tool builders in the world.

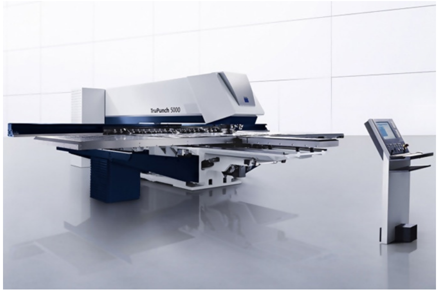

*Figure 231: TruPunch 5000 Punch Press by TRUMPF (Image TRUMPF GmbH + Co. KG under the CC-BY-SA 3.0 Germany license)*

Its main products are machine tools for flexible sheet metal processing, especially laser cutting and welding but also combined punch and laser processing, punching and bending. It also sells lasers for other uses besides sheet metal cutting, e.g. lasers for the automotive industry with its many laser-based applications or for micro-processing applications such as display and PCB production.

## 39.2 Starting the Change Process

*Figure 232: Dr.-Ing. Mathias Kammüller (Image Trumpf Group with permission)*

About 25 years ago, Trumpf was like most other German machine tool builders. Outstanding German engineering and top-notch products, but unsystematic manufacturing, postponed deadlines, and excessive inventory. This started to change in 1995, and especially since 2000, when Trumpf family member Dr.-Ing. Mathias Kammüller became head of the machine tool division and responsible for production and quality management.

Mr. Kammüller spent significant time in Japan with a Bosch joint venture, and was able to see the Toyota production system up close. With an enormous motivation and drive he started to implement Lean at Trumpf, changing the corporate culture away from disorganization and towards order. You could say he is the Taiichi Ohno of Trumpf.

## 39.3 The Changes (Part 1)

*Figure 233: 5S at Trumpf (Image Trumpf Group with permission)*

In 2000, Mr. Kammüller started to roll out his Synchro lean production system. Synchro stands for the Synchronization of man, machine, market, and material. Changes were numerous, including many of the basics of the Toyota production system as for example 5S, Andons, or SMED. However, a few things stand out, into which I would like to go in greater detail

### 39.3.1 Flow Production


*Figure 234: Trumpf Flow Line (Image Trumpf Group with permission)*

One of the impressive achievements in my view was the **implementation of flow production/an assembly line**. Implementing an assembly line is easier if you produce lots of similar parts, as for example cars. Machine tools, however, are usually few products with high variety, and hence machine tools are usually assembled on the spot.

Trumpf, however, implemented a flow line. All its (bulky) machines are on hover cushions or on rails, and hence they can be moved from one spot to the next. With about 500 to 1000 units per line and year, they have a cycle time of about 8 hours. Their fastest lines have a cycle time of 1.5 hours. In comparison, automotive cycle times are around 1-2 minutes.

In production theory it is said that a cycle time of 1-2 minutes is ideal. Too little and it becomes boring, too much and the workers need more time to learn the process. 8 hours is about 250 times of the normally recommended time, hence this was one of the challenges for Trumpf. Their cycle times do include a bit of slack for unforeseen events, but not much. The machines also do not move automatically (as with an automotive assembly line), but only at the press of a button.

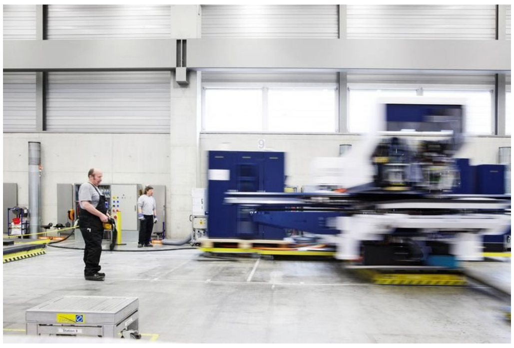

*Figure 235: 15 ton on the move… (Image Trumpf Group with permission)*

Interesting is also the adaption to changing demand. In automotive, the speed of the line is increased or decreased. Such a re-balancing of the line would be too much effort for an 8 hour cycle time. Hence **Trumpf opts to have an empty hover cushion every now and then if demand is low rather than changing its cycle time.**

In automotive with a cycle time of 1-2 minutes, this would be wasted time of the workers. However, if you have a cycle time of 8 hours skipping one cycle gives you a block of time that is quite useable. And Trumpf has a system in place both to predict beforehand when an empty board will come around and to move workers between lines and stations in order to use this time.

Overall, Trumpf managed to successfully implement flow production and an assembly line for its machine tools. These assembly lines are not only a pampered pilot line in a flagship plant, but are installed in all plants for all products worldwide. Furthermore, such flow production also extends to its sub components, with the exception of e. g. the largest lasers of which they sell 10-20 per year. But even there they try to use a sort of cycle time for the different steps, even though the laser itself does not move! Naturally, all production is based on Pull production using a kanban system. At the same time, production of a machine starts only if there is an order. Hence there are no finished machines on stock, which makes sense for such usually customized and expensive products.

### 39.3.2 Inventory Reduction and Supplier Integration

*Figure 236: Check out the inventory – or lack thereof (Image Trumpf Group with permission)*

Yet another success of the system is the reduction of inventory. if you walk through their assembly halls, there is very little inventory compared to what I am used to see at other manufacturers. Their goods receiving area is not much larger than a fancy living room. Depending on the line they have only hours worth of material on site.

They achieved this through different measures. One of the key steps was one piece flow, i. e. the **batch size is one**. This sounds unimpressive for the machine tools, where every tool is different anyway. However, they also extended this to its sub-assemblies and component manufacturing. For example in milling they can and do produce parts automatically in any sequence. Thus they approach the ultimate goal of Taiichi Ohno and Just-in-Time (JIT): *To produce only what is needed, when it is needed and in the amount needed*.

Trumpf also extended JIT to their suppliers. Most of the other (failed) JIT approaches simply demand from the supplier to deliver whatever they need whenever they need it, or else they get whacked. With nothing else changing the supplier has only the options to build up stock themselves or to get whacked. In any case it is unlikely to be cheaper.

Trumpf aims to give a reliable and accurate forecast of the demand. The next month demand is fixed, the two months thereafter are not. This system works, and Trumpf has a good reputation with its suppliers, with deliveries actually arriving within their fixed windows. Suppliers also know that if they miss the window, production at Trumpf will stop shortly thereafter due to lack of parts.

*Figure 237: Kanban at Trumpf (Image Trumpf Group with permission)*

Such a three month forecast of course clashes with changing demand through a Kanban based pull system. Yet suppliers need a longer forecast (or they have to build up inventory and subsequently raise prices). In many other companies the integration of Kanban and Forecast is ill defined. If the forecast tells to produce but the Kanban says no, the decision is often unclear, and usually manufacturing opts to produce to be on the safe side, with resulting excessive inventory. At Trumpf the relation is clear: **Produce only if there is a Kanban!** If the forecast is too high store the inventory, do not merely shove the problem to your suppliers.

Overall, Trumpf seems to have a very low inventory reach compared with other machine tool builders, or even with automotive companies. While Toyota gets away with a two hour reach (after working on it for 50 years), most other companies I have seen have a two week reach or more. Trumpf with about 1-2 days of inventory reach appears to be quite good.

In the next post I will talk about how Synchro uses KPI's and team boards, and also how they establish a continuous improvement process. Finally I would like to discuss why Synchro worked where so many other attempts at Lean have failed. In any case, **go out and Organize your Industry!**

# 40 A Successful Example of Lean Implementation – Trumpf and its Synchro Manufacturing System (Part 2)

*Christoph Roser, October 05, 2014, Original at https://www.allaboutlean.com/trumpf-synchro-2/*

TRUMPF

*Figure 238: Trumpf Logo (Image Trumpf for editorial use)*

Half a century ago, Toyota started to develop its Toyota Production System, the archetype of every lean manufacturing system. Almost every manufacturing company nowadays seems to try to implement lean manufacturing. At the same time, most also seem to fail miserably, creating a lot of huff and puff with little benefit. However, occasionally there are (very) few companies that have implemented lean manufacturing successfully. Trumpf **and its Synchro production system is such a successful example of Lean manufacturing,** and one of the finest production system for machine tool builders. Due to the length I have split this post into two parts. This is the second part. If you have not yet done so please read the first part here beforehand.

## 40.1 The Changes (Part 2)

In the previous post I have described the company Trumpf, and went into detail of its Flow Production, inventory reduction, and supplier integration. But there is more:

### 40.1.1 KPI tracking on all levels


*Figure 239: Trumpf team board (Image Trumpf Group with permission)*

I was also particularly impressed with their team boards. While many plants have fancy-schmancy team boards they often see not much use and have even less benefit. At Trumpf there are team boards for the operators and supervisors, for group leaders, and for plant managers. And they seem to be used for daily meetings (called "Stehung", German for Standing-Meeting). Please note that the image on the left is a stock picture by Trumpf, and the boards I have seen looked much more lively and much less printed!

Almost all of the data is written by hand (see also my post The Advantage of Handwritten Data on the Shop Floor), and I was unable to find an outdated sheet or KPI (which is usually one of my easier exercises in other companies).

The data tracked also seems to make sense, including some sort of productivity measure, delivery performance, number of employees available, and so on. For middle and upper management the board also included a tracking KPI if these managers actually participate in the meeting. Most of them also seem to have an understandable level of complexity (although there was one printed sheet with more complex KPI's pulled out of the ERP system). Overall it looked like a reasonable solid implementation to me.

### 40.1.2 Continuous Improvement


*Figure 240: Kaizen (Image Roser)*

One key part of lean manufacturing is its continuous improvement (or Kaizen in Japanese). Toyota does it successfully, frustrating other companies that simply want to copy the *RIGHT SOLUTION* from Toyota. After they have glimpsed *THE TRUTH* at Toyota and struggled implementing it, they come back a year later just to see that Toyota has changed it completely.

Trumpf seems to take inspiration from others, but to go its own way with its solutions. This includes the continuous improvement process. For example, the team boards described above are anything but static. About once per month the plant manager changes his or her own board, taking out KPI's that are no longer needed, and adding others that become a problem or a focus topic.

Currently Trumpf is also updating its production system with a new **Synchro Plus** being implemented since 2011. The focus of Synchro Plus is on management to drive its continuous improvement process. The goal is to increase participation of management directly on the shop floor. Indirect areas also seem to come more into focus besides production and logistics. From what I have seen in 2014, it seems to work.

These details above and in the previous post are just a few aspects of the Synchro production system, but these are the ones I was most impressed with.

## 40.2 Why Synchro worked where so many others failed


*Figure 241: Success and Failure (Image unknown author in public domain)*

Many companies try to implement lean, but quite frankly, most fail. Trumpf obviously did some things differently. Productivity, inventory, cost, and many other KPI's have improved dramatically during the last 15 years. So what is the difference?

I believe one key difference is that Synchro has a **strong driver** with Mr. Kammüller, who managed to change the corporate culture. Other companies delegate Lean to middle or higher management, who see it as a step in their career building but have their eyes already on the next higher up position. Hence there is a focus on short term measures to impress the boss to achieve a promotion. And if the measures don't work there is always the option to fudge the numbers. Trumpf seems to be different with more consistency and a long term view.

This is helped by Trumpf being a family owned company, with the top executives being sister, brother and brother-in-law. Synchro is running under the same management for fifteen years now. In regular public owned companies a CEO can be happy to have five years before another CEO changes direction, and all underlings are just waiting to kick the CEO out in order to take its place.

Also, Trumpf seems to share its success with its workers. Both production and offices looked very clean and modern, with lots of art in public spaces. Some parts of the plant felt to me more like walking through a museum than a factory. The restaurant was also way above average quality (With restaurant I mean the factory canteen, but Trumpf prefers to call it a restaurant – rightfully so). Relations between management and unions also appear to be cooperative.

The employees also seem to be involved in decision making and interested in their product. For example, behind the receptionist was a CNC laser engraving machine. I first thought this was a display only, but no: the receptionist was engraving parts when there were fewer visitors, and she enjoyed doing it. She told me that it makes her feel good to produce for Trumpf, too. In my opinion this is quite unusual in a good way. Or how many receptionists do you know that are so interested in their products, let even know how to operate the machinery?

*Figure 242: Row of people (Image unknown author in public domain)*

Of course, the system at Trumpf is not perfect. There is no perfect system. Delivery performance is not quite as good as it should be (but still better than many other machine tool builders I know), some numbers on the KPI board did not quite add up, and so on. That is normal. Yet it seems such issues are taken on much more seriously at Trumpf than at other companies. Also, Toyota is working on its production system for over 60 years now, whereas Trumpf is just 15 years down its journey.

If you read my blog more frequently (which you should ☺), you will know that I am often critical, maybe even cynical of what is claimed to be *Lean* by most companies. Hence I am just happy to see a company that seems to be truly on the right path. In any case, I hope this post gave you some motivation and insight for your own company. Now go out and **Organize your industry!**

# 41 Eight Rules for Total Gridlock in the Organization (Video)

*Christoph Roser, October 12, 2014, Original at [https://www.allaboutlean.com/eight-rules-peter-kruse/](https://www.allaboutlean.com/eight-rules-peter-kruse/)*

*Figure 243: Prof. Dr. Peter Kruse (Image Daniel Seifert under the CC-BY 2.0 license)*

There is an excellent and highly sarcastic video around by Prof. Dr. Peter Kruse, professor of organizational psychology at the University of Bremen. In this, he describes his **Eight Rules for Total Gridlock in the Organization** (*8 Regeln für den totalen Stillstand*). Since these eight rules are quite relevant to the lean change process, I have transcribed, translated, and subtitled the German video for you into English.

Additionally, it is another attempt at my so-far-futile quest to prove to my wife that Germans indeed do have a sense of humor. In any case, below is the subtitled video and the complete transcript of Professor Kruse's highly entertaining speech. Enjoy:

*The video by AllAboutLean.com originally by Ulrike Reinhard is available on YouTube as "Eight Rules for Total Gridlock in Organizations (German with English subtitles)" at https://youtu.be/ZAWCWz1QPL4*

*### Beginning of Transcript ###*

## 41.1 The Eight Rules for Total Gridlock in the Organization

I would like to give you a few rules that you may find useful—my favorite eight rules for total gridlock. Hence, if you want to be absolutely positively sure that there is definitely no change, I can help. Eight rules that create total gridlock.

### 41.1.1 First Rule – Alternate Total Control with Total Freedom

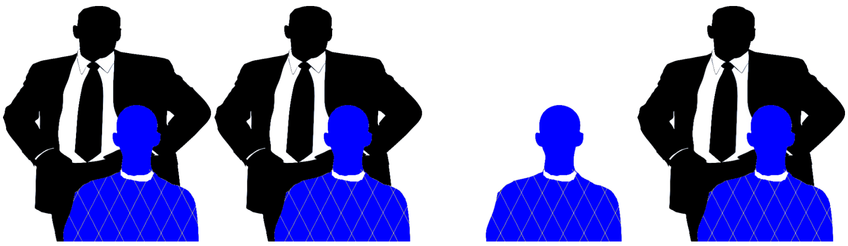

*Figure 244: Do exactly what I tell you, except when I don't… (Image Roser)*

The first rule has to do with leadership. **Management should either keep out completely, along the lines "Guys, you will do it," or have everything under control.** When the manager has everything under control, the whole company is as intelligent as the manager, hence necessarily limited. If you give total freedom, everyone has their own visions. And when everyone has their own visions, nothing will come together.

The best thing you can do is to try to have everything under control all the time but then sometimes suddenly give project-based complete freedom. People will be totally confused. Hence, always behave in these extremes.

### 41.1.2 Second Rule – Discuss Change Only at the Informal Level

*Figure 245: Make me bubble! (Image Roser)*

Second rule, also very popular: **Discussions about the goals and content of possible change should be consistently held only at the informal level.** Make rumors! The very best rumors you can spread are rumors about the stability of the system.

Ideally, you do it every morning. Go around every morning through the company, go to a random department, and say "*I think the department will be closed*" and then move on. Fantastic! Do this every morning! You will always have an enormous hullabaloo in the organization, but definitely nothing will change. Make rumors! The more rumors you make, the better.

### 41.1.3 Third Rule – Maximize the Number of New Activities

Third rule: Simultaneously start as many activities as possible. **Ensure constant work overload.** Make operations hectic! Make an action of the second or minute, but never an action of the year, because then something may really change.

### 41.1.4 Fourth Rule – Competition and Survival of the Fittest

Fourth Rule: **There should always be intense competition.** Inform everyone that only the fittest and strongest will survive in your organization. Make internal competition! Or, as I would say nowadays, make crab baskets!

*Figure 246: Lots of dynamics… (Image Jeff Costlow in public domain)*

Do you know this example? If you watch the fishermen bringing their fish ashore, they use baskets to throw the fish in. And these baskets usually have no cover, because the fish on land stay there.

But they have only one type of basket, which they also use for large land crabs. I've always wondered, damn it, why does this basket also have no cover? Couldn't the land crabs get out at any time?

It's simple. The fishermen know the principle of internal competition. If you throw two crabs in a basket, neither gets out. For whenever a crab crawls up, the other one comes along, pulls itself up on the first, and drags the other one back down.

Hence, in a crab basket you always have enormous dynamic, but nothing moves forward. And that is the principle of internal competition. It looks tremendously good, but definitely nothing changes. Hence, make crab baskets! The more crab baskets, the better.

#### 41.1.5 Fifth Rule – Always Find the Guilty One

*Figure 247: I found the guilty one… (Image Лобачев Владимир in public domain)*

Fifth rule, especially popular in Germany: **There should always be a persistent and unrelenting quest to find the person responsible for the problems.** Find out who is to blame! Analyze! Do not simply start changing things; always analyze the culprits first.

It's excellent when a depressed person gets together with an analytical person—you will have two depressed people. It is absolutely great! Be as thorough as you can! Analyze! Do not simply start changing things, because then something really may happen! Always analyze first!

#### 41.1.6 Sixth Rule – Do Not Question Existing Rules

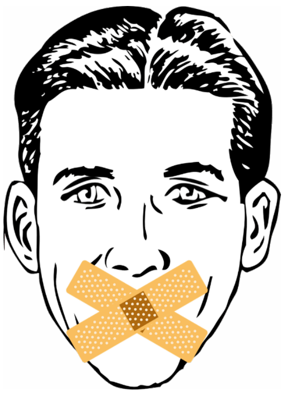

*Figure 248: Do Not Discuss (Image Roser based on public domain sources)*

Sixth rule: There should be under no circumstances any public discussion about the sense and nonsense of existing rules. So do not start to question your internal parking rules.

### 41.1.7 Seventh Rule – Fast Formal Decision Making Followed by Questioning on the Informal Level

*Figure 249: Hurry up and agree! (Image unknown author in public domain)*

In my opinion, the two best reasons are by far the two last ones. The seventh rule is: Decisions should reach a consensus as fast as possible on the formal level, and then be extensively questioned on the casual level.

Ensure fast commitment. This is very popular with steering committees and task force teams. Make sure that people nod quickly. The faster they nod, the less they understood what they just agreed on. And the moment they stand up, you can see it in their faces—"Not sure if this will work…" They take everything back that they just agreed on. Hence, ensure fast commitment! Do not struggle before the decision, because then you can struggle extensively after the decision.

### 41.1.8 Eight Rule – Maximize Decision-Making Speed and Minimize Implementation Abilities

*Figure 250: Decision making is not the bottleneck here…(Image Roser based on public domain sources)*

But the best rule is, in my opinion, the last one. This proved to me that we are already a learning organization. Peter Senge has already won. The eighth rule is: **The rate of change on the decision-making level should always be greater than on the implementation level.**

Provide maximal decision-making momentum while at the same time minimizing implementation abilities. If you do, you will soon have a learning system. Your people will realize quickly that "Change is like the flu. With a doctor it takes fourteen days, and without a doctor two weeks, and then it's over!" In one company they told me, "I know, we call it BAW." I asked, "What do you mean BAW?" – "Well, bend and wait!" Bend aside, wait until it's over, and come back up. And the people have practiced this friendly rocking motion extensively over the years.

But, of course, these things surely don't happen at your place. Hence, forget what I just said. This is way too abstract and far away from any form of reality.

*### End of Transcript ###*

There is definitely a lot of truth in the rules by Prof. Kruse. But, of course, as he said, none of these would ever happen at your place, right? If they do … well … now you know how to do the opposite. In any case, go out and **organize your industry!**

## 41.2 Sources:

The original German YouTube video is 8 Regeln für den totalen Stillstand (2008), uploaded by Ulrike Reinhard under the CC-BY 3.0 license and linked to Prof. Kruse's website, www.nextpractice.de.

Besides the video with permanent English subtitles above I provided the video also with optional subtitles in German or English. Transcription, translation, and subtitling are by me.

The presentation itself is a repeat of an older presentation, also available on YouTube. You can find these if you search YouTube for "*8 Regeln für den totalen Stillstand.*"

# 42 Top Five Cases When NOT to Use a FiFo

*Christoph Roser, October 19, 2014, Original at*
*https://www.allaboutlean.com/not-fifo-part1/*

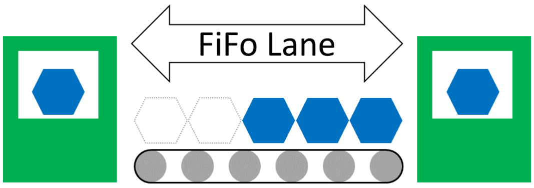


*Figure 251: FiFo Lane (Image Roser)*

Standard wisdom for creating a good material flow is to use FiFo lanes (First in, First out). In other words, the first part that goes into the line should also be the first part that comes back out. As such, FiFo lanes and its big brother, Supermarket, are essential for any lean material flow. However, some rules of wisdom can be bent and others can be broken. Here are the **top five cases when NOT to use a FiFo lane.**

## 42.1 Prelude

Please don't get me wrong. **I love FiFo. It is one of the easiest tools for getting your material flow under control.** However, all too often I hear people claim that all material flow MUST be FiFo. This is not true. The idea of lean manufacturing is to apply the principles, not to slavishly copy rules without understanding.

The same applies to FiFo. There are examples when a FiFo will give suboptimal results. Granted, most of these examples are cases where after further implementation of lean, the system would benefit from a regular FiFo. However, until these implementations are made, you may opt not to use FiFo. The following five cases of when not to use a FiFo lane were inspired through a discussion on the LinkedIn Group TPS Principles and Practice (private group, membership on request).

## 42.2 When to Break FiFo between Two Processes

### 42.2.1 1: Batch Processing

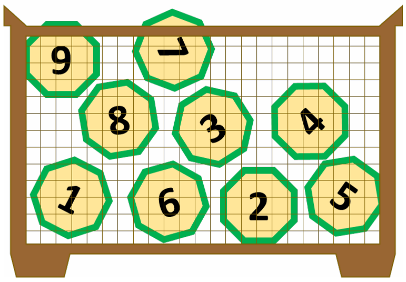


*Figure 252: Hard to maintain sequence (Image Roser)*

FiFo in its strictest sense is difficult to maintain in batch processing. If you are moving or processing your parts in boxes or batches, then it will be difficult to maintain a FiFo within the box. It is possible using some creative numbering scheme, but unless there is a compelling reason to do so, the effort is not worth the benefit. Naturally, the boxes or crates themselves should be in FiFo if possible, only the parts within are in random order.

### 42.2.2 2: Priority Orders

*Figure 253: Built-in Priority (Image Brett Levin under the CC-BY 2.0 license)*

Sometimes it makes sense to prioritize your production order. As police or an ambulance can overtake other cars in a traffic jam, so can parts overtake others in the production line. In some cases, this may help your production.

For example, you may have high runners and rarely sold exotic parts. It may make sense for high runners to be *built to stock*. If your exotic parts are also *built to stock*, your inventory will go up disproportionately. You may choose either to *build to order* or try to reduce inventory. In any case, a **faster throughput time for exotic parts may be helpful for customer satisfaction**. By allowing these exotic parts to cut in line, you may significantly improve delivery performance and inventory for exotics, while only marginally increasing inventory for high runners.

Another example may be when something goes wrong with production or planning. One order was forgotten/delayed/missed/messed up/etc., and now the **key customer is screaming for his parts.** (Maybe you are familiar with such a scenario. I certainly am ☹). In this case, it may also be possible to reduce pressure by allowing these jobs to cut in line.

**The key for prioritizing parts is to do it sparingly.** No more than one or two out of ten parts should be allowed to overtake the queue; otherwise the whole system may be thrown into chaos. For example, imagine standing in a supermarket checkout line. If one or two people out of ten are allowed to cut the line in front of you, it is annoying but will be only a minor delay. On the other hand, if every other person can cut in line in front of you, you may never get through the line.

Same happens to parts. The more parts cut in line, the more erratic the throughput time of non-prioritized parts will become. **If all your parts are prioritized, then none are, and the chaos will be endless!**

### 42.2.3 3: Parallel FiFo Lanes due to Space Constraints

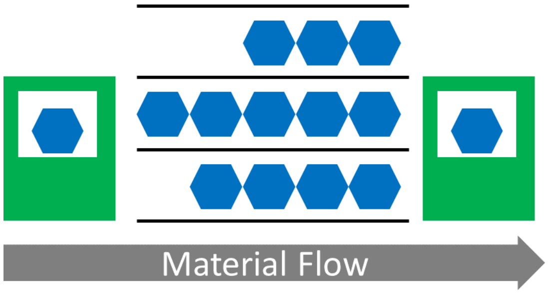


*Figure 254: Parallel FiFo (Image Roser)*

Another example for breaking FiFo is when you have a longer FiFo lane but not enough space on the shop floor. In this case, you may break the FiFo lane into different parallel segments.

The challenge here will be to maintain FiFo across multiple parallel lines. Both the source and the destination process need to follow a structure when adding or removing parts to maintain FiFo across multiple lanes.

I have seen different approaches that try to wrestle control over such a system and signal the user when to add or remove parts, from elaborate digital signals to mechanical barriers to cheap plastic flower pots on top of the goods. All of these required that filling and emptying must be different lanes. Only when a lane was completely empty did the delivering process have permission to fill that lane again. Of course, this makes a suboptimal use of your floor space.

In this case, it may be easier to simply forgo FiFo and have both source and destination pick lanes at random. In all likelihood, unless your guys are able to follow a standard to the letter, there will be hiccups in the sequence anyway.

However, there are some important caveats! If you have different products in the system, then you probably will need to maintain a FiFo, even with the occasional hiccup. Otherwise there is a high risk of some products being in the lanes for an excessive time, either by chance or because they are more difficult and the destination process does cherry-picking of easy work (happens all the time!).

Only if you have identical products should you consider breaking FiFo and allowing random picks. The downside is that products may stay in the lanes for different periods and that traceability in case of errors may no longer be available. For example, if the destination process notices an error, it will be more difficult to determine which parts in the lanes have the same problem or what the cause at the source was.

It all boils down to a trade off: the effort of maintaining FiFo vs. the benefits of having FiFo. I had situations when I choose to break FiFo. Of course, the best way would be to reduce inventory to have only a single FiFo lane within the available space; then the entire problem would be gone.

### 42.2.4 4: Variation in Storage Cost


*Figure 255: Is there a free spot? (Image Luiz Eduardo under the CC-BY-SA 3.0 license)*

Yet another example where it may make economic sense to break FiFo is for differences in storage cost. Assume, for example, that your warehouse is full and you have to rent space in an external warehouse. Your own warehouse is paid for no matter how many products are in there. The external warehouse, however, may charge per storage slot.

In this case, it makes sense to fill up your own warehouse completely before adding to the external warehouse. Similarly, you should satisfy demand by delivering from the external warehouse first to reduce storage cost before emptying your own warehouse. Overall, the sequence will be no more FiFo, but possibly more of a LiFo (Last in, First out).

Again, there are some caveats. Make sure your products do not expire while sitting in your warehouse. And, of course, the best option would be to simply improve your system so you can reduce your inventory altogether.

### 42.2.5 5: Changeover Optimization

Finally, yet another reason to break FiFo is changeover optimization. In many examples, it may be easier to change your machines to a new process if the products come in a certain order.

For example, in injection molding, it may be easier to start with a light color and gradually move to darker colors with the next batch. This way you will have less cleaning of your machine, since a speck of lighter-colored plastic left in the machine will be much less noticeable. On the other hand, a speck of darker-colored plastic left in the machine may ruin clear or white parts.

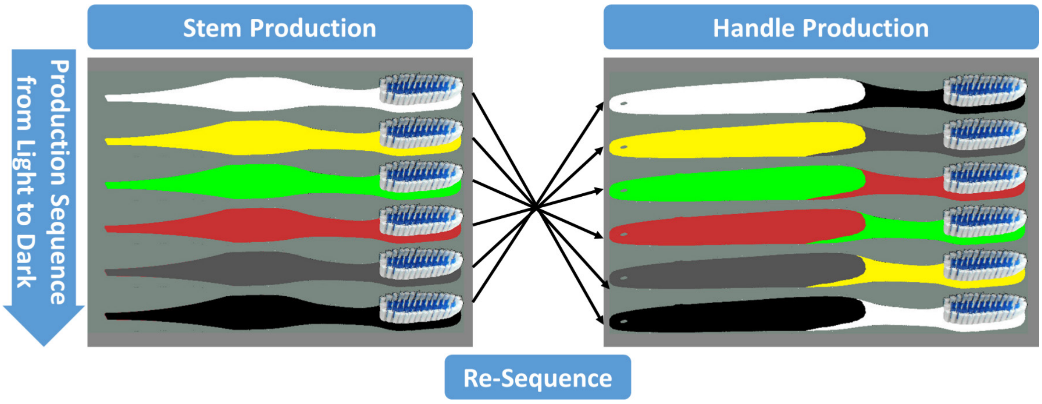


*Figure 256: Production sequence light to dark for a toothbrush example (Image Roser)*

In such a case, it may be beneficial to break the sequence coming from the previous process and order the parts to reduced changeover time. If different processes in your value stream have different ideal changeover sequences, you may break the sequence more than once. Overall this will reduce changeover cost, although at the cost of a higher inventory.

Again, it boils down to a trade-off between the benefit of reduced changeover and the effort related to the added inventory. Naturally, pure lean theory would be to optimize changeovers into nothingness and have a one piece flow (i.e. a batch size of one with zero changeover time). However, until you have achieved this, you may opt to break FiFo here.

## 42.3 Some More Examples When Not to Use FiFo across an Entire System

The examples above all apply to a FiFo between two processes. Just for the sake of completion, here are some more examples of when to break FiFo across the system, even though you maintain them between the processes. In effect, the parts will leave the system in a different sequence than they entered. This happens in many systems and is usually not a big problem.

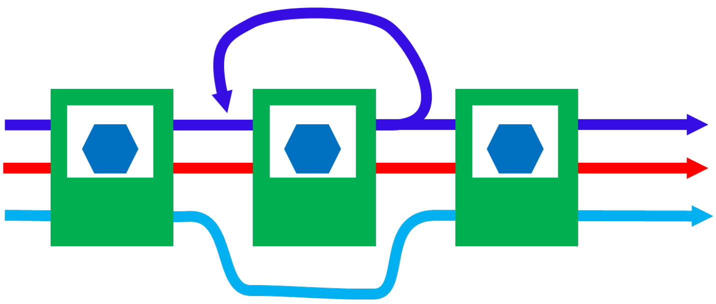

*Figure 257: Flow Shop (Image Roser)*

**Break FiFo when the part flow is not identical for all parts**. This may be, for example, in the case of branching, looping, or skipping steps. In this case, the parts will leave the system in a different sequence than they entered.

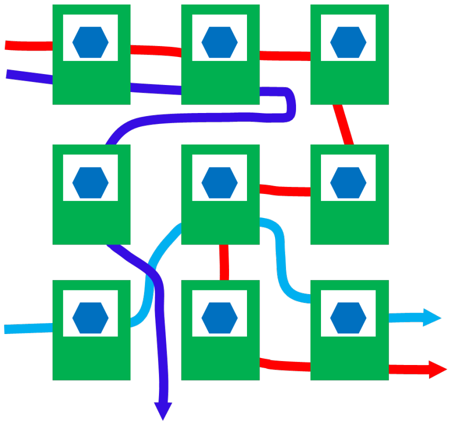

*Figure 258: Job Shop (Image Roser)*

**FiFo almost always gets broken in job shops.** If the value stream is different for every part, then the sequence of the parts entering and leaving the system will be almost certainly different. This is sort of an extension of the non-identical part flow above.

**Batching, optimizing, and prioritizing open jobs**. It is common in many systems to batch and prioritize the open jobs. The most urgent batch is the one processed first. In this case, the sequence of the orders or jobs entering the system is different from the sequence of the parts leaving.

Finally, **you should not use a FiFo if a supermarket is the better option**. Of course, a supermarket is nothing but parallel FiFo's, one for every product type. For more details, check my posts Ten Rules When to Use a FIFO, When a Supermarket – Introduction and Ten Rules When to Use a FIFO, When to Use a Supermarket – The Rules. Some of the content above was inspired through a discussion on the LinkedIn Group TPS Principles and Practice.

I hope this post was interesting to you. Please let me know if I missed a reason. Again, try to use FiFo whenever you can, but keep in mind that there are some examples where it may be not the best option. **Now go out and organize your industry!**

# 43 Common Mistakes of Top Executives – A look at "Undercover Boss"

*Christoph Roser, October 26, 2014, Original at [https://www.allaboutlean.com/undercover-boss/](https://www.allaboutlean.com/undercover-boss/)*

*Figure 259: Undercover Boss (Image Personeelsnet under the CC-BY-SA 2.0 license)*

I occasionally watch the reality show *Undercover Boss*, where top executives work undercover in their own companies. Over and over again I see these managers making the same mistake: They have no understanding whatsoever of what is really happening on the front lines. It is a typical case of not going to the shop floor often enough, or in lean speak, no **genchi genbutsu** (Japanese for "go and see"). So, <dramatic voice> *Why do bosses all make the same mistake? Will they ever learn? Will you enjoy this post? See for yourself in the post below!* </dramatic voice>.

## 43.1 Undercover Boss

*Figure 260: Boss with umbrella (Image geralt in public domain)*

*Undercover Boss* is a TV reality show that started in the UK in 2009 and now has successful spin-offs in USA, Australia, Austria, Canada, France, Germany, Italy, Norway, and Spain, with more countries in the pipeline. In each episode, a top executive works for five to ten days undercover in his or her own company, each day at a different job. The tasks are usually manual labor or customer handling, occasionally with a bit of data entry added.

The employees the boss works with think he or she is a *contestant* on a reality show trying to start his or her own business, or is part of a documentary. In any case, the boss has a cover story explaining the cameras. Afterward, the employees the boss worked with come together, believing that they have to judge the "contestant." Instead, the boss reveals his or her true identity, and hands out rewards for good employees or punishments for the not-so-good ones.

Naturally, as in most reality shows, there is some control over the situations. For example, the positions they work in and the employees they work with are selected beforehand. Some bosses opt to go to the best-performing sites/employees to see what they are doing right (a good approach). Other bosses also opt to go to the worst-performing sites to see what is going wrong, or to the oldest or newest location (also valid approaches in my opinion). And, in other cases, the reasons for selection are not known.

I also believe that some of the worst scenes that could seriously damage the brand, the company, or the boss are cut out, but there are still enough meaty situations left. In any case, it is a nice opportunity to watch top management in action from the comfort of your own living room. <dramatic voice> *But who are these bosses? Let's meet 'em up close and personal!*</dramatic voice>.

### 43.1.1 The Bosses

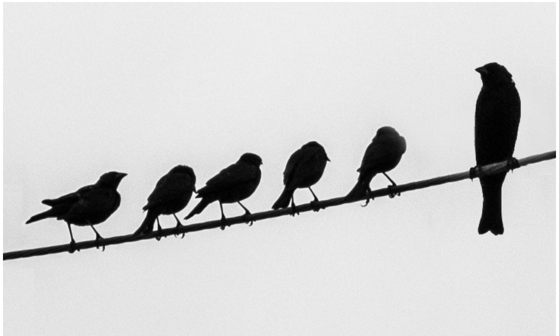

*Figure 261: Who's the boss? (Image Tomascastelazo modified by Roser under the CC-BY-SA 3.0 license)*

The bosses, of course, know that they are on camera and probably behave differently than in real life. For example, I have not yet seen a choleric boss, but they surely must be out there. Nevertheless, through body language and behavior their character shows through. Contrary to the "All Top Executives are Evil" attitude sometimes found in the media, many of them are actually trying to do good within their means.

Some have the look of a rabbit staring at the snake, although a well-kept secret of managers is that most of them feel overwhelmed with the decisions they have to make, and they try hard not to show their fear. But, of course, there are also bosses who think that the sun shines out of their every orifice, and that that they know everything and can do everything. If I would have to choose, I'd rather take a manager that knows his limits. By the way, a good test is to look at the size of the CEO photo in the annual report. If it is passport size, then the company is more important than the manager, whereas the full-page images clearly state that the company is only second to the CEO.

### 43.1.2 The Companies

The companies featured on *Undercover Boss* come from all parts of industry, although the service industry is more often featured than others. Hotels, restaurants, fitness centers, etc. may see this as a way for additional publicity, but there is also other industries like food processing and waste management. There are even two automotive companies (Hyundai and Isuzu, UK season 5 episode 3 and season 4 episode 4), although they unfortunately do not look at the manufacturing.

### 43.1.3 The Jobs

*Figure 262: Man working on wall (Image Walton LaVonda, U.S. Fish and Wildlife Service in public domain)*

The jobs are usually frontline jobs far away from management. Processing food, serving food, cleaning rooms, fixing cars, selling products, typing data, etc. I was particularly impressed, for example, with the CEO of Synagro, a waste management company, who had to enter a half-filled sewage tank to swish the sh*t into the drain (US Season 2 Episode 28). However, in other jobs, they also get down and dirty.

These are the jobs that the CEOs have to manage, but it usually turns out that they have little knowledge of the actual tasks. Most of the time they slow down the processes considerably, and quite a number of bosses undercover have been fired for failing to perform.

## 43.2 The Common Mistakes

Almost all bosses make the same mistakes. However, before I get to the mistakes, let me emphasize that **not performing well on your first day is not a mistake!** Everybody has a learning curve. As for manual work, most CEOs have little recent experience in manual work, hence it is even more difficult for them. If you remember your first day on the job, you were probably a stumbling mess too.

Having said that, let's go in more detail about the mistakes that they as leaders should have known about but still failed.

### 43.2.1 Lack of *Gemba*

*Figure 263: Here is the action! (Image John Oxley Library in public domain)*

Bosses have lost touch with the shop floor (in lean terminology from Japanese, *Gemba*). Most of the bosses are surprised by the situations they find in their businesses. From a desk, everything looks nice. Handling only the numbers, people can't image how many things go wrong in reality. This includes bad and broken machines, counterproductive standards, unrealistic demands, dirty and dangerous work, and often a general lack of respect for the common worker.

They do not know the real situation on the shop floor, and hence make decisions that are difficult or impossible to implement and may hurt the business. In short, management has often lost touch with the actual value-adding work. The steering wheel has lost its connection to the tires.

I have seen this in my work too. I have seen a lot of plant managers who spend only around one hour per week on the shop floor. Some did not have the time, others thought it was too dirty, some only went there if they had to show a visitor around, and again others were just worried about an employee asking them a question they couldn't answer.

Nuts!

How can you make decisions if you don't know the real situation? One of the important principles of the Toyota production system is to go where the real action is (in Japanese, *genchi genbutsu* for "go and see," and *gemba* for the "real place"). A manager needs to understand the abilities and flaws of the system. Granted, usually the system is too big for managers to understand in its entirety. However, that must not stop them for doing some sampling of the real situation.

Most CEOs on *Undercover Boss* saw this value. Many of them called it the most insightful week in their career, and some even announced that they want to repeat it regularly. There is hope!

### 43.2.2 Deciding for the Employees

The CEOs during their undercover stint saw lots of problems that they never knew existed. Of course they wanted to fix it. That's where they usually made their second mistake. They thought about a solution and told their people to implement it. After all, that is what managers do—make decisions, and the more the better, right?

Wrong!

The value-adding systems are usually quite complex. Changing one part even with the best intentions may have lots of unintended consequences. These are usually difficult to predict, most of all for the CEO that has only a limited understanding of the details of this particular system.

*Figure 264: Ask us! (Image Cherie A. Thurlby in public domain)*

In lean manufacturing, it is important to consult the involved parties. Ask the workers and foremen. Or, if there are too many, ask the worker or foreman with the most experience. Depending on the problem, it may also be beneficial to involve someone from engineering, logistics, possibly also the unions, sales, and so on. Have the group find a solution, in the hope that there are less unintended consequences.

On *Undercover Boss*, most managers do not ask the employees about a possible solution; instead, they merely decide what the solution should be. Of course, the episode then ends and we don't know much about the aftermath. However, based on my experiences, I suspect that in many cases the executive decision was not ideal, sometimes even wrong. The impact could have been much better if the manager would have asked the employees for their opinions.

Besides, there is also a theory that the number of decisions someone can make is limited per day (the so called "decision fatigue*,"* also known as "ego depletion"). The more decisions you have to make, the worse your decisions get. Your rationality suffers, impulsive behavior increases, and overall your decisions are no longer as good.

When I go shopping, I usually reach for the brands I always buy. Of course, there may be better yogurt or bread, but I just don't want to make a decision. I have enough decisions to make otherwise. The term here is *decision avoidance*. It is fine in the supermarket, but it is a problem if you avoid decisions in industry.

All this can be avoided by making less decisions and empowering your employees to decide for themselves. Luckily, some of the CEOs did ask the employees, and I suspect the results were better, cheaper, and the workers were definitely happier.

Overall, *Undercover Boss* is sometimes for me quite interesting. Hence, if you happen to have time to waste on your hands, why not pick an episode from *Undercover Boss* to watch (Excerpts of the US episodes are officially available on YouTube, and some full episodes can be found there, too). Granted, it is not fine art, but they did win an Emmy in 2012 and 2013. Maybe you'll even learn from others' mistakes, or even others' successes. And now <dramatic voice> **Go out and organize your industry!**</dramatic voice>.

# 44 Bottleneck Management Part 1 – Introduction and Utilization

*Christoph Roser, November 02, 2014, Original at https://www.allaboutlean.com/bottleneck-management-utilization/*

*Figure 265: Seven empty green wine bottles (Image Roser)*

In the past I've written a few posts with some nifty methods on how to find the bottleneck (The Bottleneck Walk – Practical Bottleneck and The Active Period Method), and some warnings of which methods don't work. In this post I would like to go into more detail on **what to do once you find the bottleneck!** Due to the length of this topic, I have split it into multiple posts. This first post gives an introduction and goes into more detail about increasing utilization. The next post talks about planning. A third post looks at Bottleneck Decoupling and Capacity Improvement.

## 44.1 When Do You Need to Find the Bottleneck?

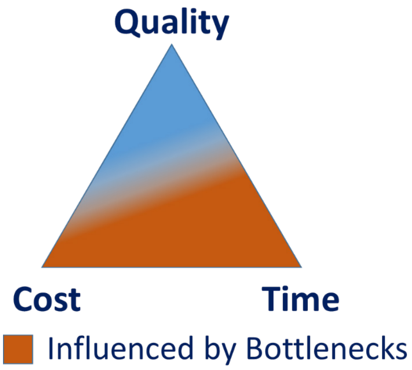


*Figure 266: Quality Cost Time Triangle (Image Roser)*

Knowing and managing your bottlenecks are important for performance. However, you should always work on your biggest problems first. Just because you can find the bottleneck does not mean that finding the bottleneck should be your top priority.

Most problems in a manufacturing system revolve around cost, quality, and time, often involving a trade-off between these three criteria. If your biggest problem is quality, and your customers are sending your products back and switching to the competition, then a bottleneck probably has little influence on your most burning issues. Hence bottleneck detection and management may not be your top priority. Rather, you should fix your quality issues first.

If your top concern at the moment is cost, then improving a bottleneck may help. However, before jumping to a bottleneck detection, you should first check which of your levers influence your cost. Bottleneck capacity is only one of many levers influencing cost. You should focus on the most promising levers, which may not be your bottleneck capacity.

If your key concern is time, as, for example, your delivery performance or your lead time, then your bottleneck may have quite some influence. But again, it depends on your circumstances whether this is your best approach to improve the issue. For example, for lead time it may be better to reduce inventory through an improved material flow. On the other hand, if you are facing capacity constraints, then improving the bottleneck may be the right thing to do.

Not only for bottlenecks but also in general: Before changing anything on the shop floor, make sure that this is the most promising lever to tackle your most significant problems! As for the following bottleneck management approaches, we assume that for your current situation, bottleneck management is indeed the best approach.

## 44.2 Bottleneck Management Overview

There are different approaches you can take to manage your bottleneck. They all start with finding the bottleneck in the first place. However, after that there are different ways in which you can improve your bottleneck capacity. In the graph below I have sorted them in order of their cost and benefit.

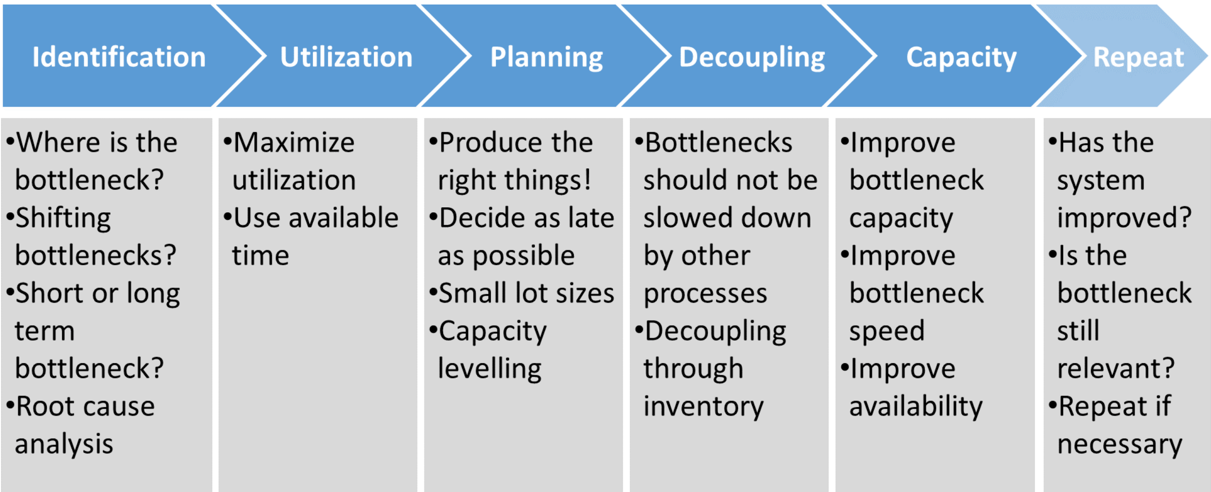


*Figure 267: Bottleneck management (Image Roser)*

Improving utilization is usually the fastest and cheapest approach. Adjusting your planning is a bit slower but also has little overhead. Decoupling may need some time and money to implement. The (usually) slowest approach is improving the capacity, which usually involves engineering or purchasing. However, I still don't fully comprehend why, for some reason, most people in Europe and America start with the slowest and most expensive technical capacity when they are faced with a bottleneck.

In any case, after a bottleneck improvement (or for that matter, after any improvement), the system should be checked. If necessary, the process should be repeated. All of the above methods will be presented in more detail below. Due to length, I have split this into multiple posts.

## 44.3 Identification of Bottlenecks

Managing your bottlenecks requires finding your bottlenecks first. This is tricky, in particular for shifting bottlenecks found in most production systems. If you improve a process that is not the bottleneck, then your system will not change. Hence, you should understand what bottlenecks are – especially shifting bottlenecks – and which methods do and don't work in finding bottlenecks. This topic is rather extensive and requires several posts to cover it. Luckily, I have written these already. The posts below may help you with this:

- Shifting Bottlenecks
- Common Bottleneck Detection Methods that Do NOT Work!
- Mathematically Accurate Bottleneck Detection 1 – The Average Active Period Method
- Mathematically Accurate Bottleneck Detection 2 – The Active Period Method – My preferred method if you have lots of data (e.g., from a simulation).

- The Bottleneck Walk – Practical Bottleneck Detection Part 1 – My preferred method on the shop floor.
- The Bottleneck Walk – Practical Bottleneck Detection Part 2

Ideally, finding the bottleneck should also give you clues about the root cause of the bottleneck. For example, if a process always becomes the bottleneck during a breakdown, then this breakdown may be part of the root cause. If afterward the bottleneck shifts to another bottleneck that is working normally, its cycle time may be part of a bottleneck root cause. In any case, we assume you have found the biggest bottleneck for the following improvements below.

## 44.4 Improve Bottleneck Utilization

### 44.4.1 Why Utilization is Often the Easiest Approach

As part of my research focus, I frequently look for bottlenecks in manufacturing lines. To get a first overview, I also ask management where they believe the bottleneck is (although I do strongly prefer to make my own opinion about that during my own analysis). Most of the time, management believes it knows the bottleneck and points toward the suspected *bottleneck machine*. **The kicker is: Very often management points at an idle machine! The** *bottleneck machine* **is not operating! This process supposedly constrains the entire operation, yet it stands idle and does nothing!**

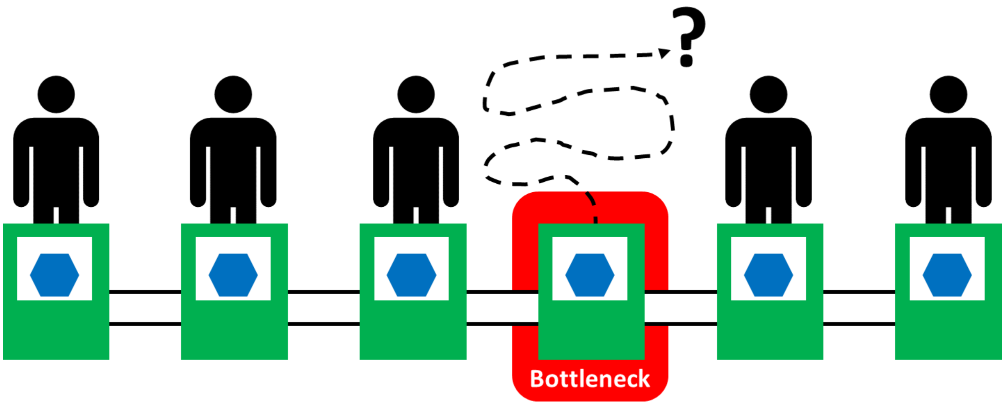


*Figure 268: Bottleneck yet idle? (Image Roser)*

With my typical German *Schadenfreude,* I ask the management, "*If that is the bottleneck, then why is it idle?*" The usual next step is a flurry of activity to find someone who actually knows what is going on on the shop floor (unfortunately, middle and upper management are often too detached from the shop floor to know). We then find a supervisor or foreman, who cheerily tells us that the person that usually operates this *bottleneck machine* is doing more urgent business like... sweeping the floor or something.

This happens way too often. The bottleneck process constraining the entire system is idle due to flawed work assignment. I want to emphasize that this is usually not the fault of the foreman or supervisor that assigned the worker to another task. Rather, shop floor management is not involved in the big picture and didn't know the necessity of keeping this process running. Hence:

To improve the bottleneck, first make sure the bottleneck is not idle!

This is probably your fastest, easiest, and cheapest approach to improve your bottleneck. You have your parts, your machine, and your operators; you just have to bring them together. **Just make sure the bottleneck is actually running!** This basic idea can also be enhanced with a few more details.

### 44.4.2 Covering Scheduled Breaks

Workers take breaks, both scheduled and unscheduled. Besides the scheduled breaks for breakfast, lunch, etc., they also have unscheduled breaks, for example, when nature calls. Usually the machine falls idle during such breaks. However, it is also possible to schedule separate breaks to keep the machine running. Operator A takes his break a little earlier while Operator B still works. When Operator A comes back, he takes over the task from Operator B, who goes for his break. In effect, the machine is running continuously without a break.

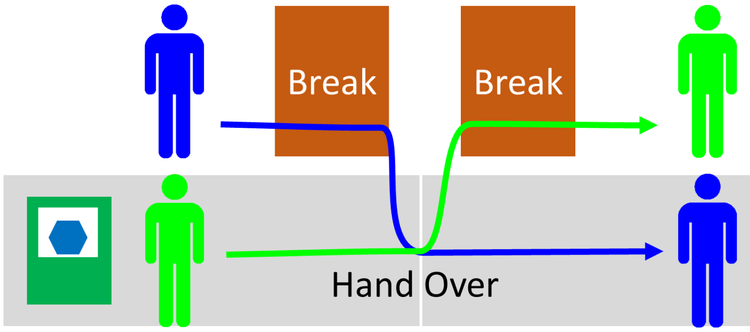


*Figure 269: Break Handover Procedure (Image Roser)*

Naturally, this comes at the expense of another task having twice the break due to first Operator A and the Operator B being on break. Also, depending on your location and regulations, workers' representatives may or may not agree with this approach.

### 44.4.3 Covering Unscheduled Breaks

It is a bit more difficult to do this with unscheduled breaks. An operator's need to go to the bathroom cannot be planned days in advance. In this case, it may help to have another worker on standby (sometimes called a jumper). This operator is able to cover the absence of the first operator on short notice.

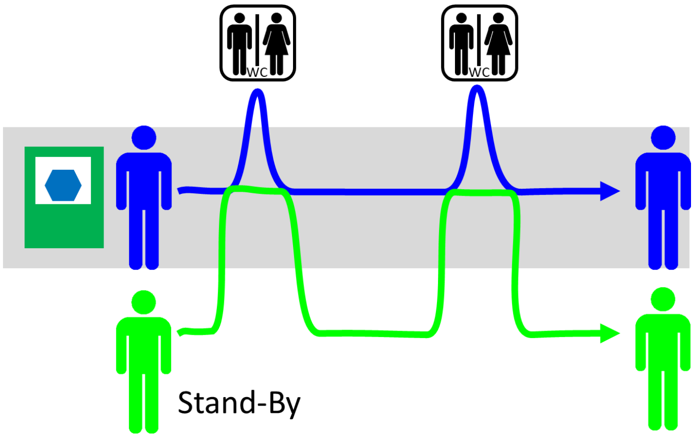


*Figure 270: Short Break Stand By (Image Roser)*

Naturally, it would be inefficient to have one operator on standby waiting around until he can prove himself while the colleague relieves himself. Rather, this jumper is given a number of additional tasks that can be interrupted without ill effect for the overall system. At Toyota, the team leader is usually the jumper for such short breaks, but helps also with other difficulties and problems that may happen.

Important: Before you give your shop floor supervisor the task of toilet break coverage on top of all his additional tasks, please keep in mind: A Toyota team leader is responsible for four to five operators. In many Western companies, on the other hand, a shop floor supervisor manages twenty to twenty-five people. The latter is clearly not able to cover for bathroom breaks too, in addition to his usually enormous volume of other responsibilities.

### 44.4.4 Overtime and Additional Shifts

There are also some other methods to increase the utilization of the bottleneck process. In theory, your machine can run twenty-four hours a day seven days per week. In practice this is often less. If you are in a stretch, you can also consider doing overtime or adding additional shifts. All of this will increase the utilization of the machine.

For highly automated processes, it is even possible to fill the machine with parts at the end of the shift. After the workers leave, the machine will continue to run until either all parts are processed or the machine encounters an error and stops by itself.

Overall, increasing utilization is often the fastest and cheapest way to improve your bottleneck. In the next posts I will talk more about how to plan your bottlenecks for maximum effect. A third post looks at Bottleneck Decoupling and Capacity Improvement.

# 45 Bottleneck Management Part 2 – Improve Bottleneck Planning

*Christoph Roser, November 09, 2014, Original at https://www.allaboutlean.com/bottleneck-management-planning/*

*Figure 271: Eight empty green wine bottles (Image Roser)*

Bottleneck detection and management are important when managing or increasing your production capacity. In the first post of this series, I talked about fundamentals and improving utilization. This second post looks at the **impact of planning on the overall production capacity**. A third post looks at Bottleneck Decoupling and Capacity Improvement.

Just as a quick recap, below is the overall structure for bottleneck management. In this post we will discuss the impact of planning.

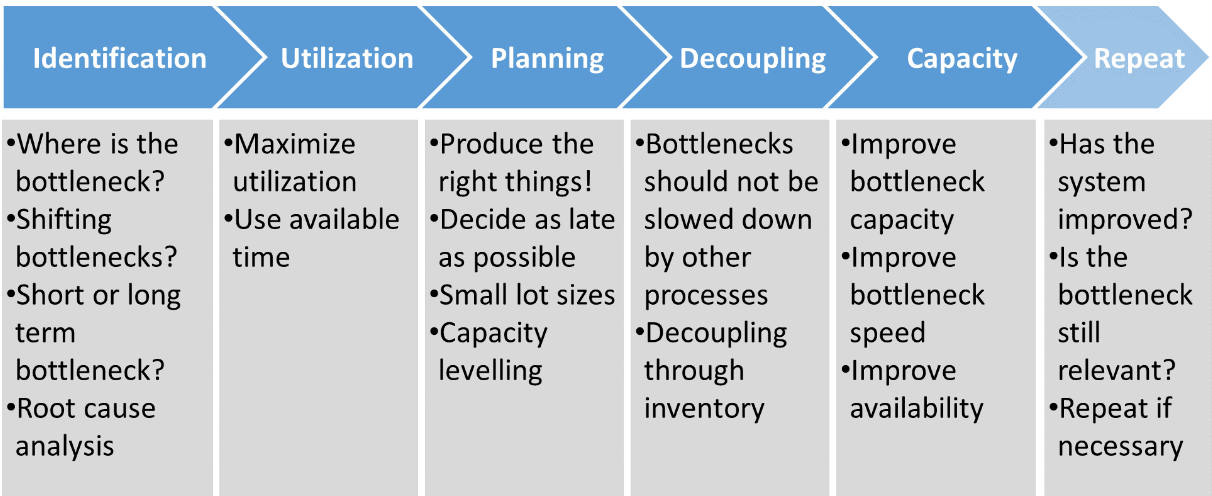


*Figure 272: Bottleneck management (Image Roser)*

## 45.1 Planning and Material Flow

There are different ways in which the production plan of your system can influence the overall capacity. In the short term, you have to produce the right products. In the long term, you can level your capacity to cope with seasonal bottlenecks.

### 45.1.1 Use a Pull System

One key to maximizing the use of your bottleneck is to produce the right products. However, in most industries – and hence probably also in yours – the "right" product can change very quickly. Some customers may cancel orders. Other key customers may have a rush order. And, of course, most importantly, your boss can call anytime and tell you what is really important right now. Does this sound familiar?

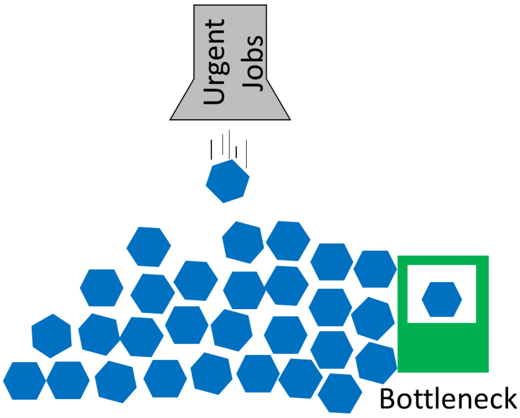

*Figure 273: Urgent Tasks in a Push system (Image Roser)*

In sum, what would have been the most urgent product yesterday may be totally different from what is the most urgent product today. Your production system needs to be agile enough to take these changes into account. **Hence it is important to decide as late as possible what to use your bottleneck capacity for!**

By its nature, jobs will accumulate in front of the bottleneck as the slowest process. If you have a push system, your tasks will accumulate in front of the bottleneck. Any prioritization you may have had when the job was added to the system is now long gone.

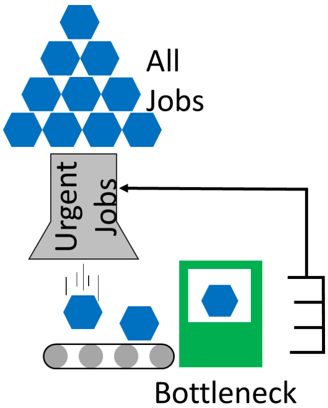

*Figure 274: Prioritization in a Kanban System (Image Roser)*

Hence, in a push system, you are more likely to produce the wrong products with a lower priority. Use a pull system to control your bottlenecks! Of course, in fact almost any manufacturing system will benefit from a pull system (using kanban or CONWIP or similar). However, it has special benefits for the bottleneck by deciding the priority only when the system actually has the capacity to do the work.

If your pull system produces only products made to stock through kanbans, it is automatically self-prioritizing. If you produce some custom-made products to order, then obviously you cannot keep them in stock. In this case the kanban is only a signal that a new order can be started. When such a signal comes, you should pick the most urgent job from the complete list of available jobs.

### 45.1.2 Use the Right Pull System

If you have a kanban system, then you are already past the first hurdle with bottlenecks. However, if your bottleneck does not shift very much, you can fine-tune the system. If there are multiple processes that make up your system, then there are different ways you can set up kanban loops. (See also my Ten Rules When to Use a FIFO, When a Supermarket).

For example, in a system with three processes, you have four options how you could loop the kanban as shown below. You could make (1) one big loop, (4) three small loops, (2+3) or a medium and a small loop.

However, as for the bottleneck, you need to decide as late as possible what to produce. When the signal below comes from the customer, you need to get the signal to the bottleneck in the most direct way possible, and then get the product to the customer as fast as possible. Hence, out of the four options below, one is superior to the other ones. Granted, it is not a huge difference, but what do you think? Which of the four options below is best? See the end of the post for the answer with explanation.

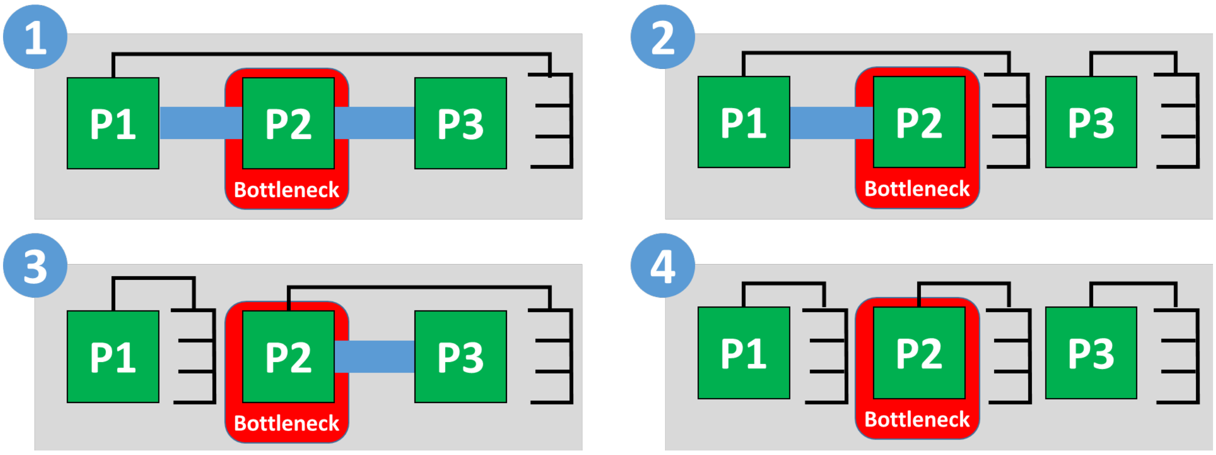

*Figure 275: Four Kanban Options (Image Roser)*

### 45.1.3 Lot Sizes

Similarly, lot sizes can also influence the use of your bottleneck. In general, the smaller the lot size, the closer you can follow the customer demand. Naturally, if your changeover time is not zero, you may not want to change over too often. However, you also should not change over too rarely, as you may produce the wrong goods. (See also SMED for improving change over time.)

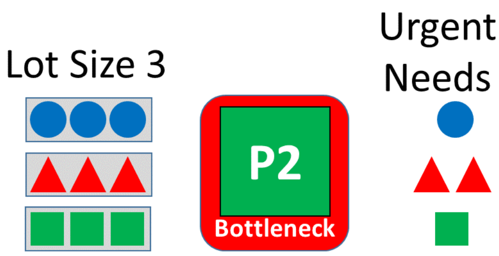

*Figure 276: Lot Size 3 and Bottleneck (Image Roser)*

Assume the example on the left with a lot size of three. If you want to satisfy your urgent customer needs, no matter what you produce, you will produce some items that are not needed. If you produce red triangles, you will have one excess triangle with a lot size of three.

Similarly, if you produce blue circles or green squares, you will always have two circles or squares that the customer does not need. Yet with lot size three, you have to waste your precious bottleneck capacity for goods that nobody needs at that time.

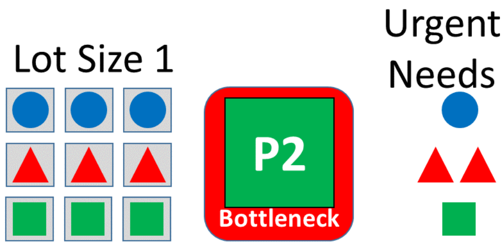

*Figure 277: Lot Size 1 and Bottleneck (Image Roser)*

Imagine the same example with a smaller lot size of one. Having exactly the same demand, now you can produce exactly what the customer needs and not a single piece more. You produce two triangles, one circle, and one square. Not one bit of your bottleneck capacity is wasted for a good that is not (yet) needed.

Overall, a smaller lot size often allows you to produce closer to the actual customer demand, wasting less bottleneck capacity on producing goods nobody needs, just to reach your lot size.

### 45.1.4 Seasonality

Many industries have seasonal customer demand. During some times of the year, the demand is high, but it is low at other times. The image below could be, for example, a winter sports manufacturer. Demand peaks in fall and early winter when people buy their gear for the upcoming winter season. Demand falls in spring and summer, when few people other than Australians buy their skis. (Australians love fun and sport, but there are just not enough of them to make up for the lack of demand in North America and Europe.)

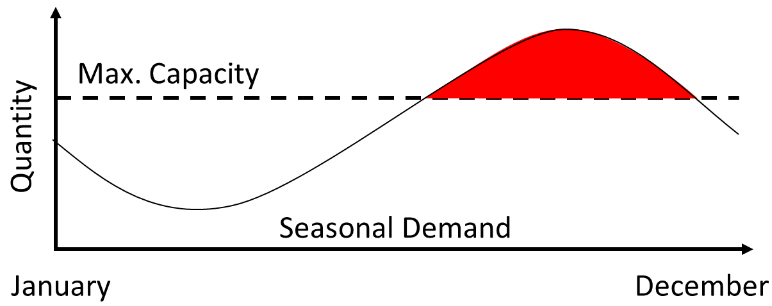

*Figure 278: Generic Seasonal Demand Curve (Image Roser)*

If you are a winter sports manufacturer, you could invest in all the machines to have enough capacity for peak demand. However, this would be expensive. More commonly, there is not enough capacity to satisfy peak demand. Instead, the drop in demand is used to make goods that cannot be made during peak demand.

Below is another exercise with four options for how this seasonal demand can be handled using the available capacity during low season. In these examples, the lack of capacity (red) is made up before and/or after with available capacity (green). Of these examples, two is (usually) a very bad idea, one is troublesome, and one is my preferred approach. If you know which one is which and why, click here to jump to the answers at the end of this post.

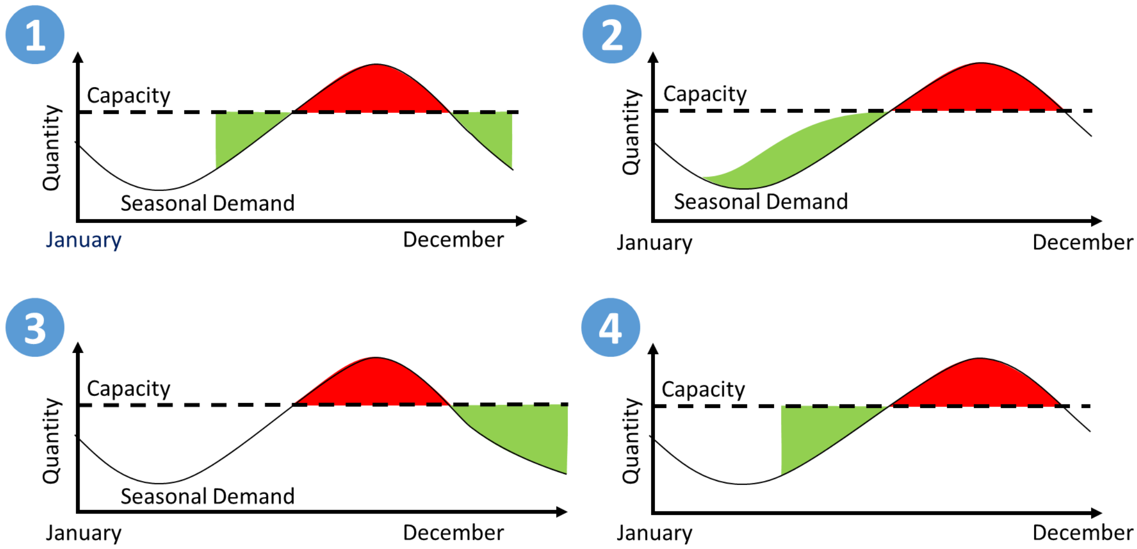


*Figure 279: Four examples on how to cope with seasonal demand (Image Roser)*

On a side note, make sure you use the capacity outside of the peak season to produce your high runners, products that you're sure will sell during season. If you produce exotics, you will have a harder time determining demand and a much higher risk of ether lacking or having leftover products during peak season.

In any case, planning and organizing your material flow will help you greatly in managing your bottleneck. Additionally, these methods above are usually not expensive (compared to simply buying a new machine) and can be implemented faster. Hence this is my second preferred approach to handling bottlenecks besides simply increasing utilization as described in the last post. In the next post I will talk about the more expensive and slower options of decoupling and adding capacity before closing this series of posts on bottleneck management.

Below are the answers to the exercises from above in case you haven't yet read them.

## 45.2 Answer to the Exercises Above

### 45.2.1 Answer: Which Kanban Loop is Best

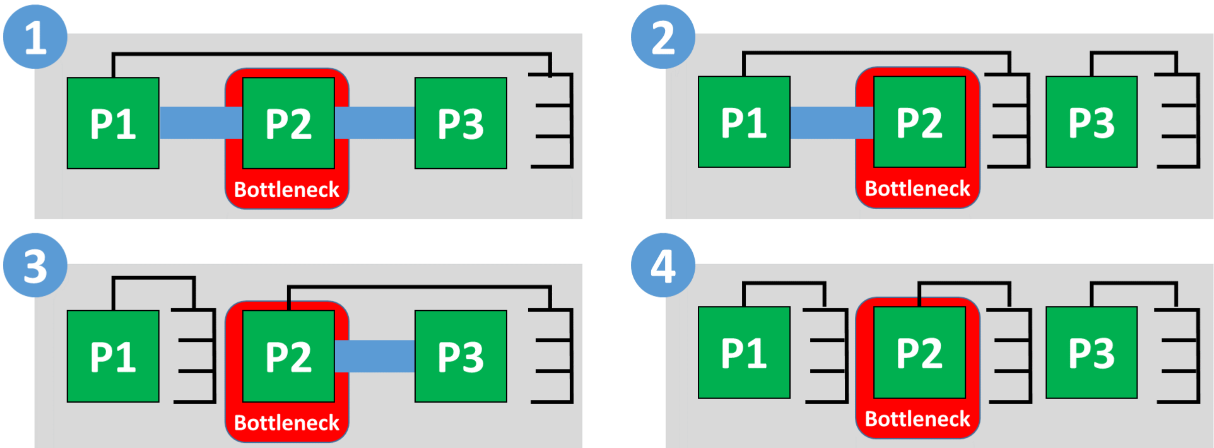


*Figure 280: Four Kanban Options (Image Roser)*

In the example above, **option (3) is the best one.** The kanban goes straight and without delay to the bottleneck. After the part passes the bottleneck, the part goes straight to the last supermarket and from there to the customer.

Option (4) is worse, since the signal from the customer has to pass the loop around P3 before reaching P2. Similarly, the part can potentially wait in the supermarket after P2.

Option (1) also takes more time. While the part goes from P2 to P3 and to the customer with minimal delay, the kanban loop includes P1 and hence takes longer.

Finally, option (2) is the worst, since the kanban first has to go through the entire loop of P3, and then through the big loop with P1 before reaching P2. After production, the part can potentially wait in the supermarket after P2.

### 45.2.2 Answer: How to Handle Seasonal Demand

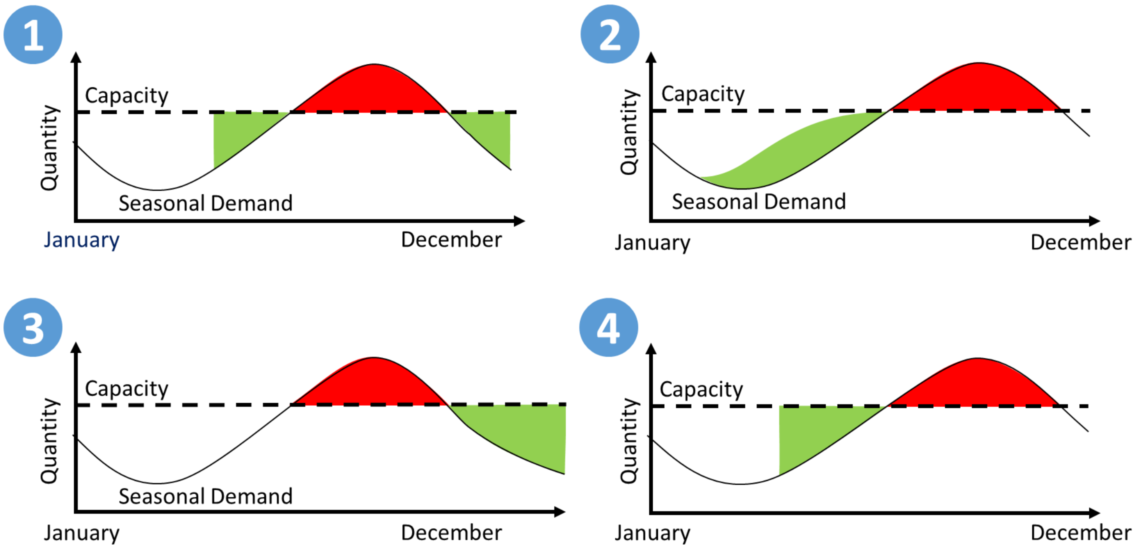


*Figure 281 : Four examples on how to cope with seasonal demand (Image Roser)*

Out of these four examples, option (2) is the best. But let's start at the other end.

Option (3) is probably the worst, since the season is already way over when you have your goods. Not only did you miss sales, but you also have to rent warehouse space for the goods till next season. (Please note that there are, as always, exceptions, as, for example, some high-tech industry monopolists can afford to have the customer wait on their goods, in which case (3) is viable again.)

Option (1) is little better. You have some goods made to stock before the season, which you can sell off during the season. However, some more goods after the season will have the same problem as option (3), being too late for this season and too early for the next.

Option (4) looks good at first glance. You minimize your inventory with option 4. However, in many cases you will break your supply chain. First, your entire organization has to double its output within a few days. While you have the machine capacity, you may have to stretch a bit for the manpower, but this is doable. What will break, however, are your suppliers.

It is not only you that will have to make this jump, but your entire supply chain. In all likelihood someone will either mess up or consider you not important enough to care. (In case you ask your supplier if you are important, *of course you are the most important customer for them*, just like all other customers. Just consider how you talk about some of your customers at the water cooler.)

Hence you will probably get most of the material you need, but not all. Unfortunately, if only one part is missing, you cannot produce. You will miss your production window because one part is missing, and at the same time you have to store all the other parts that arrived on time. That sucks!

Naturally, there are some exceptions to this too. If you are a small company and/or using only generic parts, your suppliers won't even notice you doubling your output. Hence this may just work. Or if you have complete control over your supply chain, say as a brick maker with its own clay pit. But anybody else should think twice before testing the breaking point of their supply chain.

This brings me to my preferred option (2) above. It is similar to option (4), but with a gradual increase. Your supply chain has a chance to catch up. Additionally, you may be able to produce a bit more if your demand forecast improves. Overall, it will be much smoother sailing for most companies.

# 46 Bottleneck Management Part 3 – Bottleneck Decoupling and Capacity Improvement

*Christoph Roser, November 16, 2014, Original at [https://www.allaboutlean.com/bottleneck-management-decoupling/](https://www.allaboutlean.com/bottleneck-management-decoupling/)*

*Figure 282: Nine empty green wine bottles (Image Roser)*

Bottleneck detection and management are important in managing or increasing your production capacity. In the first post of this series I talked about fundamentals and improving utilization. The second post looked at the impact of planning on the overall production capacity. This final post in the series will look at the **effect of decoupling and the actual process capacity improvement**. Just as a quick recap, below is the overall structure for bottleneck management. In this post we will discuss the last two elements, decoupling and capacity, before closing this post series.

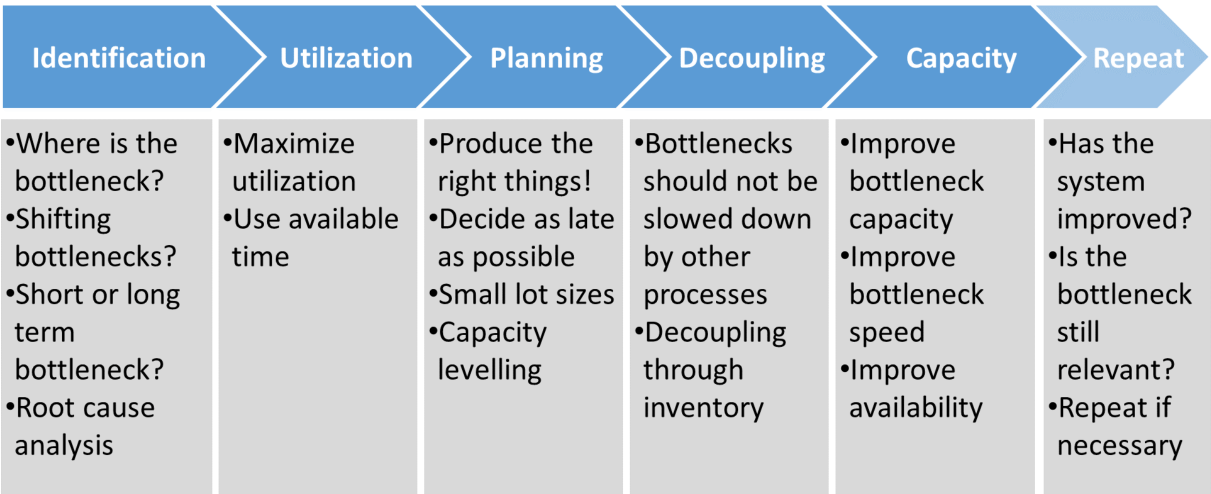


*Figure 283: Bottleneck management (Image Roser)*

## 46.1 Decoupling Your Bottleneck

By their nature, bottlenecks shift. The less bottlenecks shift, the less likely is it that the largest bottleneck is temporary slowed down by other secondary bottlenecks. The larger the buffers, the less likely it is that a bottleneck will shift. Hence you can improve your system capacity by adding buffers before and after the largest bottleneck process.

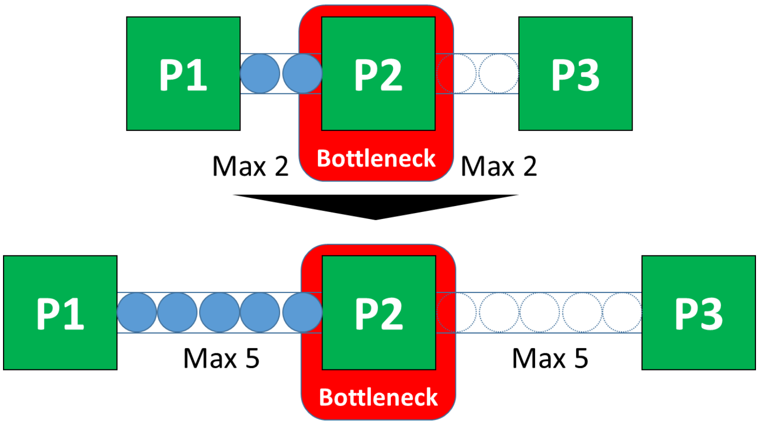


*Figure 284: Bottleneck Decoupling (Image Roser)*

Of course, this is also a trade-off. Through decoupling, you slightly increase your inventory and your system response time becomes more sluggish. But here is a small trick: By their nature, buffers in front of the bottleneck are usually full. Hence you get all the negative effects that come with increased inventory, like tied-up materials and slower throughput time.

Buffers after the bottleneck, on the other hand, are usually empty. They are filling up when an actual decoupling toward downstream processes is needed. Hence you get all the benefits of decoupling, but few of the disadvantages of inventory (yes, you still need to have the space ready to store the parts). Therefore, buffer after the bottleneck may be preferable to buffer before the bottleneck.

However, in all likelihood, you should not drop your buffer before the bottleneck to zero, otherwise your bottleneck will lose efficiency due to occasional not-decoupled lack of parts coming from upstream.

Also, just because you are decoupling the bottleneck does not mean that there are no other buffers needed in the system. If you buffer only your bottleneck and nothing else, chances are that the interactions between the other processes overall starve and block the otherwise biggest bottleneck frequently. Hence it is good practice to have at least some buffer between stations.

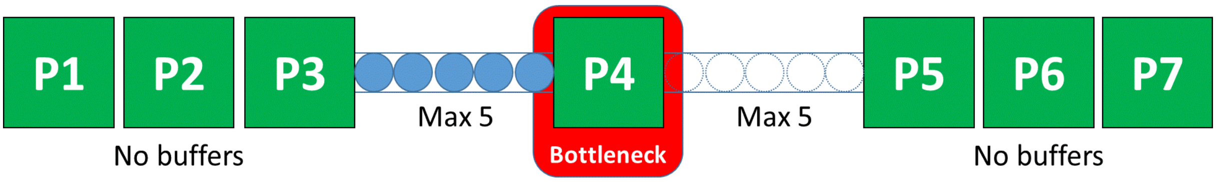


*Figure 285: Not a good system … (Image Roser)*

This is, of course, unless the stations are locked in speed like a conveyor belt. For example, automotive assemblies often have no inventory between stations, but only between larger line segments. As for determining the buffer size, this is tricky business. The common industry approach is to take the expert estimate of someone knowledgeable on the shop floor (i.e., a rough guess of someone who knows at least a little about the system). There are mathematical methods available too (see Determining the Size of Your FiFo Lane – The FiFo Formula), but I still recommend the expert estimate approach. However, if you insist on a calculation, you can use my FiFo calculator.

## 46.2 Capacity Improvements

### 46.2.1 Update or Install New Machines

Finally, the last approach to improve your system performance is to improve the capacity of the bottleneck. Most often this involves updating existing or installing new machines (i.e., lots of time and money). For some strange reason, this slow and expensive approach is usually the first one undertaken by most companies. Rather than improving utilization quickly for free, or adjusting the planning with little effort, or spending some time and effort for decoupling, many companies go out and order an expensive new machine.

Not only is this slow and expensive, but also risky. In case you didn't detect the correct bottleneck, you installed expensive additional capacity without any benefit for your system. Hence my strong advice: Before calling engineering, check if there are cheaper and faster options to ease your system capacity constraints.

### 46.2.2 Improve Changeovers

Even if you want to increase the capacity of the process, there are different approaches that also may work. For example, you can reduce changeover time. Through a SMED workshop, you may be able to change product types quicker. Please note that you probably should not change over less frequently, but rather more frequently due to the lot size issues shown in the last post on the impact of planning on the overall production capacity.

### 46.2.3 Improve Maintenance

Maintenance can also be investigated. There is also a trade-off between the time needed for too much maintenance and the risk of a machine failure. In Total Preventive Maintenance (TPM), it often feels like more maintenance is always better. I disagree. It depends. For example, too much maintenance (besides costing time and money) also has a possibility to put a machine out of whack, and you may produce more scrap until all settings have been optimized again after maintenance. In any case, if it is the bottleneck you can look at its maintenance too, in the search for improvement potential.

### 46.2.4 Reduce Scrap and Rework In and After the Bottleneck

And, if we are talking about scrap anyway: Any part that passes through the bottleneck but is scrapped afterward is lost capacity at the bottleneck machine. While it is always of interest to reduce scrap and rework, it is of particular importance at and after the bottleneck process. If a part gets thrown out after the bottleneck, you throw out not only the part, but also the urgently needed capacity at the bottleneck.

### 46.2.5 Don't Put Your Worst Worker at the Bottleneck

Finally, don't put your worst worker at the bottleneck process. Your employees have different skills, and some are probably better than others. The bottleneck process should be operated by a worker who can keep the machine running reasonably well, so that the use of the process does not suffer due to lack of experience of ability of the worker. However, please note that because a worker is not the best one, it does not automatically mean that he is a bad worker.

## 46.3 Is It Now Faster?

After detecting the bottleneck, selecting an improvement approach, and implementing the improvement, you expect your system speed to improve too. However, too often people are satisfied with the expectation of the improvement. This does not mean anything. Of course the system was changed, but is it now better than before? Don't just believe or hope it is. Measure!

After an improvement in the (presumed) bottleneck process, check if your improvement actually did improve the system. (In fact, you should check after every and any improvement to determine if it really worked along the PDCA principles). The flowchart below shows an idealized approach after checking the new system speed and comparing it to the one before the changes.

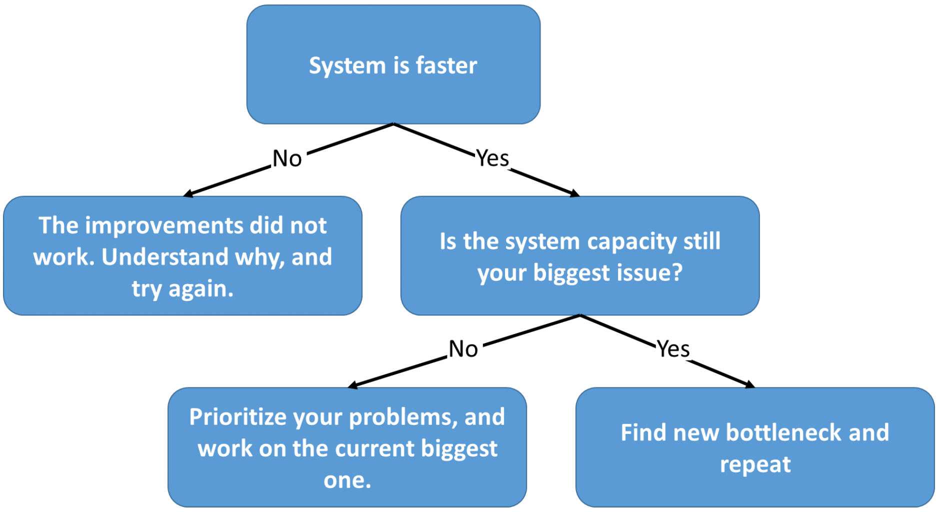


*Figure 286: Flowchart when to repeat bottleneck improvement (Image Roser)*

If your system did not improve, then something went wrong. Check what happened, why your changes did not improve the system, and what you would need to do to really improve the system speed. Then try again.

If your system is indeed faster, then congratulations. You've made a difference. Now see if the system not only increased, but if the reason why you did the bottleneck management in the first place is resolved. If your system capacity is still your most pressing issue, then even though you improved the system, it was not enough. Find the bottleneck again (due to your improvement, the bottleneck may have changed) and repeat the process.

If, however, your system is now fast enough that the system capacity is no longer your biggest issue, then you should pick the next urgent issue from your (probably) way-too-long list of problems.

Overall, among these different approaches to increase your system speed, there should be one that works for you. Please keep in mind that increasing utilization is the fastest and cheapest, and if possible you should start with that. Planning is usually next, but still pretty fast and often not expensive. Decoupling is also a possibility that can be explored. Adding machine capacity is usually the slowest and most expensive, and should be used only of the other approaches are unlikely to satisfy your needs.

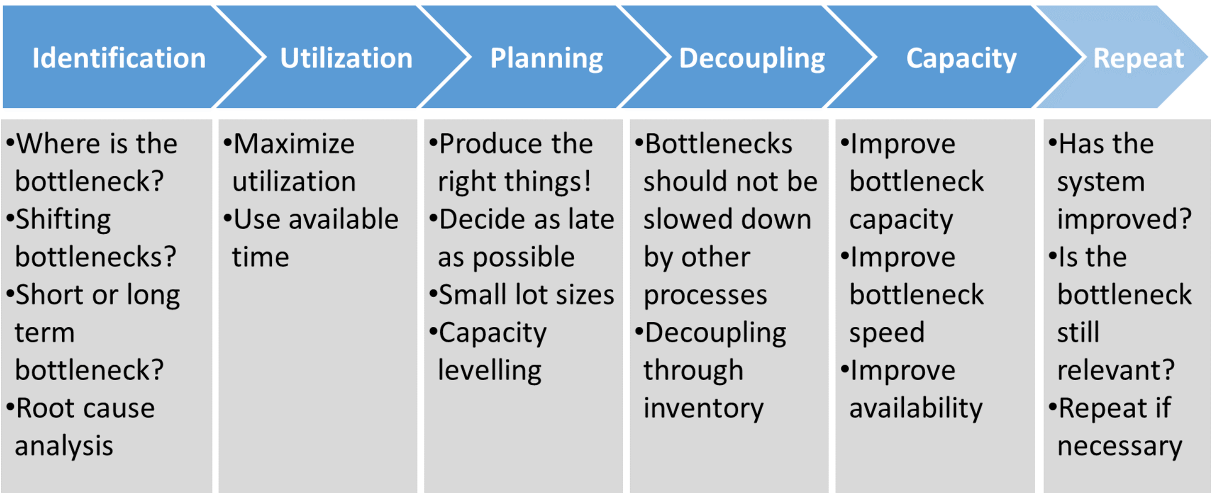


*Figure 287: Bottleneck management (Image Roser)*

This concludes this three-post series on bottlenecks. I hope this was interesting to you.

Now go out and organize your industry!

# 47 A Critical Look at Goldratt's Drum-Buffer-Rope Method

*Christoph Roser, November 23, 2014, Original at https://www.allaboutlean.com/drum-buffer-rope/*

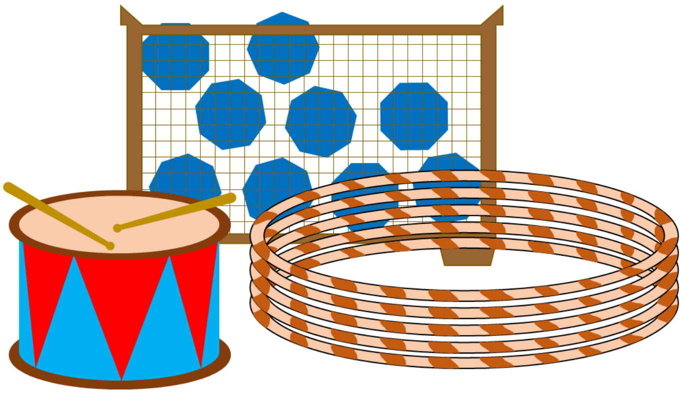

*Figure 288: Drum Buffer Rope (Image Roser)*

Eliyahu Goldratt developed different methods on how to manage production systems. These methods are nowadays known as the Theory of Constraints, or TOC for short. One key method described is called Drum-Buffer-Rope, or DBM for short. Similar to Kanban or CONWIP, it aims to constrain the work in progress (WIP) in the system. There is much discussion on which method is better than the other, although the result often depends heavily on with which method the respective author earns its living. In this post I will present how Drum-Buffer-Rope works, and discuss its advantages and shortcomings.

## 47.1 Details about Drum Buffer Rope

### 47.1.1 Where the method came from

Drum-Buffer-Rope originated with the famous book by Goldratt "The Goal", although it got its name only later in "The Race". In "The Goal" Goldratt combines management science and romance novel. As a romance novel, the story is mediocre. As a science book, it is a nice collection of general wisdoms and good suggestions. In combination it was a bestseller, since it is one of the few management science books that almost everybody can understand. (*However, in my opinion a much better production-management – novel – cross-over is* The Gold Mine: A Novel of Lean Turnaround *by Freddy and Michael Balle*)

### 47.1.2 The Boy Scout Example in The Goal

*Figure 289: Herbie and his friends teaching production control. (Image unknown author in public domain)*

A very illustrative example was how the protagonist of the book manages a boy scout outing, especially how to keep the group together while different boys walked at different speeds. The solution was to put the slowest boy scout Herbie at the front, and prohibiting all others from overtaking him. Additionally, he lightens Herbie's backpack so that he can walk faster.

### 47.1.3 How Drum-Buffer-Rope Works

Taking these boy scouts as an analogy for a factory created the Drum-Buffer-Rope method. The drum is the bottleneck, defining the overall speed of the system. The system cannot go faster than the drum.Pretty much all sources on Drum-Buffer-Rope agree on that.

As for the buffer and the rope … well … that is where it gets a bit fuzzy.

### 47.1.4 Drum-Buffer-Rope for People

Many sources take the example of the boy scout literally. The drum is the slowest person. The rope extends to the first person in the line, which cannot walk faster than the drum. The buffer is the free space between the drum/bottleneck and the next person in front of him, allowing him to walk even if the next person is temporarily slowing down (for example to tie his shoe laces)

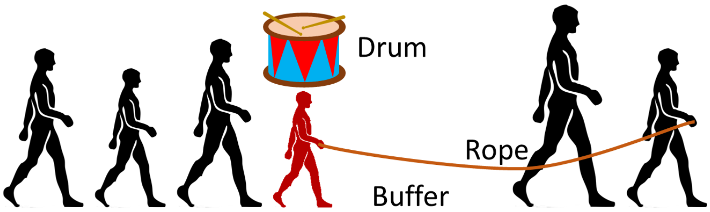

*Figure 290: Drum Buffer Rope for People (Image Roser)*

This may work for people, but it needs a fair bit of imagination to extend this version of Drum-Buffer-Rope to manufacturing systems. You have to remember that the people in this example are the processes, not the parts. The parts are actually the ground covered. In the image above the people walk from left to right, but the ground covered (the parts processes) would move from right to left. Hence, it looks more like the image below.

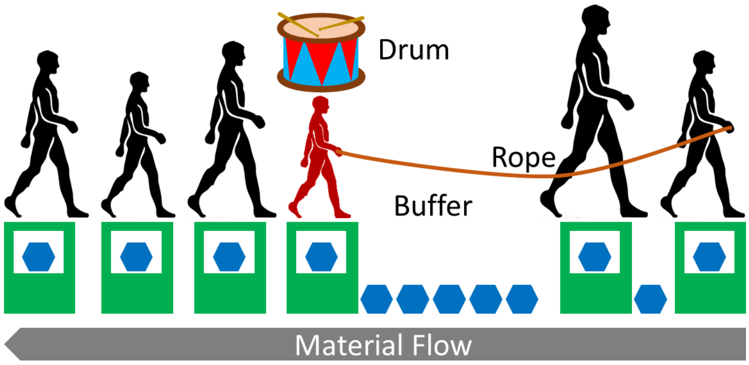

*Figure 291: Illustration of Drum Buffer Rope for People (Image Roser)*

Therefore, let's take this example and put it in a proper manufacturing setting.

### 47.1.5 Drum Buffer Rope for Manufacturing Systems

In manufacturing, the drum is still the bottleneck. The buffer is the material upstream of the bottleneck and has to make sure that the drum is never starved. The rope is a signal or information from the buffer to the beginning of the line. If the drum processes parts, the buffer moves forward. The rope is a signal when material is taken out, and gives an information to replenish another part at the beginning of the line as shown in the Illustration below.

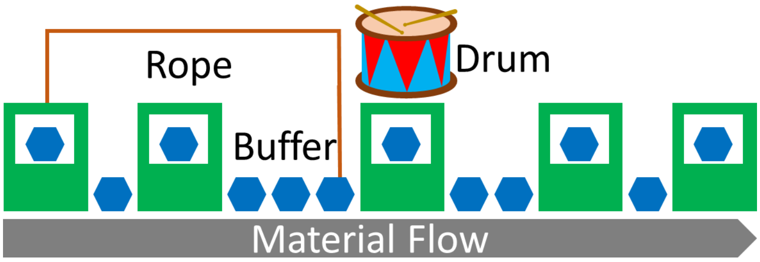

*Figure 292: Illustration of Drum Buffer Rope for Material (Image Roser)*

Signal when material is taken out … information to replenish … I have heard something very similar before … Kanban! Yes, Drum-Buffer-Rope is similar to Kanban with the supermarket before the bottleneck. Whenever a part is taken out of the buffer/supermarket, a signal is sent via the rope/kanban to the beginning of the line/kanban loop to replenish material. A Drum-Buffer-Rope system as shown above is very similar to a kanban loop as shown below.

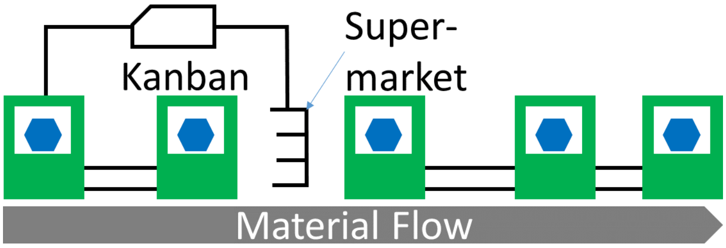

*Figure 293: DBR and Kanban (Image Roser)*

However, there are some differences which I would like to go into some detail below. But before that first for completeness sake another variant of Drum-Buffer-Rope, the Simplified Drum-Buffer-Rope:

### 47.1.6 Simplified Drum Buffer Rope (S-DBR)

Simplified Drum-Buffer-Rope is very similar to Drum-Buffer-Rope. The key to simplifying the approach is the assumption that the market or the customer is the largest bottleneck. I.e. in average your system always has enough capacity to satisfy demand. The rope then spans the entire length of the system.

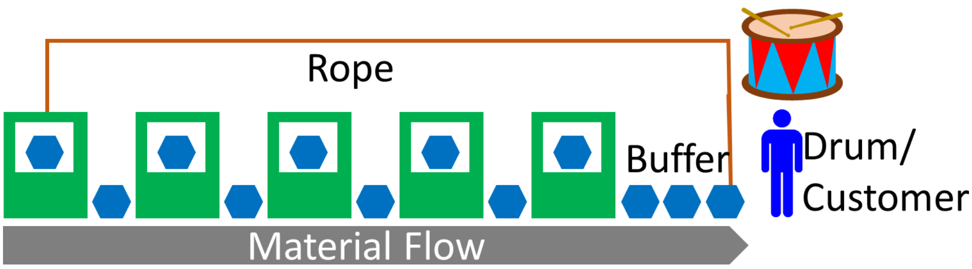

*Figure 294: Simplified Drum Buffer Rope (Image Roser)*

## 47.2 Good Things about Drum Buffer Rope

Drum-Buffer-Rope has some underlying good ideas.

### 47.2.1 Prevents Overloading of the System

Most importantly, it does try to constrain the work-in-progress and aims to prevent an overloading of the system. As such it can be considered sort of a pull system like Kanban or CONWIP, and hence Drum-Buffer-Rope is superior to the traditional push systems.

Furthermore, the WIP in Drum-Buffer-Rope fluctuates less than with Kanban. A Kanban system defines the number of Kanban, which consists of the WIP, the supermarket stock, and the kanban without parts. Drum-Buffer-Rope (like CONWIP) is more precise as it limits only the physical parts (WIP and Stock), but dose not include the variation through fluctuation of kanban without parts.

### 47.2.2 Measuring Workload in the System as Time

Another good thing about Drum-Buffer-Rope is that it measures the work in the system not in pieces, but in time. Depending on how many hours worth of work are in the system the rope may release another part in the system.

In comparison, a Kanban system usually only counts pieces. In my view, counting pieces is fine if the pieces are similar, as in mass production. Measuring the workload in time may be beneficial if the items to produce have vastly different work content, as for example in a job shop. However, measuring time is also more difficult, as you need to determine the time for each product rather than merely counting them. In any case, a Kanban system can be adapted to measure time if needed, resulting in the same complexity as a Drum-Buffer-Rope system.

## 47.3 Flaws and shortcomings of Drum Buffer Rope

In my view, however, Drum-Buffer-Rope does have quite some shortcomings. For my daily work I therefore much prefer a Kanban system.

### 47.3.1 No Consideration for Shifting Bottlenecks

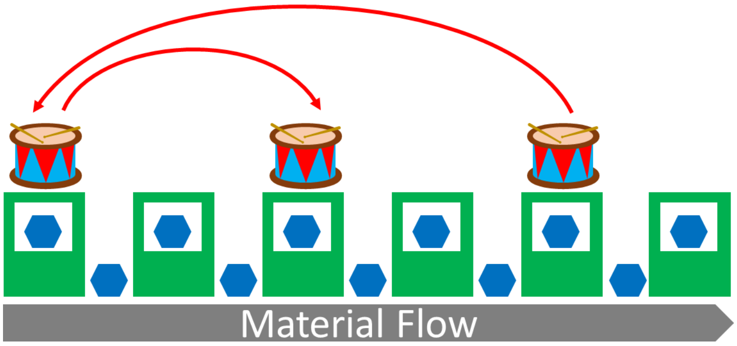


*Figure 295: Moving around… (Image Roser)*

One of the major underlying assumptions of Drum-Buffer-Rope is the assumption of a fixed bottleneck. I.e. the bottleneck does not move. If the bottleneck shifts, then the drum is in a different place over time, which makes Drum-Buffer-Rope more difficult.

Goldratt claimed that in his experience this was not a problem in practice. However, Goldratt claimed many things if it benefited him. For example he claimed that his software MARS was able to find the optimal solution, until a judge ordered him to stop (He then rolled out hsi next software package with the most unfortunate name DISASTER).

In my experience, shifting bottlenecks are not the exception but the norm in most manufacturing systems, and simply assuming a fixed bottleneck will lead to problems. This problem may be confounded that his Theory of Constraints does not offer any good approach to find the bottleneck (*see also my methods* Bottleneck Walk *and* Active Period). Of course, increasing buffer sizes will lead to less shifting, but increasing buffers has a lot of disadvantages by itself.

### 47.3.2 Drum-Buffer-Rope considers only Starving of the Bottleneck, not Blocking

Drum-Buffer-Rope explicitly places a buffer in front of the drum to prevent starving. I.e. the buffer prevents the drum from running out of material. However, it completely omits the possibility of the drum being blocked by a downstream process, which may equally lead to bottleneck downtime. While the buffer after the bottleneck is usually near empty, it is necessary to provide the space in case a downstream process acts up and blocks the bottleneck.

To be fair, some sources of Drum-Buffer-Rope have recognized this problem and introduced a space buffer after the drum, although many other sources still omit this.

### 47.3.3 Only the Upstream Inventory matters in Drum-Buffer-Rope

Drum-Buffer-Rope controls not only the buffer in front of the drum, but the entire inventory upstream of the bottleneck. However, little or no consideration is given for the downstream inventory, not only the buffer immediately afterwards, but the entire value chain to the customer. Hence, the inventory is not limited and under the right circumstances can still lead to overproduction. Combined with shifting bottlenecks it is almost certain that the downstream inventory will at least temporarily spiral out of control.

### 47.3.4 Which Part to Produce next?

A Kanban pull system not only constrains the total inventory, but also helps deciding which part to produce next. In the simples case it is merely the next Kanban waiting in line that is produced. Hence at least for high-runners it is clear what to produce next. Drum-Buffer-Rope does not really offer much guidance. If there are multiple product variants in the system, Drum-Buffer-Rope leaves more decisions to humans with all its flaws. For example the bullwhip effect may lead to overproduction of some parts while others are short in supply.

### 47.3.5 Limited Flexibility in Line Management With only One Loop

*Figure 296: Be flexible! (Image Kennguru under the CC-BY 3.0 license)*

Drum-Buffer-Rope has only one major loop between the bottleneck and the first process. However, there are many good reasons why you may want to use more than one loop, as for example differences in cycle time, merging or splitting material flows, or system boundaries. For an entire list see my [Ten Rules When to Use a FIFO, When a Supermarket](#).

Hence, with Kanban the system is better controlled and maintained, whereas with Drum-Buffer-Rope some parts of the system may escape notice, while the other part is thrown together simply based on the (presumed) location of the bottleneck.

## 47.4 Popularity

Just out of curiosity, i also checked how popular Drum-Buffer-Rope was over time. Below are the percentages of books that mention either Drum-Buffer-Rope or Eliyahu Goldratt over time. It seems both terms started around 1980-1985, peaked around 2000-2005, and are since in decline. In comparison, the term Kanban is about 80 times as popular as Drum-Buffer-Rope, and with no significant decline.

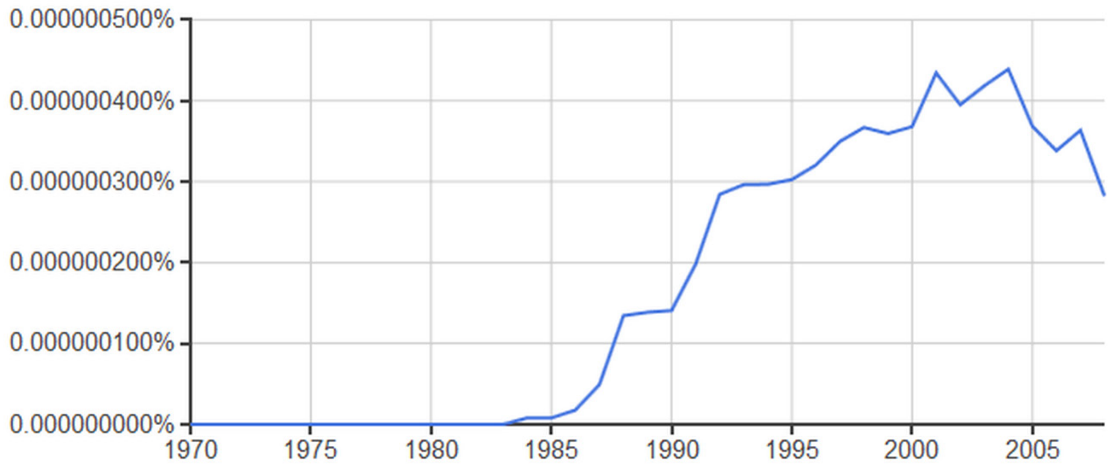


*Figure 297: Occurrence of drum-buffer-rope in literature over time (Image Roser)*

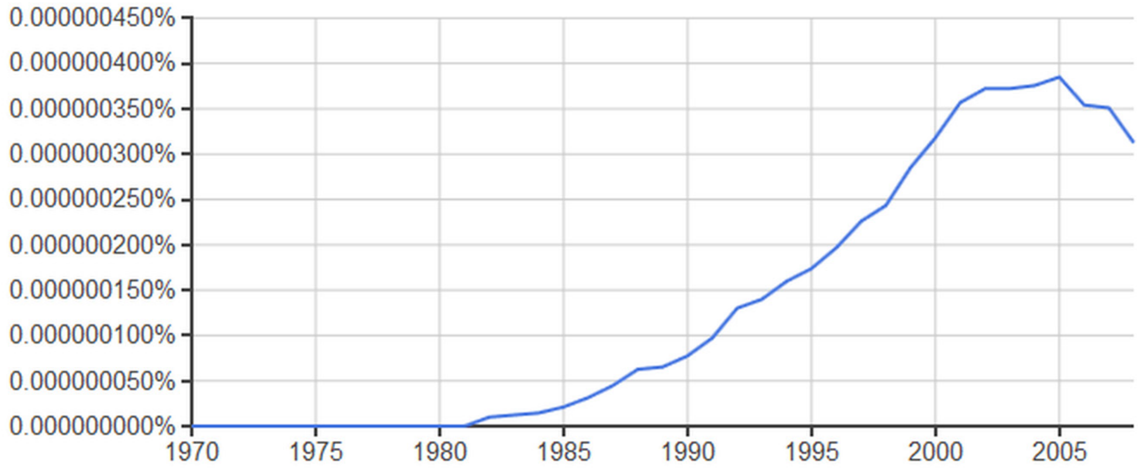


*Figure 298: Occurrence of Eliyahu Goldratt in literature over time (Image Roser)*

## 47.5 Summary

Overall, i find a Kanban system (or alternatively a CONWIP system) much preferable to a Drum-Buffer-Rope approach. Both approaches have its merit, but I find Kanban much easier to use and less troublesome than Drum-Buffer-Rope. Another problem I faced when researching Drum-Buffer-Rope was that it was sometimes explained differently

The academic community seems to be split here in two camps. One side that reveres Goldratt and his methods, and the other side that tries to ignore him unless they criticize his ways. He did have a knack of making things easy to understand, but he was less skilled in giving credits to previous sources, while his methods often fall far short of his claims.

Overall, if you need to get on top of a manufacturing system that is out of control, a Kanban or CONWIP based pull system will probably give you faster and better results than Drum-Buffer-Rope. Now **go out and Organize your Industry!**

# 48 Why Leveling (Heijunka) is important

*Christoph Roser, November 30, 2014, Original at [https://www.allaboutlean.com/why-leveling/](https://www.allaboutlean.com/why-leveling/)*

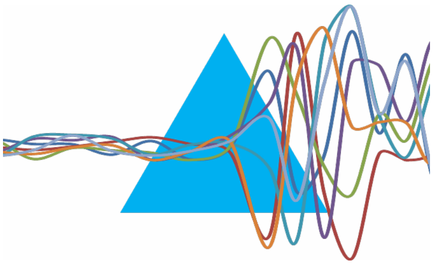

*Figure 299: Leveling (Image Roser)*

Production leveling, also known as *heijunka* (平準化) or production smoothing, is one of the hottest topics in lean manufacturing. Successful leveling is considered one of the highest achievements in lean manufacturing. Unfortunately, **if the production system is not ready for leveling, it also has lots of potential to make things worse. A lot worse!** This is the first post in a longer series of post about leveling, where I will present different types of leveling and their advantages and disadvantages.

## 48.1 Why Leveling?

### 48.1.1 In a Perfect Manufacturing World…

*Figure 300: Your shop floor? (Image unknown author under the CC-BY 3.0 license)*

In a perfect manufacturing world, there would be no fluctuation. Every day you would make exactly the same number of products, of the same product type. There would be no lack of material, no rush orders, no change in customer demand. The predicted demand would exactly match the true demand. There would be no absences, broken machines, or other problems. **In short, nothing would disrupt the peace and calm that is your shop floor.**

### 48.1.2 Back to Reality!

*Figure 301: That's more like it! (Image Jon Sullivan in public domain)*

"The peace and calm that is your shop floor"… yeah…right…

In all likelihood, your shop floor is anything but peace and calm. It is more likely to be a constant source of trouble. If your shop floor is anything like the shop floors I have seen, then not a single day goes by without a minor crisis due to missing parts, broken machines, last-minute changes in customer demand, and many other things.

Dealing with all these issues costs you time. And it is not only you, but also a lot of other people, who are needed to fix these problems. Often, it leads to increase in material, while other products are out of stock. Even so, some orders may be missed. Other parts may be flown in by airplane or put on expensive express order. (There is a rumor that all airlines would go bust if industry would no longer ship urgently needed and often heavy parts by air mail.) Overall, these fluctuations are expensive. Very expensive.

### 48.1.3 Yes, Chaos Sucks! So What Now?

Having realized the enormous waste associated with fluctuations, it would be the logical step in lean manufacturing to address these issues to reduce fluctuation and to improve efficiency and ultimately profitability.

## 48.2 Sources of Fluctuation

There are different sources of fluctuations that mess up your shop floor. Different tools and methods are used to address these fluctuations. Leveling reduces the negative effect of fluctuations in demand. Hence let's have a look at the sources of fluctuations.

### 48.2.1 Your Customers

One common sigh heard on the shop floor is that "*life would be so easy if there would be no customers.*" Well, yes, except that the customer is also your source of income. In any case, customers are a fickle bunch, and their demand varies.

If you win an award or receive good reviews, demand may go up. If you are in the news due to product failures, demand may go down. Even without such effects, customer demand fluctuates. Even if the total number of products sold are reasonably stable, demand by part type varies usually more widely.

### 48.2.2 Your Suppliers

Yet another source of fluctuation is your supplier. I think it is a safe guess that on your shop floor you have a lot of trouble with supply being overdue and late, quality problems, or even shipping the wrong product altogether. One of the worst cases are suppliers that ship the wrong goods in the right boxes or with the right labeling. You do not know that you have the wrong product until you open the box. Hence, suppliers are also a major source of fluctuation on the shop floor.

### 48.2.3 Your Own Shop Floor

It is easy to blame others, like your suppliers or customers, especially if they are not there to defend themselves. However, a major source of fluctuation, if not the largest, is your own shop floor. You may misplace parts, have unplanned absenteeism of key workers, have broken machines, or simply have a messy and uncoordinated planing.

Also, other departments may mess things up. Development may request time in your shop floor to do some testing (sometimes even with parts that they simply took out of your inventory without telling anyone ☹), have ramp-ups of new products, and generally make life harder on the shop floor.

Often there seems to be the trend of Development to justify their existence by developing many new variants of existing products, not realizing that if you split the same total sales on more variants, your fluctuations and hence your cost will go up.

In any case, your own shop floor and its connected departments are a major source of the mess you are having (even though I would probably phrase it differently if my boss would ask me about it ☺).

## 48.3 Realize that These Sources of Fluctuation Are Connected

With the different sources of fluctuations, it is important to realize that they are connected. You receive the fluctuations from your customer. You also receive fluctuations from your supplier. However, **you are the customer of your supplier, and they also receive fluctuations from you!** Hence the fluctuations on your shop floor are not only a result of others, but also by itself a source of fluctuation.

*Figure 302: Influencing each other (Image Roser)*

Hence you have the ability to reduce the fluctuations at your suppliers, and in return receive better service and availability of parts.

## 48.4 How Not to Do It – The Bullwhip Effect

But before we go into how to do it, let's illustrate it first by describing how NOT to do it. Assume you have a fluctuating demand. You struggle to produce the parts the customer needs. Your production plan is different every day. You expect your suppliers to deliver whenever and whatever you order – after all, you are their customer. Nevertheless, you miss deliveries to your customer much more often than you would like to.

Your suppliers, however, now struggle with your orders. Similar to your shop floor, their shop floor is a mess too. And, like you, they also push this mess toward their suppliers (which you probably don't even know). And these suppliers again push the mess backward. Overall, these fluctuations of the end customer work their way backward through the value chain, making it hard for everybody.

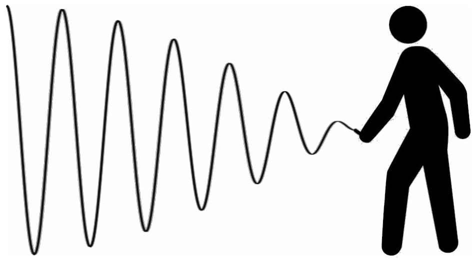
*Figure 303: The Bullwhip Effect (Image Thwongterry under the CC-BY-SA 3.0 license)*

And it gets worse! Not only do the fluctuations work backward, they also increase. Your production planning department probably tries to guess what your customer orders next. It is human nature to overestimate both growth and decline. Hence human nature amplifies these fluctuations.

Your suppliers do the same. So do their suppliers. These fluctuations not only propagate through the value chain, but they also amplify. The further back you are in the value chain, the worse it is. This effect is known as the bullwhip effect, as it is similar to a whip making wider swings the further you are from the hand.

I once had an extreme case during a project at a lithography manufacturer, producing machines to make computer chips. Now many computers go into industry, where the business goes up and down. These fluctuations are amplified within industry in general, amplified again in computer vendors, amplified again in computer manufacturers, then chip manufacturers, and finally in lithography tool makers. If the general stock market went up or down 1%, the impact on the lithography tool maker was amplified thirty times. Throughout their business cycle of roughly three years, demand went up and down by 300%, requiring enormous efforts to manage the work load of the employees.

## 48.5 Again, Why Leveling?

Hence, breaking this vicious cycle of fluctuations can yield great benefits throughout the value chain. Usually, these benefits materialize upstream where your parts come from. However, these can also be within your own system, where your workers can probably work more efficient if production is leveled. The benefit of leveling is probably least downstream, as the customer just orders whatever he wants. Yet, it may be beneficial if you have downstream processes in house where you push your produced goods (although you should not use push, and you should level the last process before the parts leave your system.

There are a lot of things you can do to reduce fluctuations. Obviously, the demand fluctuations are a big lever, and leveling usually means demand leveling. We will go into more detail in these in the next posts.

### 48.5.1 Some Other Measures Against Fluctuations

But do not forget other levers, such as, for example, your product portfolio. It is easy to let your product portfolio multiply, although actual sales usually have a harder time catching up. Hence selling the same quantity through more product types increases your fluctuations.

Similarly, quality problems and machine issues also cause fluctuations. Having consistently good-quality production at well-maintained machines also reduces fluctuation. Same goes for the qualification of your employees. If only a few of your people can do a certain task, then demand fluctuations may quickly exceed the ability of your small group of experts for a certain task. Cross training can do wonders here.

*Figure 304: Doing their thing against fluctuations… (Image Malcolm jarvis under the CC-BY-SA 3.0 license)*

Also, you may be able to influence your customer behavior. For example, a Finnish ski pole manufacturer was facing very seasonal demand on ski poles. Lots of people bought ski poles in autumn, but nobody did in spring. Addressing this problem, the manufacturer invented a new sport: Nordic Walking. Now ski poles are also sold in spring and summer for walking and hiking.

Even if you are not inventing a new sport, you can influence your customer to a certain degree with special offers or promotions to increase sales during lull demand. Of course, if you do not coordinate this well, you may also make things worse. I have seen companies where, during peak season, the factory was stretched to the limit, and marketing started a promotional campaign to increase sales without telling anybody. Let's just say that the result was not pretty.

### 48.5.2 Production Leveling

However, with production leveling, production smoothing, or *heijunka*, usually the decoupling and smoothing of customer demand is met. There are different ways to do demand leveling.

- Capacity Leveling – Do not add more production orders into the system than what the system can handle. Try to produce the same total quantity every day. Doable for almost everybody, and one of my favorites. In fact, if you are using a pull system like Kanban or Conwip, then you are already almost there.
- A pattern repeating every 1, 2, 3, or 4 weeks – This is what most people mean when they talk about leveling or *heijunka*. It is also known as **Every Product Every Cycle** (EPEC). In my experience, this is one of the biggest sources of chaos and waste in the name of lean. It can work, but it has very high requirements, and I usually advise against it. More rants about this in subsequent posts.
- One Piece Flow – Produce the same total number every day, trying to match customer demand as much as possible. However, produce in lot size one and distribute your part types evenly throughout the day. This is difficult, but can be done. In terms of leveling, this is the highest achievement of leveling.

I will talk in more details about how to do leveling – and more importantly how NOT to do leveling – in the subsequent posts. In any case, I hope you enjoyed this post, and I would love to hear from you. Now **go out and organize your industry!**

# 49 An Introduction to Capacity Leveling

*Christoph Roser, December 07, 2014, Original at [https://www.allaboutlean.com/capacity-leveling/](https://www.allaboutlean.com/capacity-leveling/)*

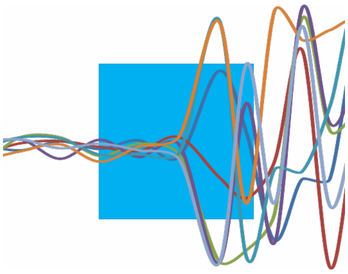

*Figure 305: Leveling (Image Roser)*

One approach to leveling (also known as *heijunka* [平準化], or production smoothing) is capacity leveling: Do not add more production orders into the system than what the system can handle. Try to produce the same total quantity every day. Doable for almost everybody, and one of my favorites. In fact, if you are using a pull system like kanban or CONWIP, then you are already almost there.

This approach is not the highest and best form of leveling, but it is doable for almost all firms. Some other approaches, notably an Every Product Every Cycle (EPEC) approach, often do more harm than good.

## 49.1 How to Mess Up Your System

### 49.1.1 Too Many Open Production Orders

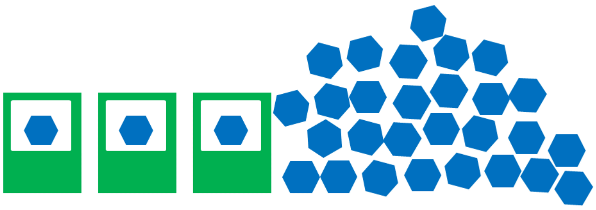

*Figure 306: Overproduction is not good! (Image Roser)*

Overproduction is one of the seven wastes (Japanese: muda 無駄). It is considered the worst type of waste, as it has negative synergies leading to many other types of waste. It is possible to keep this waste in check through a pull system like kanban or CONWIP.

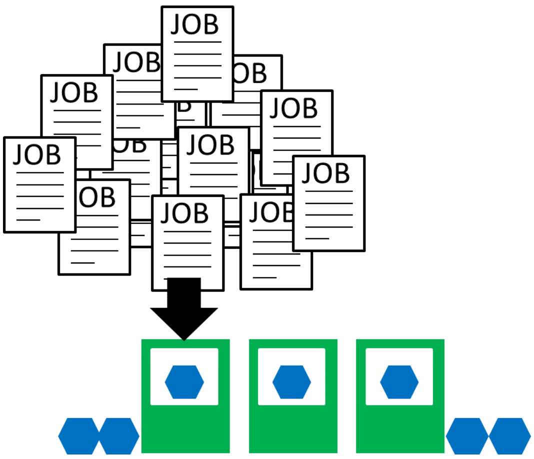


*Figure 307: Not good either! (Image Roser)*

However, almost as bad as producing too much is having too many open production orders in the system. One issue is that you no longer know when you produce which order. This means any priority you had when adding the production order is gone (see Bottleneck Management Part 2 – Improve Bottleneck Planning).

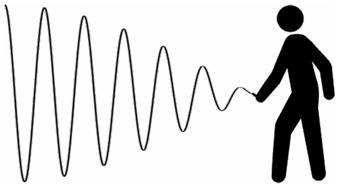

*Figure 308: The bullwhip effect (Image Thwongterry under the CC-BY-SA 3.0 license)*

Since you do not know when an order will be started, you no longer know when the supplier needs to deliver its goods. What typically happens is that the person in charge plays it safe and orders everything that may be needed for any of these jobs. Raw material inventory increases. At one point that person gets scolded for having too much material and steps on the brakes. When material starts to run dangerously low, urgent orders are added again. And hence we have the **bullwhip effect**.

### 49.1.2 Capacity Variations

A second effect – albeit usually less drastic – is capacity fluctuations. On a big scale, there are fluctuating absences, vacation periods (e.g., school holidays), and outright plant closures during holidays.

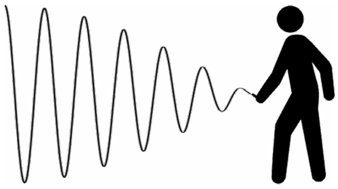

*Figure 309: Here we are again … (Image Thwongterry under the CC-BY-SA 3.0 license)*

Additionally, there are also effects on a small scale. One week the priority is on product A, and lots of the available capacity flows into product A, whereas other products have to wait. A week later the plant notices that it overshoots on A and its inventories are exploding, while product B is running out of stock. Hence it stops producing A and focuses on B. A week later the situation is reversed. A is out of stock, and B is exploding. Again, we have the **bullwhip effect**.

## 49.2 How Capacity Leveling Works

All this mess can be avoided through a pull system and capacity leveling, where you keep the number of your workers and your working times as constant as possible to produce the same total quantity every day with minimal fluctuations. (Depending on how you define capacity, you could also call it leveling of *capacity utilization*)

### 49.2.1 Use a Pull System

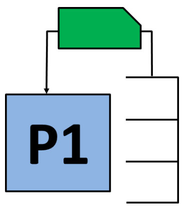


*Figure 310: Simple Kanban Loop (Image Roser)*

Pull systems, especially kanban, are one of the cornerstones of lean production. Produce only to replenish your inventories. This way you can avoid the negative effect not only of overproduction but also of too many open product orders. Similar systems can also be adapted for products that are made to order rather than made to stock. I have talked about kanban in many other posts, and hence won't go into too much detail here.

With kanban, such variation in product orders is significantly reduced. However, it is not completely eliminated. The two extremes in theory could be that all kanban are waiting for replenishment in front of the first process, or that all kanban are with material in the supermarket and there are no orders waiting in front of the first process. In reality, however, these situations are rare, and fluctuations are overall much reduced.

An alternative to kanban with less fluctuations would be CONWIP, where the number of jobs in the system is kept constant. However, in my view it is a little bit more difficult to implement. I will blog about CONWIP later in more detail.

### 49.2.2 Keep Capacity Constant and Adjusting the Product Mix to Produce Regularly in Small Lot Sizes

Another element in capacity leveling is to keep the production capacity used as constant as possible. This applies not only for the entire plant or for individual production lines, but ideally also for individual product types and products.

Actually, the ideas here in capacity leveling are only the beginning. Most of what is considered leveling focuses on capacity leveling, and subsequent posts will go into more detail about these, including, for example, a **repeating pattern (Every Product Every Cycle EPEC / Every Part Every Interval EPEI) or One Piece Flow**. However, especially the EPEC comes with a big warning label attached, as it can make things much worse than before.

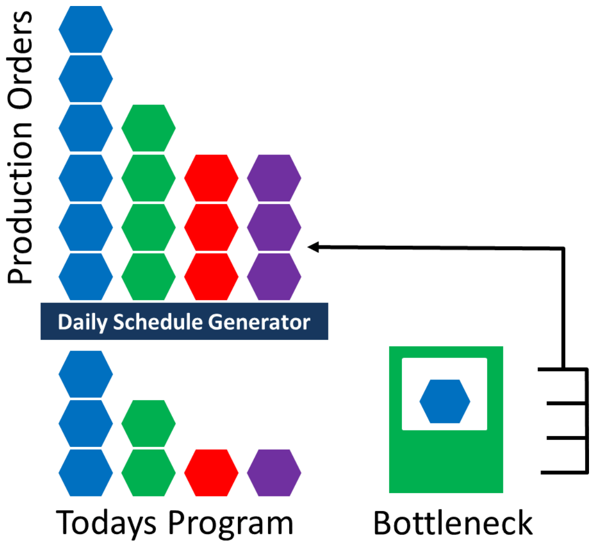


*Figure 311: Daily Production Schedule (Image Roser)*

But for now let’s keep it simple. Try to avoid wild swings in your production capacity for individual parts. For your high runners that have a stable regular demand, try to produce them every day. In a perfect world, this would also be the same quantity every day, but this may lead to disastrous results (see my next post). For now, simply try to produce these parts every day.

For example, all of your waiting production orders (kanban or otherwise) represent the overall mix you have to produce. Out of these open orders, make a similar mix that matches your daily capacity. You may need to adjust for lot size. This is the mix that you should produce.

Of course, for exotic parts that are produced only once every two weeks, it cannot be completely avoided. But even then, produce these exotics once every two weeks, and do not pool it into larger batches every half year.

It helps to have smaller lot sizes. With larger lot sizes, your capacity used for individual products will fluctuate more. Smaller lot sizes help to reduce fluctuations of the used capacity by part number (see SMED for details).

### 49.2.3 Match Released Production Orders to Available Capacity

A kanban system avoids overloading the production line with open orders. However, this can be also adjusted more finely. Estimate the available production capacity for the next few days. Ideally, estimate the total capacity between today and the expected completion of the production orders that are issued today. Now compare that to the capacity that is already allocated within the same period. The production orders released for production match the difference between the available and already allocated capacity (i.e., you fill the capacity up with new production orders).

Let's make an example as shown in the image below: If you expect that today is Wednesday, and today's production orders will leave the production line in seven days, then your time interval is seven days. This includes not only production but also ordering and supplying of material, set ups, and so on.

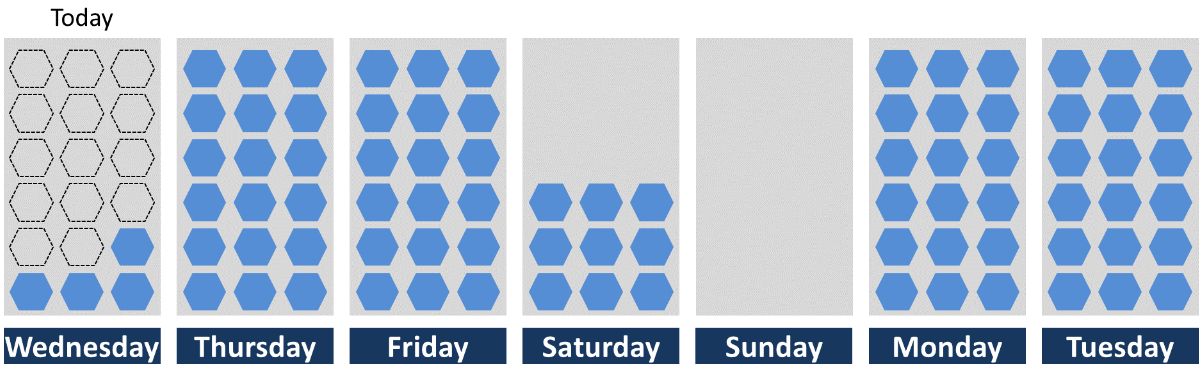

*Figure 312: Production Schedule Matching Capacity (Image Roser)*

Every day you have the capacity to produce 18 products, except Saturday with only one shift for 9 products and Sunday with no production. Therefore, for the entire seven-day period you have capacity for exactly 99 products.

However, you already have 85 open orders waiting or being built (the blue hexagons). The remaining open capacity is now 14 parts (the dashed-line hexagons). Hence you should add another 14 parts to the list of production orders waiting for production.

Through such a system, the open orders will always closely match the available capacity. When there are delays, fewer new production orders will be released. A surprise increase in speed is rare, but this can be handled with having, for example, one additional day of open orders as a buffer for the rare surprise capacity increases.

Of course, the image above shows only one part type (the blue hexagon) for simplicity. In reality, these open orders should of course be a representation of all product types, as explained above in the section Keep Capacity Constant.

Overall, you can significantly improve your production through leveling by using the three steps below:

- Keeping capacity as constant as possible
- Matching released production orders to the available capacity
- Adjusting the product mix to produce regularly in small lot sizes

Overall, your production will run much smoother, as will the production of your suppliers. I hope this post was interesting to you. Please let me know if you have any questions. Otherwise, **go out and organize your Industry!**

# 50 Theory of Every Part Every Interval (EPEI) Leveling & Heijunka

*Christoph Roser, December 14, 2014, Original at https://www.allaboutlean.com/epei-pattern-leveling/*

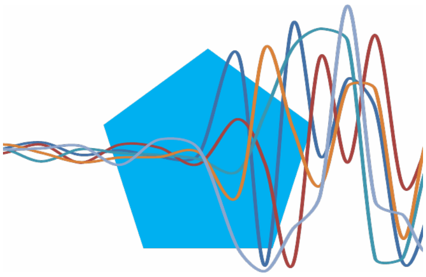

*Figure 313: Leveling (Image Roser)*

Probably among the most popular leveling approaches is **Every Part Every Interval (EPEI)**. Often, this is the method people mean when they talk about **leveling** (also known as *heijunka* [平準化]).

The theory about this type of leveling is not very difficult. Unfortunately, hard facts of reality often nullify any possible advantage of this type of leveling. **In fact, most of these types of leveling that I have seen were complete rubbish. They were a dog-and-pony-show to please management at the expense of performance and shop floor efficiency.** In this post I will explain to you how it is supposed to work in theory. In the next post I will explain why it rarely works in practice.

## 50.1 Different Names for (Often) the Same Thing

This approach to leveling is quite popular. For some reason, many different names are used to describe (mostly) the same thing. Some of the names I have come across are listed below, but I'm sure there must be some more. For the sake of simplicity, I will just call it EPEI below.

- Every Part Every Interval (EPEI)
- Every Product Every Cycle (EPEC)
- Every Product Every Time Interval x (EPEx)
- Fixed Repeating Sequence
- (Production) Leveling
- Production Smoothing
- *Heijunka* [平準化] (Japanese for Leveling)
- Green Stream/Red Stream (green for predictable high runners and red for fluctuating exotics)
- Fixed Sequence Fixed Volume

## 50.2 Theory of EPEI Leveling

But let's look at how EPEI leveling works (please note that this is complicated by the fact that that not everybody has the same thing in mind when they talk about EPEI leveling).

### 50.2.1 The Good Basic Idea – Distribute the Demand Evenly

The underlying idea of EPEI leveling is to distribute the demand evenly across a period of time. For example, you break your daily production quantity in lots as small as feasible and distribute these lots evenly throughout the day. This underlying idea is actually pretty good and solid. It is also the basis for the one-piece flow I will talk about in the next post.

### 50.2.2 The Fixed Repeating Sequence

The approach of using a fixed repeating sequence takes the expected total demand for a longer period – often one, two, or four weeks – and aims to distribute the resulting production orders evenly. In industries with shorter cycle times such as, for example, the automotive industry, this is often distributed into daily chunks of equal size. If your change overs differ depending on from what to what you change, the fixed repeating sequence also allows you to optimize these change overs.

However, if your cycle time is longer or if you have larger changeover times, you may use larger chunks to distribute the orders in your period. Similarly, if you have small changeover times, you may even produce the same product more than once at different times throughout the day.

## 50.3 An Example

Usually, this approach is best explained using an example. Lets assume you have 7 different products labeled A to G. Products A, B, and C are your high runners that you sell frequently. Together they make up more than 80% of your sales. Products D, E, F, and G are your less frequently sold exotic parts. Production planning estimates that you will sell 40 product A's next week, 25 product B's, 15 times C, 5 times D, 2 times E and F each, and only 1 product G as shown below. Every day you have the capacity to produce 18 parts, so your capacity matches the overall demand of 90 products.

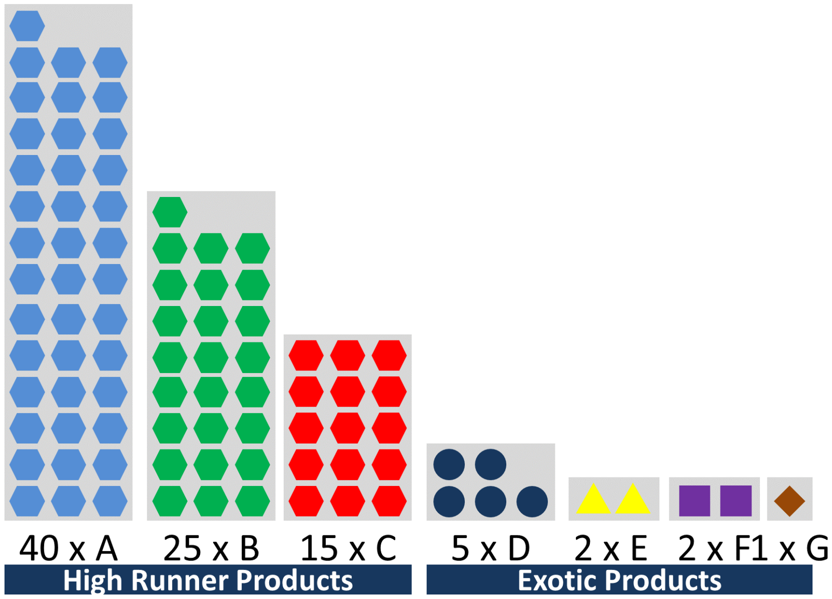


*Figure 314: Weekly Demand for the Leveling Example (Image Roser)*

### 50.3.1 Not-Leveled Initial State

If someone would not know anything about leveling, they would probably try to minimize the number of changeovers and make batches as large as possible. Hence your production schedule for Monday to Friday would look like the image below. First you produce all 40 products of A, followed by all 25 products of B, and so on.

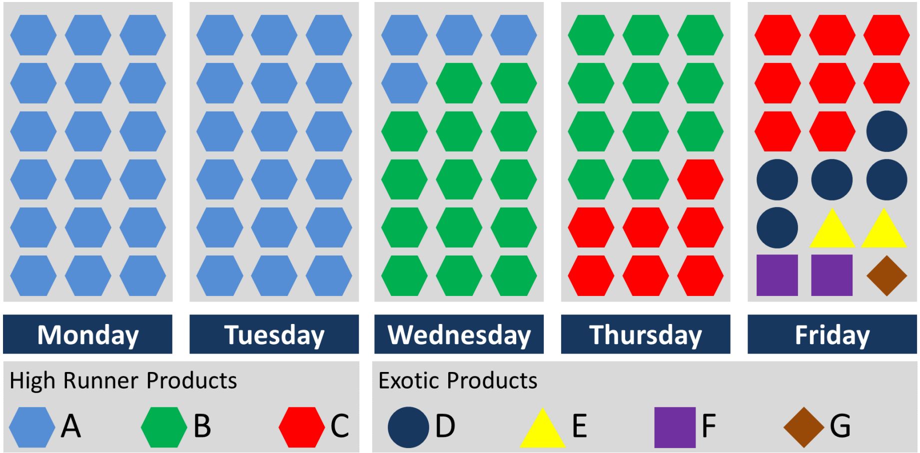

*Figure 315: Not (yet) Leveled Example (Image Roser)*

### 50.3.2 Fixed Repeating Sequence Leveling

With an EPEI or fixed repeating sequence approach, you would split the expected demand into daily batches. The high runners would be produced every day. This means every day you would produce 8 product A's, 5 product B's, and 3 product C's. The remaining capacity is used for the exotic parts, which are also distributed evenly across the week. Product D has a demand of 5 pieces, hence we can also produce it every day. Products E and F are produced every other day, and the lone product G is produced on the remaining available day.

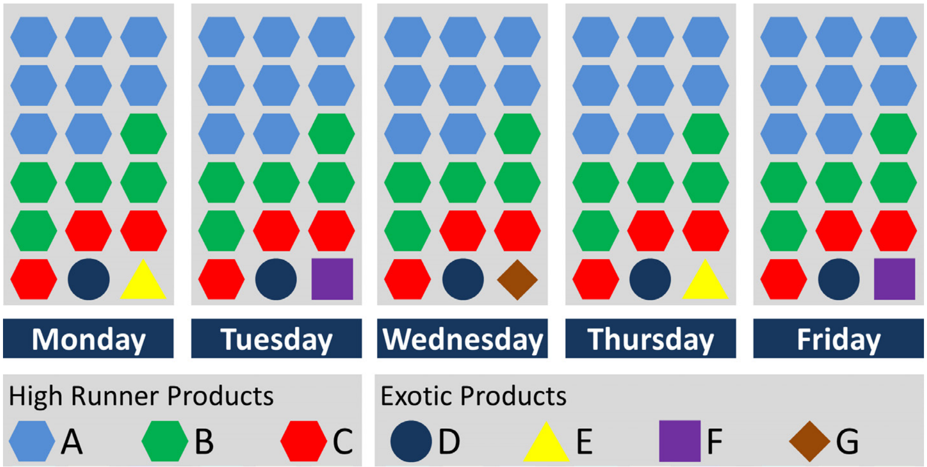

*Figure 316: Leveled Example (Image Roser)*

Compare the not (yet) leveled illustration farther above with the leveled example directly above. The latter looks much more evenly distributed. Your weekly demand is leveled evenly across the days of the week.

## 50.4 Some Variations to the Method

### 50.4.1 Length of Repeating Sequence

In the example above, I used a weekly period with a daily repeating sequence. This, of course, depends on your circumstances. Many real world examples I have seen use a two-week period, also with a daily repeating sequence. But there are also longer or shorter periods such as, for example, one day or one month. The repeating sequence can also be shorter or longer than one day.

Ideally, the shorter the repeated sequence is, the better the leveling effect. In a perfect state it would be a one-piece flow, where every part is different from the next one. However, this may not be economically feasible if you have larger changeover times. Of course, always remember that changeover times are not fixed but can be reduced (see SMED for more details).

### 50.4.2 (Flawed) Mathematical Approach for Length of Repeating Sequence

There is even a mathematical approach to calculate the repeated sequence, although I think it is flawed. You take your total available production capacity and subtract the production capacity required to satisfy the demand. The remaining capacity is used for changeovers in order to make the sequence as short as possible.

For example, if you have 80 hours of capacity, but need only 70 hours to satisfy demand without changeovers, then you should use the remaining 10 hours for changeovers. If you need 15 minutes per changeover, then you can afford 40 changeovers to create your pattern.

However, this method does not work very well if you have **way too much capacity**. It does not work at all if you have **not enough capacity**. Having a good number of changeovers for a good pattern will be rather arbitrary. In any case, it will be a tough sell to the manager who has to pay for the time for changeovers rather than send people home and reduce overtime.

### 50.4.3 Length of Interval Leveled

As for the length of the periods whose demand is leveled… well… here it gets a bit tricky. The longer the period leveled, the more leveled the overall demand is – but the harder it is to actually follow the planned sequence. Actually, the ability to follow the sequence – or to be more precise, the **Inability** – is the main reason that most attempts at EPEI leveling fail miserably. More on this in my next post.

### 50.4.4 Sequence Not Based on Time But on Quantity

You can also model the repeating sequence not based on time, but on number of parts. This gives you, in fact, more flexibility. However, the shop floor still thinks in terms of shifts and production days and will have a bit more trouble wrapping their mind around it. But it is definitely doable.

This is sometimes illustrated as a wheel, where the same production sequence starts again after the last part is completed. For our daily sequence example above, this is illustrated below. Only the last two parts would change every cycle, since these exotics are not produced every time.

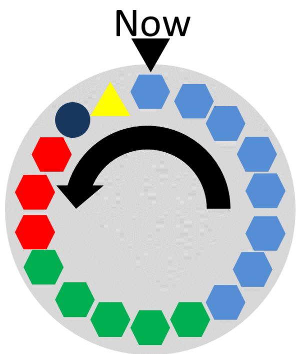


*Figure 317: The Repeating Sequence as a Wheel (Image Roser)*

### 50.4.5 Heijunka Board

The pattern is often visualized in a Heijunka Board (Heijunka Box, Leveling Board). This is a board with lots of slots to add kanban cards or production orders. Usually it is close to the manufacturing location. The different rows and columns in such a box represent the time (often days or shifts) and the product types (separate row for high runners, often shared rows for exotics). The cards are added to represent the production sequence, and are removed once the product is completed.

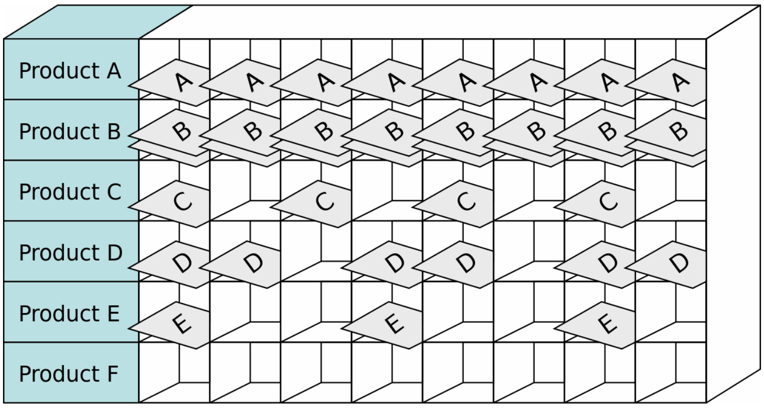

*Figure 318: Schematic of a Heijunka box (Image MithrandirMage under the CC-BY-SA 3.0 license)*

A Heijunka Box can visualize the situation within the pattern very well, but is also a significant effort to maintain, especially if there are frequent changes to the pattern. **A Heijunka Box also immensely impresses your superiors and gives them the feeling that they have managed you well. In fact, sometimes the box is all you need to impress your superiors, regardless if the leveling actually works or not.**

## 50.5 Conclusion

Well, the above all sounds pretty logic and reasonable. Unfortunately, the harsh reality on the shop floor usually messes it up pretty well. While it looks good in theory, it is a total mess on all but the very best shop floors. But more about this on the next post. In the meantime, **go out and organize your Industry!**

# 51 The Folly of EPEI Leveling in Practice – Part 1

*Christoph Roser, December 21, 2014, Original at [https://www.allaboutlean.com/flaws-of-epei-leveling-part-1/](https://www.allaboutlean.com/flaws-of-epei-leveling-part-1/)*

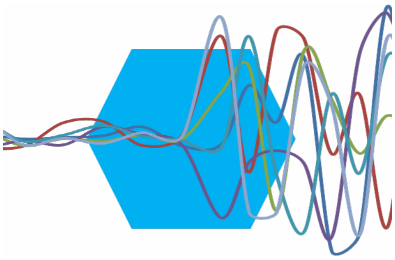

*Figure 319: Leveling (Image Roser)*

In my last post I presented the EPEI leveling pattern (also known as EPEC, EPEx, *Heijunka*, fixed repeating pattern, or simply leveling). While in theory this approach looks pretty solid, in my experience it rarely works in practice. In fact, most of these types of leveling that I have seen were complete rubbish. They were a dog-and-pony-show to please management at the expense of performance and shop floor efficiency.

Furthermore, lean manufacturing seems often to be confused with a religion. People believe that if you put up a leveling box your manufacturing system will have salvation. Well, Lean is not a religion. Lean is hard work, and you actually need to understand what you are doing. Just copying something without understanding is a good way to fail, especially with leveling.

This post will look at the different reasons why almost all of the EPEI leveling approaches fail. We will also look at what is needed to have a successful EPEI leveling pattern. The method does work, but unfortunately most companies do not have the required prerequisites to make it work.

Due to the length of this topic, I have divided it into two separate posts. The next post completes the reasons why EPEI leveling so often fails, and gives some advice on how to limit the damage or even increase the chances of success, as well as a test to determine whether your system can handle EPEI fixed repeating sequence leveling.

## 51.1 A Bit of Gripe

EPEI leveling is the creation of a production pattern that is repeated throughout a longer period, often two to four weeks (for details, see my last post). An example of such a pattern could look like the image below.

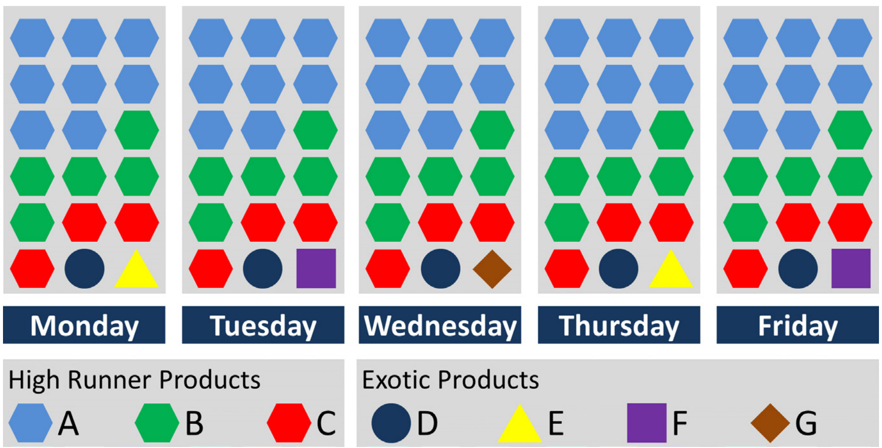


*Figure 320: Leveled Example (Image Roser)*

This repeating pattern is one of the most popular topics in lean manufacturing. Many large manufacturing firms pride themselves on including leveling as part of their lean toolbox. It is included in most lean handbooks (both publicly available ones and internal handbooks within a company), and serves as one way for a middle manager to distinguish his department or plant as a lean operation.

Unfortunately, most of that is rubbish.

Middle and upper management talk all about their successful leveling, but if you go down in hierarchy, the message is quite different. If you talk to foreman, shop floor supervisors, or lower level management, you will learn that most of these leveling implementations do not work. They do create a leveling pattern, but due to different reasons we will explore below, they cannot follow it. As a result, it creates more chaos than before. It is extra work for the operators and shop floor employees who must to create the pattern, manage it, and fix the problems created by the unstructured approach to changes in the pattern.

Even the lean experts within a company that created these leveling examples often admit that in a smaller circle, none of these leveling implementations bring any benefit! None! Zero! Zip! Nada! Nix! At best, they do not create additional chaos, but even that is rare.

I also often ask my students about their experience with leveling during internships. As a result, I am usually flooded with horror stories about time-wasting implementations that often undo previous good work and turn an otherwise reasonable production system into an exercise in chaotic firefighting.

Hence, I usually advise against EPEI leveling unless I have the feeling that the plant is already very advanced with respect to lean. However, in this case, they usually don't ask for a EPEI leveling pattern in the first place.

Please don't get me wrong. I am a big fan of leveling, such as, for example, capacity leveling or one-piece flow. It is just these EPEI leveling patterns that I had very bad experience with. In any case, let' s look at the reasons why EPEI leveling fails.

## 51.2 Reasons Why EPEI Leveling Mostly Does Not Work

### 51.2.1 Inability to Closely Follow a Production Schedule

One of the biggest reasons why EPEI leveling fails is the inability of the plant to follow a production schedule. Most plants are constantly troubled by many different problems, including but not limited to a lack of material, absenteeism, or technical problems. This does not even include changes in customer demand, which I will discuss later. As a result, most plants already have difficulties adhering to the production plan that they created three days ago. Within only three days, enough problems pop up that the initial production plan has to be changed.

With EPEI leveling, you do not issue production orders for three days in the future, but for one month in the future. To be precise, you try to fix your production schedule for the leveled period of usually two to four weeks plus the time to the first day of the leveled period.

In the example below, we assume a four-week period and three days to order material for the first day in the period. In effect, you try to fix your production twenty-three days into the future!

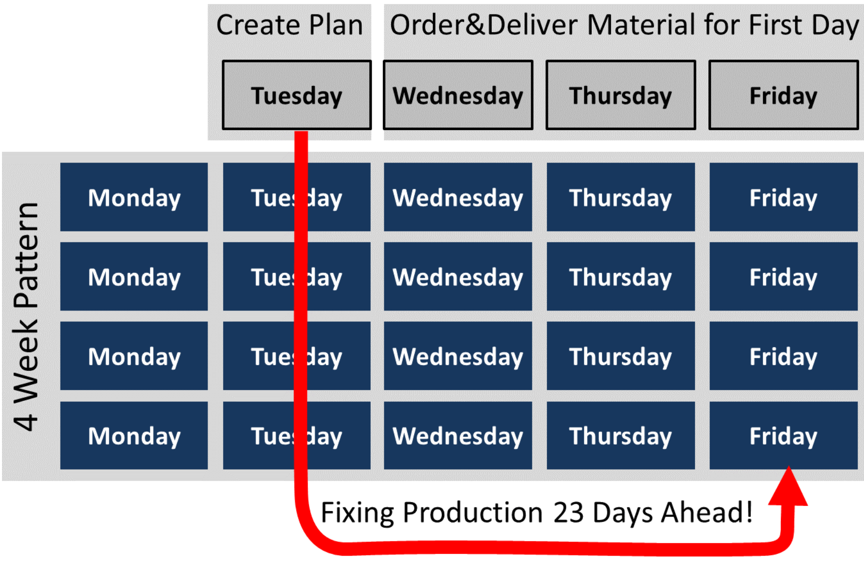


*Figure 321: Are you sure this is a good idea? (Image Roser)*

If there are already enough changes to mess up your schedule three days into the future, can you imagine how messed up your schedule will be twenty-three days into the future?

### 51.2.2 Lack of a Structured System to Handle Changes

The above inability to follow a schedule is aggravated by the lack of a system to handle changes. Without leveling, a good plant has a system in place to handle these changes. A bad plant resorts to firefighting, sometimes more, sometimes less. But even then, the firefighting usually follows some established protocols.

With leveling, however, these systems or protocols are replaced with a leveled system. And, since a leveled system by default is supposed to eliminate changes, it usually does not include a system to handle changes.

*Figure 322: The car is your schedule… the Tram is reality … (Image trams aux fils. from Chêne-Bougeries, Suisse under the CC-BY 2.0 license)*

Yet, as we have seen above, changes do happen, whether you want them or not. Without a system, however, they increase the chaos. Changes are no longer anticipated a few days ahead, giving some reaction time. Instead, these changes are much more likely to hit you without warning. Hence, unless there is at least a rudimentary system in place to handle these changes, chaos will increase.

### 51.2.3 Inability to Have a Good Prediction of Customer Demand

Customers are demanding. They do not know what they want, and then they change their mind at the last minute. But then, since they are the customer, they have every right to do so.

*Figure 323: Now that would be nice … (Image Ali in public domain)*

As a result, predicting customer demand is difficult. Toyota makes an enormous effort to predict customer demand, with the result that they often know it better than the customer. Most other companies spare this effort, resulting in predicted demand mostly based on historic demand. Usually, this is adjusted for special effects like new products or changes in the market. However, a subsequent analysis also often reveals that using simply last year's data would have been better than any additional adjustment made by the responsible department.

In sum, predicting customer demand is difficult. Yet, you want to use this low-quality demand prediction to determine a pattern for the next few weeks. Through the leveling pattern the total number for every product type is fixed. In the example above, this would also be fixed for twenty-three work days in advance. Effectively, you claim to know the number of parts sold within the next twenty-three days. Reality will probably differ.

### 51.2.4 Lack of Additional Inventory to Cover Increased Replenishment Time

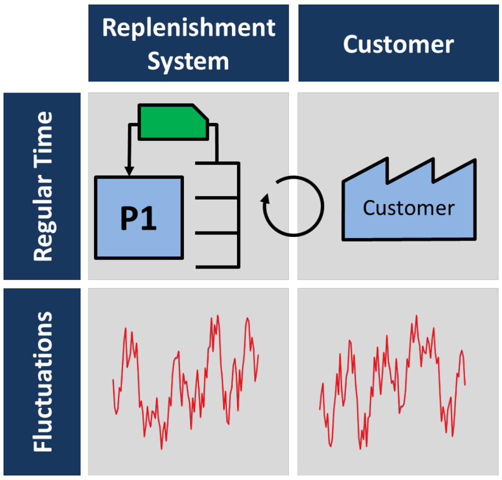

*Figure 324: Kanban Formula Factors (Image Roser)*

Since EPEI leveling fixes your production schedule for a longer period into the future, this means it will increase your replenishment time. It will take longer for a specific order to go through the system. Since leveling is also a pull system, this means you would need to adjust your kanban formula (for details on the formula, see the Kanban Formula Part 1 and Part 2). This would have a number of effects:

- You would need more kanban to cover your extended replenishment time. The number of kanban equals to the leveled period minus one day for the original kanban period. Hence, if you have a period of four weeks, you would need to add four weeks' worth of production minus one day as kanban.
- Your fluctuations on the customer side may increase. The buffer stock now not only has to cover the demand swings during the initial replenishment time, but also the demand swings during the extended replenishment time. If the customer orders more than expected, you have to cover the entire leveled period rather than the shorter initial replenishment time.
- Your fluctuations on the supply side may increase, although this is usually a smaller problem and may not need any additional kanban. Yet, it would be good to check.

In sum, you would need more kanban cards. A lot more kanban cards. For a four-week pattern, this would be probably in excess of four weeks worth of production in kanban cards.

Naturally, many of these cards would be only cards without attached stock. But a significant number – probably 30–50% of them – will sit in storage with material attached. Hence, for a four-week leveling period, expect one or two weeks' worth of additional material in stock.

Of course, we all know what happens if you ask your supervisor for two weeks' worth of stock to put in your inventory. It will happen when hell freezes over. You won't get it. Naturally, if you slow down the reaction time of your system with a multi-week leveling period without providing adequate decoupling, short-term changes will increase even more. You will have even more difficulties following a production schedule, amplifying all the effects described above.

Overall, these above effects will cause havoc on your leveling system. In fact, they will cause havoc in any advance planning and scheduling system. Pull systems are a way to avoid this havoc, but EPEI leveling runs a high risk of introducing this havoc again in a pull system.

In my next post I will continue this discussion with two more reasons why EPEI leveling so often fails. I will also give some advice on how to limit the damage or even increase the chances of success, as well as a test to evaluate whether your system can handle EPEI fixed repeating sequence leveling. In the meantime, go out and **Organize your Industry!**

# 52 The Folly of EPEI Leveling in Practice – Part 2

*Christoph Roser, December 28, 2014, Original at https://www.allaboutlean.com/flaws-of-epei-leveling-part-2/*

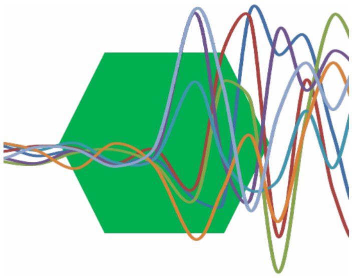

*Figure 325: Leveling (Image Roser)*

In my last post, I started to show the main reasons why EPEI leveling with a fixed repeating schedule so often fails (for details on EPEI leveling, see Theory of Every Part Every Interval (EPEI) Leveling). This post continues with more reasons and also gives some advice on how to reduce the damage or even increase its chances of success. It also has a suggestion for a test to determine if your system is ready for leveling.

Again, there seems to be a lean religion that claims that putting up a leveling box will lead to salvation. Well, Lean is not a religion or magic. Lean is hard work, and you actually need to understand what you are doing. **Just copying something without understanding is a good way to fail, especially with leveling**.

## 52.1 More Reasons Why EPEI Leveling Mostly Does Not Work

### 52.1.1 Limited Power Over Supplier and Supplier Ability

A leveling system (like most other lean manufacturing systems) depends on the ability of the suppliers to deliver in full on time. However, it takes time to develop your suppliers. Toyota has been working on this for decades, including by sending people over to help suppliers to improve.

The Western approach is often very different. Rather than helping the suppliers, Western customers often use threats to force the supplier. This is usually not a viable strategy, even if you have power over the supplier (as, for example, a car maker usually has over its suppliers).

Additionally, not every customer has power over its suppliers. If your orders are only a small share of your supplier's business, then you can expect other bigger customers to receive better treatment. Any supplier would rather ditch your 5% of his sales than endanger the 40% of his biggest customer, even if he would not tell you this. Quite frankly, you would probably do the same. **In sum, getting your suppliers to deliver in full on time is hard work on both sides, and does not simply happen just because your management has decided that leveling is the latest fad.**

### 52.1.2 Does Management Want to Be Cheated?

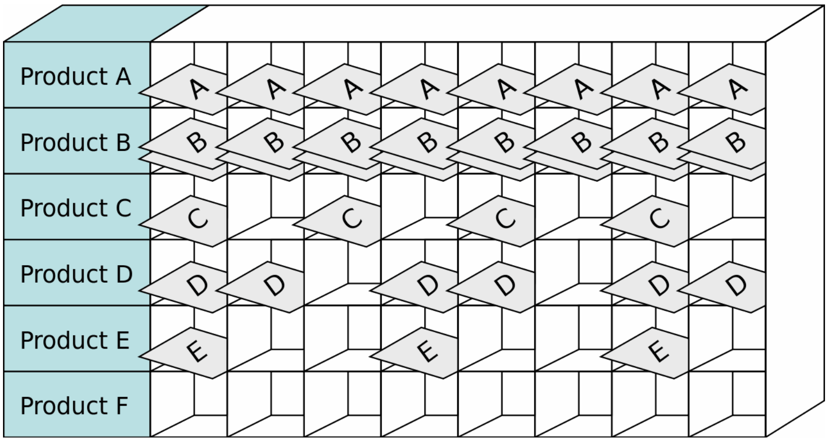


*Figure 326: Management wants a box … (Image MithrandirMage under the CC-BY-SA 3.0 license)*

Sometimes it feels to me like management wants to be cheated. Of course they would prefer to have a working leveling system. However, if they can't have a working system, they may also settle for something that looks like one, even if it doesn't work. Most often, however, they simply don't know if the leveling system is counterproductive.

*Figure 327: … management gets a box. (Image Walter Smith under the CC-BY 3.0 license)*

One of the easiest ways to look like you have a working EPEI leveling system is to install a Heijunka Box, where the cards represent the production schedule. No matter if it works or not, these boxes usually duly impress management and give the appearance of a lean shop floor. Often, this box is all you need.

Just to make sure, I definitely prefer not to do EPEI leveling with a shop floor that cannot do EPEI leveling. I also don't want to do dog-and-pony-shows with my management. However, if you are ordered to establish EPEI leveling, you are obliged to try or risk the consequences. In this case I would try my best, even knowing fully that it does not work. However, I would try to limit the damage.

## 52.2 How to Limit the Damage of EPEI Leveling

Some EPEI leveling creates havoc with the exact manufacturing system that it is supposed to smooth. However, there are some approaches to reduce the damages and to avoid the worst negative effects. Without going in too much detail, these are:

- **Create a system to handle change.** Try to establish a standard procedure of what to do if there are changes to the pattern to ensure a reliable material supply.
- **If external factors like customer demand, material supply, worker availability, or machine downtime force you to change the pattern, do it immediately. Do not try to force the pattern through the system; it will just make it worse.** Pretty much the only

EPEI leveling systems I have seen that did not end in chaos were those that ditched the pattern at the first sign of trouble. It does not help the smoothing idea, but it prevents it from becoming worse.

- **Do not cut off your production plan at the end of the day**. You probably will not hit the target quantity every day. If you have capacity left over at the end of the day, continue with the next day's plan. If you cannot make all parts you were planning to produce in one day, do roll over the remainder into the next day. If you just cut them off you are likely to get delivery problems. If you absolutely feel the need to start a new cycle every day, make sure you have produced your exotics in the morning, and have some additional buffer stock for the high runners that may or may not get produced at the end of the day.
- **Try to increase your ability to buffer customer demand swings**. These can be done through an increase in buffer stock, but also through increased flexibility in your production capacity. If these options are not possible, the buffering will default to the third option: the customer has to wait.
- **Try to minimize the additional organizational overhead.** Often, a Heijunka Box is added to make the leveling look good. These boxes can be useful. However, if you also keep the previous ERP-based scheduling system, your people now have to maintain TWO systems. Additionally, they have to sort out what to do if the two systems disagree. Rather than making things easier, it will be harder for the shop floor.
- **Keep the leveled interval as short as possible**. If you do a four-week leveling interval, you have to fix your production schedule in for more than four weeks in advance, with all the associated problems. Doing a two-week interval halves this (presumably) frozen period. Similar, one week is even better. Of course, the shorter the interval, the smaller the smoothing effect, but since you will have difficulties in following the pattern anyway, there is not really much smoothing to begin with.

## 52.3 Test Your EPEI Ability

EPEI leveling is pretty advanced and has high requirements on the production system. As I said above, only the very best systems have the ability to do EPEI leveling. **If you are wondering if your system is an excellent production system ready for leveling, here is a professional opinion: probably not. Sorry!** If, despite all my warnings above, you nevertheless want to try EPEI leveling, I would suggest doing some tests first.

**In the first test, fix the production schedule for the next few weeks** (for whatever leveling period you desire). Afterward, compare the schedule with the actual production on a daily basis, both for quantity and for sequence. This will tell you a lot about your ability to follow a schedule. If this analysis makes you shiver, then don't do EPEI leveling. By the way, this is also a good test to check if your existing EPEI leveling system is any good.

**A second test would require you to get the best possible customer forecast for the desired leveling period.** Afterward, check the forecast with the actual sales. Again, if it makes you shiver, then don't do EPEI leveling. Or at the very least increase your buffer stock to cover these prediction uncertainties.

## 52.4 A Personal Statement

This double-post is a good bit longer than my usual posts. However, I have been planning to write it for a long time and finally got it off my chest. I spent a lot of time seeing failed EPEI leveling systems in other plants, which was just sad. I also spent a lot of time arguing with management about the uselessness of leveling, showing tons of data and analyses, only for the management to decide to go ahead anyway. This was very frustrating. (Although, in all fairness, if even higher-up management wants leveling no-matter-what, then it would be not wise for my own management to oppose.)

Fortunately, as a professor, I no longer have to do the frustrating part, but it still saddens me to see all this misguided EPEI waste in the name of lean. Hence, do yourself (and me) a favor and be very, very wary of EPEI leveling with a fixed repeating pattern. **Now go out and organize your industry (but please use one of the other types of leveling that are more likely to work).**

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# 54 Author

*Figure 328: Christoph Roser (Image Roser)*

Prof. Dr. Christoph Roser is an expert for lean production and a professor for production management at the University of Applied Sciences in Karlsruhe, Germany. He studied automation engineering at the University of Applied Sciences in Ulm, Germany, and completed his Ph.D. in mechanical engineering at the University of Massachusetts, researching flexible design methodologies. Afterward he worked for five years at the Toyota Central Research and Development Laboratories in Nagoya, Japan, studying the Toyota Production System and developing bottleneck detection and buffer allocation methods. Following Toyota, he joined McKinsey & Company in Munich, Germany, specializing in lean manufacturing and driving numerous projects in all segments of industry. Before becoming a professor, he worked for the Robert Bosch GmbH, Germany, first as a lean expert for research and training, then using his expertise as a production logistics manager in the Bosch Thermotechnik Division. In 2013, he was appointed professor for production management at the University of Applied Sciences in Karlsruhe to continue his research and teaching on lean manufacturing.

Throughout his career Dr. Roser has worked on lean projects in almost two hundred different plants, including automotive, machine construction, solar cells, chip manufacturing, gas turbine industry, paper making, logistics, power tools, heating, packaging, food processing, white goods, security technology, finance, and many more. He is an award-winning author of over fifty academic publications. Besides research, teaching, and consulting on lean manufacturing, he is very interested in different approaches to manufacturing organization, both historical and current. He blogs about his experiences and research on AllAboutLean.com. He also published his first book, “Faster, Better, Cheaper,” on the history of manufacturing.

Prof. Dr. Christoph Roser is an expert for lean production; Toyota, McKinsey, and Bosch Alumni, and professor for Production Management at the Karlsruhe University of Applied Sciences. He is interested in everything related to lean manufacturing, bottleneck detection and management, as well as historic developments of manufacturing. His first book is "Faster, Better, Cheaper" on the history of manufacturing.

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.

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