All About Pull Production

Designing, Implementing, and Maintaining Kanban, CONWIP, and other Pull Systems in Lean Production

With a Foreword by John Shook

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Chapter 1
Introduction

Pull is an excellent tool to establish flow and limit your inventory. With very few exceptions, all production systems would benefit from pull. Pull is a cornerstone of lean production.

This book on pull production is **written for the practitioner**. Focus is on **actual use of pull systems in real-world applications**. However, before we start with the actual details on pull systems, here is some advice on whom this book is for, and when you should use pull. I will also give you some guidance on reading this book, and a bit on the history of pull systems.

In this book, I go into detail on the **selection, calculation, implementation, and maintenance of the various pull systems**. The book is based on my experience in implementing and using pull on actual shop floors. It also includes academic research to explain the theories behind it. Again, the primary aim of this book is to help the practitioner on the shop floor.

1.1 Whom This Book Is For

This book is a practical guide for anyone looking to implement pull systems. It does not try to explain all of lean manufacturing, but has a **rigorous focus on pull**. I find it difficult to fit all of lean production into a single book. After all, it was difficult enough to fit *All About Pull Production* into a single book!

This book focuses heavily on practical application. It values functionality over theory, albeit I point out the underlying relations. It is not a high-level philosophical discussion of lean, but a book to help you roll up your sleeves and get the job done. It is **written for the practitioner**, especially in **small and medium enterprises** that may not have a lean back office for support. If you are in charge of a (or part of a) small- or medium-sized company and want to implement pull, then this book is for you. It can also be used in **larger corporations**. However, it also serves as a useful **reference for students and researchers of lean manufacturing**.

It serves as a guide for anyone connected to manufacturing. It can help **people in charge of manufacturing** and other systems, from the supervisor to middle management, to the COO and CEO. It is also relevant for **people supporting manufacturing** or other systems. This could include people responsible for designing, maintaining, and planning such systems, including operators in maintenance, production planning, line layout, and line design, industrial engineering, and others. More broadly it can help with **any kind of processing system that could use pull, including healthcare, services, administration, military, government, banking**, and many more.

Since people in industry are under constant time pressure, I structured this book to support **selective reading**. While I would love for you to read this book cover to cover, I completely understand if **you just need a solution for your problem… fast!** Hence, I tried to point out which type of pull system is useful for you, and structured the book to allow skipping to the most interesting parts. For the same reason, I have a list of variables close to the equations that use them, even if I have explained the variables before. A complete list of variables can be found in the appendix. The table of contents has quite a few levels more than what may be esthetically pleasing, but this also helps you to quickly find what you need. **Text in bold highlights key points**, helping you to scan the pages for the parts relevant to you.

This book should ideally be read before you implement pull in your system. However, it can also help you if you already have an existing pull system and want to improve or maintain it. Overall, the goal of this book is to help you to **go out and organize your industry!**

1.2 When Do You Need Pull?

Pull production is part of the lean manufacturing *kaizen* improvement process. **Lean should always start with a problem**, and from there work toward the solution. Deciding top down that you need pull and then looking for a problem to match is the wrong direction. **If the only tool you have is a hammer, everything will look like a nail.**

Hence, the first step is to figure out **what problems you want to solve**. Usually, the answer is that there are only three problems: cost, quality, and delivery time. However, these are all the problems a production system can normally have (assuming operators' safety is ensured and that the law is not looking for you). Try to narrow down which of these problems, and where, is most relevant to you.

Pull can help you with **improving lead times** and therefore **improving delivery times**. Pull is a common solution that helps you to stabilize and control your material flow. This reduces lead times and improves delivery performance.

Pull can also help to **reduce cost**. However, there are many ways to reduce cost. This includes design changes, process optimization, and waste reduction. Pull is a possible answer, but not the only one and not necessarily the best, if cost is your biggest problem. However, pull can **reduce inventory**, which will have a lot of benefits, including cost reduction.

Implementing pull is also a way to **build lean capability for you and your operators**. It also helps **to establish trust in lean**. By establishing a pull system, the operators become familiar with the underlying principles of lean. This can help with a cultural shift toward continuous improvement and lean. If capability building and trust building is your goal, establish a pull system where the chances of success are high. Tackling the trickiest production system first with a workforce unfamiliar with pull can lead to failure and hence mistrust.

But again, **start with the problem, and then work your way forward from there**.

1.3 How to Read This Book

Pull is one of the key concepts of lean manufacturing. While it did not originate with Toyota, the Toyota Production System made pull in general and kanban in particular famous. It helped Toyota to grow and become the largest carmaker in the world. This book is targeted primarily at production; however, pull can also be used in many other areas, like service, healthcare, call centers, retail, logistics, administration, development, construction, and others.

However, the concept of pull is often misunderstood. It is often defined as the direction of the information flow, when in reality it is all about **limiting the inventory combined with a system to replenish this inventory**. Whenever a part leaves the system, a replacement is produced or shipped. Whenever a job is completed, the next job is released for production. Hence pull will prevent overloading the system. You will find more on this in Chapter 2.

This book can be read cover to cover, but it also allows selective reading. The best-known variant of pull production is kanban, but there are many more. If you make custom products or products in small quantities, you should also read CONWIP (constant work in process), but you may skip CONWIP if you only have make-to-stock production. If you have only flow production, you may not be interested in POLCA (paired-cell overlapping loops of cards with authorization). The aim is to give you practical advice beyond pure theory to help you decide which pull system is right for you, and how to set it up and maintain it. Chapter 3 compares the different approaches to pull production. This guides you in selecting the pull system best suited to your situation. Which one should you use for your situation? Which ones can be combined with others? As shown in Figure 1, Chapter 3 helps you to decide which pull system is most relevant to you.

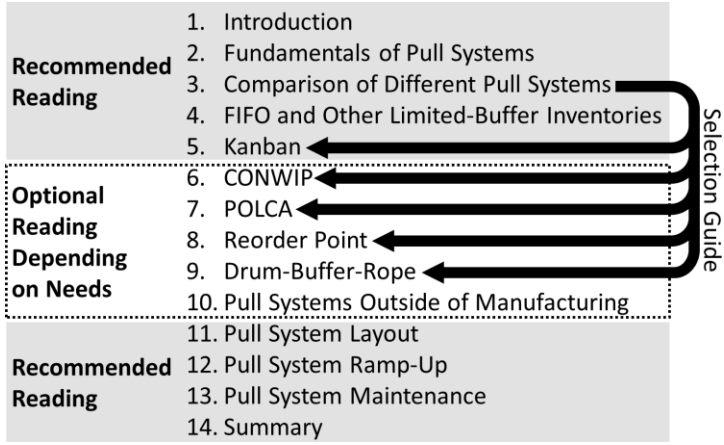

Figure 1: Overview of the chapters of this book (Image Roser)

Chapter 4 goes into the details of FIFO and its variants. Chapter 5 presents the important kanban system. Chapter 2 to Chapter 5 should be read regardless of your selected pull system, as they include many basics that will be helpful for other approaches. However, Chapter 6 to Chapter 10 can be read selectively based on your interests. Chapter 6 presents the CONWIP system for make-to-order. Chapter 7 introduces POLCA for job shops. Chapter 8 describes reorder points, which are well suited for purchasing. Chapter 9 outlines the drum-buffer-rope system popular with fans of the Theory of Constraints.

Chapter 10 goes into pull systems outside of traditional manufacturing and logistics. This includes healthcare, project management, development, administration, and construction. This chapter is not intended to be an in-depth coverage of these topics, but to give you inspiration about adaptations of pull outside of manufacturing.

Chapter 11 goes into more details on the layout of the pull system and helps you to decide where to make your pull loops. Chapter 12 describes how to ramp up a pull production, and Chapter 13 how to maintain it. Chapter 11 to Chapter 13 are again suggested reading for everybody, as they contain information relevant to any pull system.

Throughout this book I have hundreds of illustrations. Many of them are loosely based on value stream mapping. If you are unfamiliar with basic value stream maps, you will find a brief explanation in the appendix. The appendix also contains a list of variables, the theoretical COBACABANA pull method, and some recommended reading.

1.4 A Brief History of Pull Production

The concept of pull production is most commonly associated with kanban invented by Toyota. However, the idea itself precedes Toyota. One of the earliest instances of pull I know of were retail supermarkets. Before supermarkets, typical grocery stores had an attendant behind the counter. This person picked the goods you wanted from the shelf, calculated the prices, and then completed the transaction, handing you the goods in exchange for money. An example of a typical grocery store from around 1900 is shown in Figure 2.

Figure 2: A traditional grocery store around 1900, with attendants behind the counter (Image unknown author in public domain)

The Piggly Wiggly supermarket chain radically changed this concept in 1916 with their store in Memphis, Tennessee, USA. The customer walked in the store, picked up whatever they wanted, and then went to the checkout to pay. This was the first modern supermarket, a system you are surely familiar with. All items are labeled with prices. You have a basket, or a shopping cart, and your only human interaction is when you pay at the checkout. This was a radical change for its time, with large savings in labor cost far exceeding the losses due to theft. Nowadays it is the norm in most retail stores. One of the first Piggly Wiggly supermarkets from 1918 is shown in Figure 3.

Figure 3: The first Piggly Wiggly supermarket in Memphis, Tennessee, opened 1916. Photo from 1918. (Image Clarence Saunders in public domain)

The interesting part related to pull production, however, was behind the scenes. Piggly Wiggly had a system with a target stock level, and each day they simply reordered whatever they sold. Since they ordered only enough to refill the inventory to the target level, this, in effect, was a **reorder system**, and hence a pull system.

The idea of a supermarket also helped Toyota to develop kanban. The person responsible for the development of kanban at Toyota was Taiichi Ohno. At the beginning, Toyota was a spinning and weaving company. Their chief competitor, Nichibo (also known as Dai Nippon Spinning), outperformed Toyoda[3] both in quality and in cost. Ohno and his team studied Nichibo. Among other things, they learned that Nichibo had much less inventory and produced material in smaller batches.

Ohno, like many other Japanese at that time, were also very interested in the much more advanced technologies and methods of the United States. Back then, there were no retail supermarkets in Japan. However, Ohno had

[3] The family name is Toyoda with a "D". The car company eventually changed its name to Toyota with a "T" for easier international pronunciation and to have a lucky number of strokes in the Japanese writing, トヨタ. Hence, nowadays some companies in the group are called Toyoda (e.g., Toyoda Gosei), and others Toyota (e.g., Toyota Motor).

heard about these in high school, when a classmate made a presentation about his visit to the USA. This included pictures of modern supermarkets.[4] He took inspiration (and the name s*upermarket* for the managed inventory) from America for his production system at Toyota. The first implementation of these supermarkets at Toyota was by Taiichi Ohno in 1948.[5]

Continuously improving on these processes, the workers wrote small sheets of paper from 1953 onward to inform the production which parts to replenish. Soon, these scribbled notes turned into organized and color-coded cards. Taiichi Ohno visited the United States himself in 1956 and saw his first retail supermarket there. At this time, most material flow in his workshop was already controlled by pull, using these cards, although they were not yet known as **kanban**.[6]

Figure 4: Traditional engraved wooden kanban signboard over the entrance to a modern fashion store in Ginza, Tokyo, Japan (Image Roser)

[4] Masaaki Sato, *The Toyota Leaders: An Executive Guide* New York: Vertical, 2008, ISBN 1-934287-23-7.

[5] Christoph Roser, *"Faster, Better, Cheaper" in the History of Manufacturing: From the Stone Age to Lean Manufacturing and Beyond*, 1st ed. Productivity Press, 2016, ISBN 978-1-4987-5630-3.

[6] Please note that Ohno was not the only one experimenting with such pull systems. For example, in 1954 Lockheed also used similar systems in their production of jet aircraft.

Not until 1964 were those cards named kanban. In Japanese, *kanban* is written 看板. While commonly translated as "card", the original meaning is "signboard, billboard, or doorplate". Kanban is the proper name for the sign over a shop. An example of a traditional kanban over a modern store is shown in Figure 4.

In traditional Japan, this **kanban represents the reputation and honor of the store**. Maybe you have seen a kitschy martial arts movie, where the bad guy goes to another training hall (dojo), defeats the master, and then steals or destroys the sign (kanban) of the dojo. This destruction of the kanban is an additional act of humiliation for the defeated dojo master, as it also "destroys his honor".

It is said that when Taiichi Ohno named the cards for his production system, he named them *kanban* to emphasize the importance of this information for the proper functioning of the production system. The kanban is the honor of the factory, and you must not lose it! This kanban system as part of the Toyota Production System helped Toyota to become very successful. Toyota is still considered financially the most successful large car company, and it is the role model for lean manufacturing.

The Western world eventually noticed the different performance of car makers during the 1973 oil crisis, although lean itself only became popular around 1990. When the members of the Organization of Arab Petroleum Exporting Countries proclaimed an oil embargo, the world quickly ran short on fuel. Car sales fell. Gas stations ran out of gas, as shown in Figure 5.

Figure 5: "No gas" sign at a gas station during the 1973 oil crisis (Image David Falconer in public domain)

Especially American car makers with gas-guzzling vehicles had problems. They soon were overwhelmed by their unsold stock of cars. Toyota, on the other hand, could ramp down production reasonably well. After the crisis, carmakers had the opposite problem of ramping up production again. With the help of their pull production system, Toyota also managed much better.

A report by MIT and the subsequent book, *The Machine that changed the World*, summarized these achievements.[7] This publication put the Toyota Production System and hence pull production on the agenda of Western manufacturing. They found many facts embarrassing to the Western world. American carmakers needed twice as much labor time to make a car. German carmakers needed as many employees at the end of the line to fix problems as they needed to make a car to begin with. In pretty much all aspects, Toyota fared much better. This started the rest of the world's interest in the Toyota Production System, later renamed **lean production**. In the Western world, kanban is sometimes even used as a synonym for pull, as it is the best-known pull system.

However, there are more pull systems, as we will see later in this book. While their history is not as extensive, I would also like to briefly mention where they originated. Chronologically closest to kanban is **drum-buffer-rope**. This approach was coined by Eliyahu Goldratt as part of his "Theory of Constraints" (TOC) philosophy starting with the book *The Goal* in 1984.[8] The term *drum-buffer-rope*, however, got its name only later in his book *The Race*.[9]

Goldratt took inspiration for this from many other ideas, usually without giving credit. There are many similar but less famous methods by others that precede *The Goal*, as for example "Systems Dynamics" developed by Jay Forrester in the 1950s; "Critical Path Method" by Morgan R. Walker in the 1950s; "Program Evaluation and Review Technique" (PERT) by the US Navy in 1957; and Wolfgang Mewes' "Bottleneck-focused Strategy" in 1963.

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[7] James P. Womack, *The Machine That Changed the World: Based on the Massachusetts Institute of Technology 5-Million-Dollar 5-Year Study on the Future of the Automobile* New York: Rawson Associates, 1990, ISBN 0-89256-350-8.

[8] Eliyahu M. Goldratt and Jeff Cox, *The Goal: A Process of Ongoing Improvement*, 2nd revised ed. North River Press, 1992, ISBN 0-88427-178-1.

[9] Eliyahu M. Goldratt and Robert E. Fox, *The Race* Croton-on-Hudson, New York, USA: North River Press Inc., 1986, ISBN 978-0-88427-062-1.

Many other respected scientists claim that Goldratt's methods often lack mathematic rigor and are inferior to other methods.[10, 11]

Goldratt promoted his methods heavily, just when "lean" was gaining ground in the West. Some rejected the "Japanese lean" and preferred the "Western" Goldratt simply because the Japanese were, in their mind, still the enemy defeated in World War II with two nuclear bombs. Goldratt gained popularity, and even though he died in 2011, his methods still have a strong following.

Another pull system called **CONWIP** (constant work in process) was coined in an often-cited paper by Hopp and Spearman in 1990.[12] It is used for make-to-order production. It is also very similar to kanban and easy to use. This is especially noteworthy as, unlike drum-buffer-rope, there was not any major commercial promotion for CONWIP. However, it is usually not known under the name CONWIP, and often is not even properly named at all. The most common usage is as a make-to-order production line, where the limited number of slots on the line represents the target limit on inventory. The method is important, but lacks a well-recognized name. Within this book I will use the name CONWIP to explain the details behind this approach. However, please don't get hung up on the name, as the approach itself is quite useful.

The lesser-known **POLCA** pull system is a method developed by Rajan Suri in the 1990s. His first book, *Quick Response Manufacturing: A Companywide Approach to Reducing Lead Times*, was published in 1998.[13] POLCA has a

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[10] Dan Trietsch, *Why a Critical Path by Any Other Name Would Smell Less Sweet? Towards a Holistic Approach to PERT/CPM*, *Project Management Journal* 36 2005: 27–36.

[11] Dan Trietsch, *From Management by Constraints (MBC) to Management by Criticalities (MBC II)*, *Human Systems Management* 24 January 1, 2005: 105–15.

[12] Mark L. Spearman, David L. Woodruff, and Wallace J. Hopp, *CONWIP: A Pull Alternative to Kanban*, *International Journal of Production Research* 28, no. 5 May 1, 1990: 879–94.

[13] Rajan Suri, *Quick Response Manufacturing: A Companywide Approach to Reducing Lead Times* Portland, Oregon, USA: Taylor & Francis Inc, 1998, ISBN 978-1-56327-201-1.

small but dedicated group of followers. If you want to explore POLCA, a later book by Suri, *The Practitioner's Guide to POLCA*, is more helpful.[14]

[14] Rajan Suri, *The Practitioner's Guide to POLCA: The Production Control System for High-Mix, Low-Volume and Custom Products* Productivity Press, 2018, ISBN 978-1-138-21064-6.