A PRACTICAL GUIDE TO TRANSFORM MANUFACTURING OPERATIONS WITH SMART PULL

White Paper

EXECUTIVE SUMMARY

Manufacturing equipment is getting smarter. Machines, devices, sensors, Radio-Frequency Identification (RFID) tags, robots and automation controllers are now being connected together with the latest network technologies. Recent breakthroughs enable new levels of collaboration, allowing virtually any device or manufacturing resource to be more location-, context- and environment-aware to respond faster to change. The "smart factory" of the future promises to achieve a whole new level of efficiency and agility that was not previously thought possible.

This set of technologies is now referred to as the Industrial Internet of Things (IIoT), a subset of the Internet of Things (IoT). A transformation is underway that is changing how goods are produced and services are managed in the industrial world. The outcome is predicted to be nothing short of revolutionary. While there is much information overflowing public media with regards to new technologies, not much has been presented on the mechanism of business process transformation being brought about.

The mechanism of "Pull" processes—those triggered by an actual event instead of a forecast—is nothing new. It is at the heart of many successful manufacturing strategies, including Make-to-Order (MTO) and Just-in-Time (JIT) operational models. John Hagel III, John Seely Brown, and Lang Davison wrote The Power of Pull, a book that refers to the ability to draw out people and resources as needed so as to best address opportunities and challenges without sole reliance on a plan or forecast. Recent technological advances in digitization, including the harnessing of Big Data analytics, the use of the cloud, Business Process Management (BPM), social media, IIoT, and mobility, have extended the power of Pull beyond Lean manufacturing.

By systematically directing people and resources to focus on a confirmed demand versus a forecast, Pull processes can further minimize waste from forecast error while increasing responsiveness to unpredictable events. New opportunities are now unfolding, such as Manufacturing-as-a-Service (MaaS), where manufacturing capacity is sold as a utility that is charged based on actual demand consumption. This is a step further than replenishment of inventory based on actual consumption of material. By the same token, 3D printing can perform similarly by reducing manufacturing lead time and enabling products to be made and delivered according to a specific design that has been confirmed virtually.

In light of these new developments, this white paper will focus on the mechanism of business transformation enabled by these technologies, which can be attributed to two major forces: the power of Pull and digitization. Nine practical applications are detailed, showing how innovative manufacturers can better leverage digital technologies to achieve new levels of operational excellence. Dassault Systèmes calls the synergized effect of these forces "Smart Pull."

"Industry and academic leaders agree that digital manufacturing technologies will transform every link in the manufacturing value chain, from research and development, supply chain, and factory operations to marketing, sales, and service. Digital connectivity among designers, managers, workers, consumers, and physical industrial assets will unlock enormous value and change the manufacturing landscape forever."

McKinsey & Company
Digital manufacturing:
The revolution will be virtualized
(2015)

What is Pull?

A Pull process is a business process triggered by an actual event. In contrast, a Push process is triggered by a planned schedule or a forecast.

The operational model of a typical manufacturing company is complex and multi-layered. Large systems are constituted by many smaller subsystems constantly interacting with each other. Pull and Push processes can co-exist at different subsystems in an enterprise's operations model.

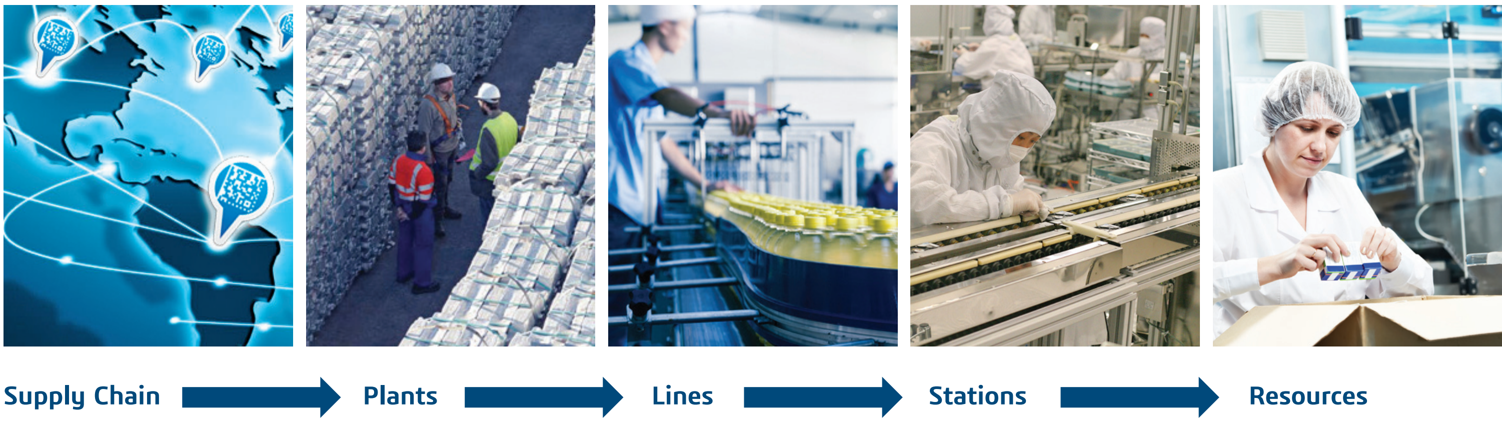

Figure 1
Pull and Push processes can co-exist at different subsystems in an enterprise's operations model.

Traditional Pull is sometimes referred as MTO operations, which is a supply chain layer model. Although business processes triggered by an actual customer order clearly fall into the category of Pull, Make-to-Stock (MTS) operations can also leverage Pull. For example, during the period of time when Taiichi Ohno[1] applied Pull concepts to production at Toyota, the sequenced schedule of making cars was typically based on a monthly forecast, which is a Push process at the supply chain layer. Pull was used to replenish the strategic stock points between plants, lines and stations, while the supply chain level model was still MTS.

Pull processes are generally recognized as a tool to achieve JIT, one of the two pillars of Lean Manufacturing. However, Pull can be applied in many other ways outside of the context of Lean Manufacturing. For example, Pull can apply to domains beyond material flow, such as quality, maintenance, and engineering, which we call multi-domain Pull processes that will be discussed later in this white paper.

1 Taiichi Ohno is considered to be the father of the Toyota Production System, which became Lean Manufacturing in the U.S.; http://en.wikipedia.org/wiki/Taiichi_Ohno

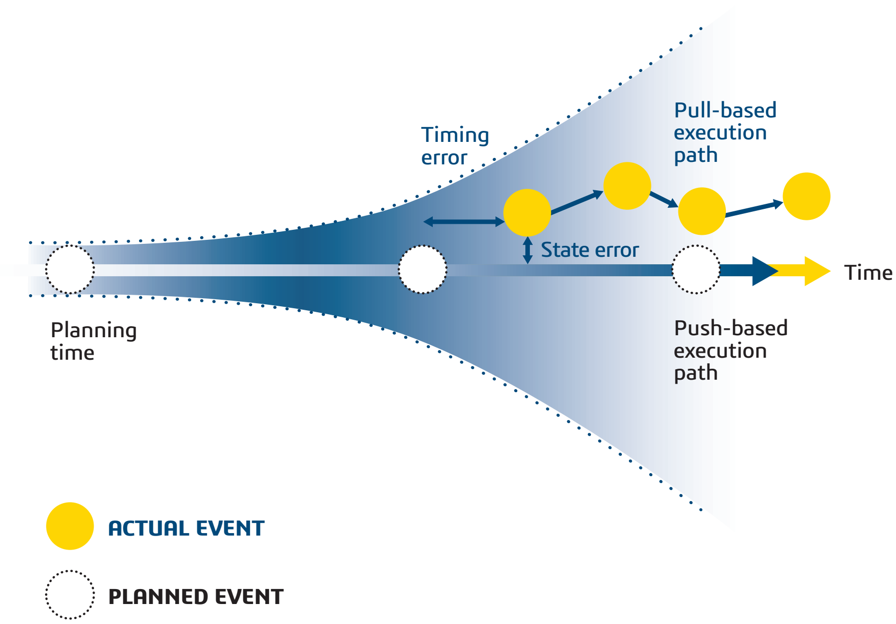

Figure 2
Pull processes enable execution to compensate for forecast errors as events occur, resulting in a more optimal execution path than the one based on Push.

Pull process is the key to enable efficient mass customization. While the terminology of mass customization has existed for a few decades, the new Smart Pull processes can take mass customization to new levels. Here are three major types of mass customization based on Pull.

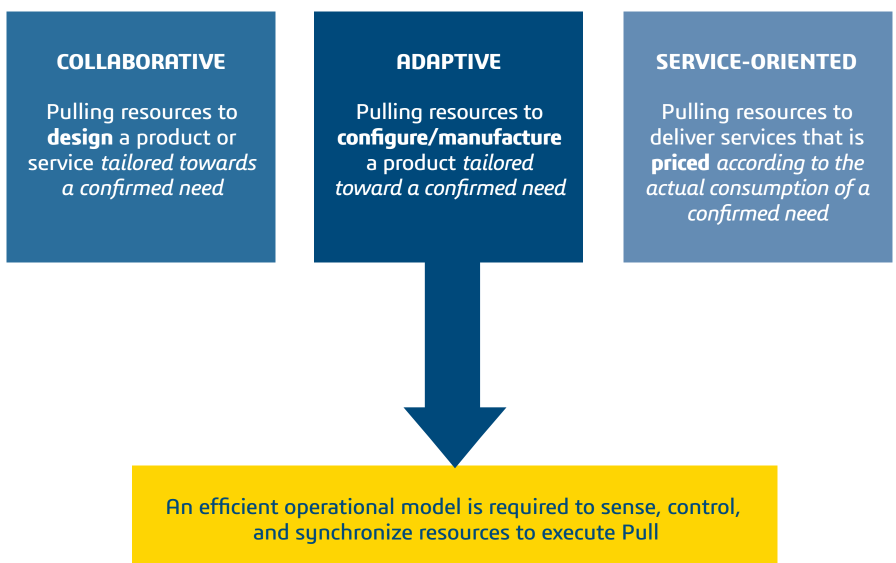

Figure 3
Types of mass customization enabled by Smart Pull.

Collaborative Pull—The ability to draw out people and resources inside and outside an organization to collaboratively design a solution that addresses a need as it appears. Some of the key technology enablers are virtual prototyping, simulation, additive manufacturing, social networking, and enterprise search. These technologies enable people and resources across the globe to be identified quickly to work on a design or to solve a particular challenge, and to do so with better efficiency. An example is Chinese manufacturer Haier's rapid development of the smart air conditioner Tianzun. Haier discovered a new need for an air conditioner that does not generate strong airflow causing "air conditioner disease". They did not have the expertise to develop such an air conditioner on their own so they recruited multiple companies to help them through their open innovation platform. As a result, the Tianzum smart air conditioner was brought to market in less than nine months.

Service-oriented Pull—The ability to deliver a capability or service that address a need as it appears. Famous examples are Uber personal transportation services or Airbnb lodging services. In each of these cases, a transportation or accommodation is delivered as a service to address a customer's confirmed need through a social platform powered by apps. In many cases, the pricing model is also based on the actual consumption of these services. This way, the hidden capacity of machines and equipment is being matched to a confirmed need to create a unique customer experience. MaaS is the consumption of manufacturing capacity as a service. Enabling technologies including IoT, intelligent sensors, cloud computing, and social network platforms that carry out transactions required for matching sellers and consumers on-demand. An example in manufacturing is a washing machine subscription services provided by a Dutch startup named Bundles. Users can pay for their usage instead of buying a high-end Miele washing machine that has installed a smart sensor to track usage. Detergent is managed like a printer ink cartridge to be replaced automatically when consumed.

Adaptive Pull—This is the most common type of Pull used in manufacturing and logistics operations. Within traditional Lean Manufacturing, Pull-based processes are being powered by digital technologies to go beyond elimination of over-production and inventory. Quality, maintenance, costing, procurement, production, and inventory control can leverage these types of Pull processes. For example, a large number of real-time quality data can be gathered to analyze and benchmark across global production sites. Frontline workers and managers can now be automatically notified based on risks identified from such actual data. This is again a form of digital Pull that can be used to trigger an action based on actual data instead of a forecast. Enabling technologies include intelligent sensors, Machine-to-Machine (M2M), IoT, Big Data analytics, BPM, simulation, and digital modeling.

The three different types of Pull processes can be mixed and matched to create new customer experiences or to pursue a new level of efficiency. An example of a Mixed Pull is the case of an agricultural equipment manufacturer. They put sensors on their agricultural equipment to gather usage data at the field. Based on these data collected and analyzed, they now offer a value-added service to the customers on how to better optimize their farming operations. At the same time, such information is used to understand demand patterns. This knowledge lets the manufacturer know when to sell what types of equipment and to which type of user. In this scenario, an equipment manufacturer and farmers work collaboratively to optimize farming operations (Collaborative Pull). The data analysis can then be sold as a service (Service-oriented Pull). The selling of additional equipment based on actual demand is also a type of Demand Pull (Adaptive Pull).

The focus of this white paper is on manufacturing operations management so it focuses on an adaptive type of mass customization. However, the principle of Pull process discussed can be equally well applied to collaborative and service-oriented types of models.

How Does Pull Work?

A Pull process typically has the following steps:

1. **Sensing an actual event**—Examples of actual manufacturing events include the completion of an assembly unit, the consumption of material, the halting of a machine, or the detection of a quality defect. In the context of supply chain operations, these events can be a confirmed customer order or a confirmed shipment.
2. **Evaluating against a digital model**—An example of a simple model is the static max/min criteria of a pull-based inventory replenishment model used in a traditional Kanban process. A more complex digital model could include quality and machine status. A quick optimization step to assess multiple what-if scenarios based on a digital model can drastically improve the effectiveness of the Pull process.

3. **Determining what process should be executed next**—As outlined in the previous step, a Pull process must be capable of making a determination of what is the appropriate process to execute next, such as starting a production job or not doing anything. When a digital model is used, the next step may go beyond pre-defined options and be dynamically determined.
4. **Assigning resources necessary for the next step**—For example, assigning containers, machine or skilled operators to perform the next step is based on business rules. In most Pull processes, resources are pre-assigned based on a plan. In cases where there is competition for resources, advanced logic might be used to assign resources.
5. **Executing the business process**—Examples of process execution include: starting a production job, picking a quantity of materials, repairing a machine, or investigating a quality defect. The design of the process parameters is critical to ensure process effectiveness.

These five steps typically occur almost simultaneously, triggered from an actual event. A single Pull process can trigger subsequent processes. For example, the arrival of an order in the Original Equipment Manufacturer (OEM) model could trigger in-house assembly processes and supplier replenishments.

Since a Pull process is generally more concerned about the next few immediate steps, a chain of Pull processes are sometimes criticized of amplifying the propagation of fluctuations, similar to the bull-whip effect in the supply chain. It is therefore necessary to rely on well-founded design, simulation, monitoring, and control methods to ensure smooth execution of Pull processes. Some of these are discussed in the following sections.

Although forecasting methods that project execution paths into the future are usually not part of a Pull process, there are many ways that Push and Pull can work together. For instance, scheduling and forecasting processes can sometimes be triggered by Pull and hence result in a combined Pull and Push business process.

A Smarter Pull

Manufacturers have implemented many electronic Kanban (eKanban) or Pull systems to digitize traditional paper-based processes. This kind of implementation offers the obvious benefits of improving the durability of paper Kanban, enabling transmission of the Kanban signal across a broader distance and allowing real-time status updates. However, the mere automation of traditional Pull-based processes misses the true potential of Pull.

Here are a few examples of smarter Pull processes:

- **Multiple- or cross-domain Pull processes**—Traditional Pull-based methods are based on single domain data, typically an inventory quantity with an application to Pull material flows. Smart Pull replenishment can now utilize information from multiple domains (such as quality trends, production yield, or an equipment failure record from an IIoT machine sensor) to optimize a replenishment quantity or a safety stock setting.
- **Automated, long-range and multi-domain event sensing**—Use of RFID sensors and scales to automate the detection of material consumption activities and then remotely triggering a supplier to replenish a part.
- **Real-time insights, higher order statistics, and digital model driven determination**—A replenishment Pull process that utilizes a dynamic buffer calculation, which is based on not only first-order data points, but also on second or higher order statistics, such as dynamically updated probability distribution parameters. These are techniques used to optimize replenishment processes.[2]

2 In some advanced scenarios it might be necessary to evaluate more than just a static metric comparison to determine a next step. Two examples are rule-based inference engines and agent-based bid-and-ask processes. Smarter next steps could consider a larger range of options, such as reserving more production capacity or increasing a time buffer, if replenishment signals should suddenly accelerate based on new demand for finished goods. And, at times, it can be beneficial to have greater human involvement in decision-making when determining next steps. In these cases, Smart Pull can actively notify decision makers with recommended options before a next step is executed.

- **Multi-domain and dynamic process parameters**—Controlling the maximum number of Kanbans run by intelligent Kanban agents. The maximum Kanban number in a Kanban loop is typically a static parameter. Controlling this parameter according to dynamic information relating to "traffic jams" within the Kanban loop can relax production leveling preconditions, helping to run a smooth Kanban process to improve overall robustness.
- **Multi-domain and dynamically defined process flow**—A Drum-Buffer-Rope (DBR) process that detects a bottleneck shift, and then repositions a Buffer and Rope dynamically.
- **Dynamic resources collaboration**—The identification and assignment of an alternative machine or production line to cope with an unexpected event, such as a supply chain disruption or new customer requirement. In a design and engineering context, this can mean identification of a technology and its resources to design a particular product as demand emerged.

Figure 4 summarizes the key differences of traditional and Smart Pull mechanisms.

	TRADITIONAL PULL	SMART PULL	SMART PULL ENABLERS
Scope	Single domain (typically applies to inventory management)	Multiple domains (example: production, warehouse, quality, maintenance, people and equipment, design and engineering)	Manufacturing BPM platform enables multiple domain integration via a unified architecture with seamless integration to Product Lifecycle Management (PLM) and Enterprise Resource Planning (ERP)
Sensing Actual Events	• Manual • Single • Short distance	• Automatic • Multiple • Not limited by distance	Mobility, barcodes, RFID, IoT, industrial sensors
Determining Next Steps	• Raw-data-driven • First order data • Static rules	• Insight-driven • Higher order statistics • Dynamic; more options • Digital model-driven	BPM, Big Data, manufacturing intelligence, inference engine, real-time analytics, discrete event simulation, digital modelling, optimization engine, social media, and collaboration
Process Parameter	• Single domain • Pre-defined • Simplistic rule-based	• Multiple domains • Dynamically defined • Intelligence-based	BPM, Big Data, manufacturing intelligence, real-time analytics, discrete event simulation, digital modelling
Process Flow	• Predefined • Single domain	• Dynamically defined • Multiple domains • Multiple process options	PM, Big Data, manufacturing intelligence, real-time analytics
Resource Usage	• Predefined and pre-assigned in process	• As-needed collaboration • Dynamic resource allocation	BPM, agent technology, enterprise social, cloud computing, optimization engine

Figure 4
Comparison of Traditional and Smart Pull and enabling technologies

Enabling Smart Pull

IT systems drive information flows that business processes are based upon. The mechanism of Pull requires an enterprise IT architecture that is more well-connected, real-time, flexible, extended, and integrated than a traditional one that is centered on planning systems, such as ERP.

Most manufacturers have invested in many IT systems to improve operational performance, responsiveness, and planning. The problem is that seldom does each of these systems work well together and most of them cannot cope with changes required for ongoing business transformation. What is needed is a new approach—one akin to how well the human body operates. If a manufacturing enterprise could adapt and operate with the responsiveness of the systems Mother Nature has provided us, the manufacturing world would be quite different.

These scenarios are now possible—through the use of a flexible and scalable Pull IT platform that encompasses all the above mentioned IT enablers and is yet scalable and adaptable. This is akin to the central nerve system of operations, while ERP is providing the general long-term direction on where to go. Aside from real-time execution and sensing, this Pull platform can tune its reflex actions through digital models and simulation. Meanwhile, such a platform has the capability to evolve and adapt quickly as business requirements change. Together, these systems could provide the foundation for the greatest success and likelihood for survival.

This need for a platform approach to Smart Pull has led to evolution from the traditional ISA-95 manufacturing architecture to one that encompasses layers of technologies at the Operations Management Systems level as illustrated in Figure 5.

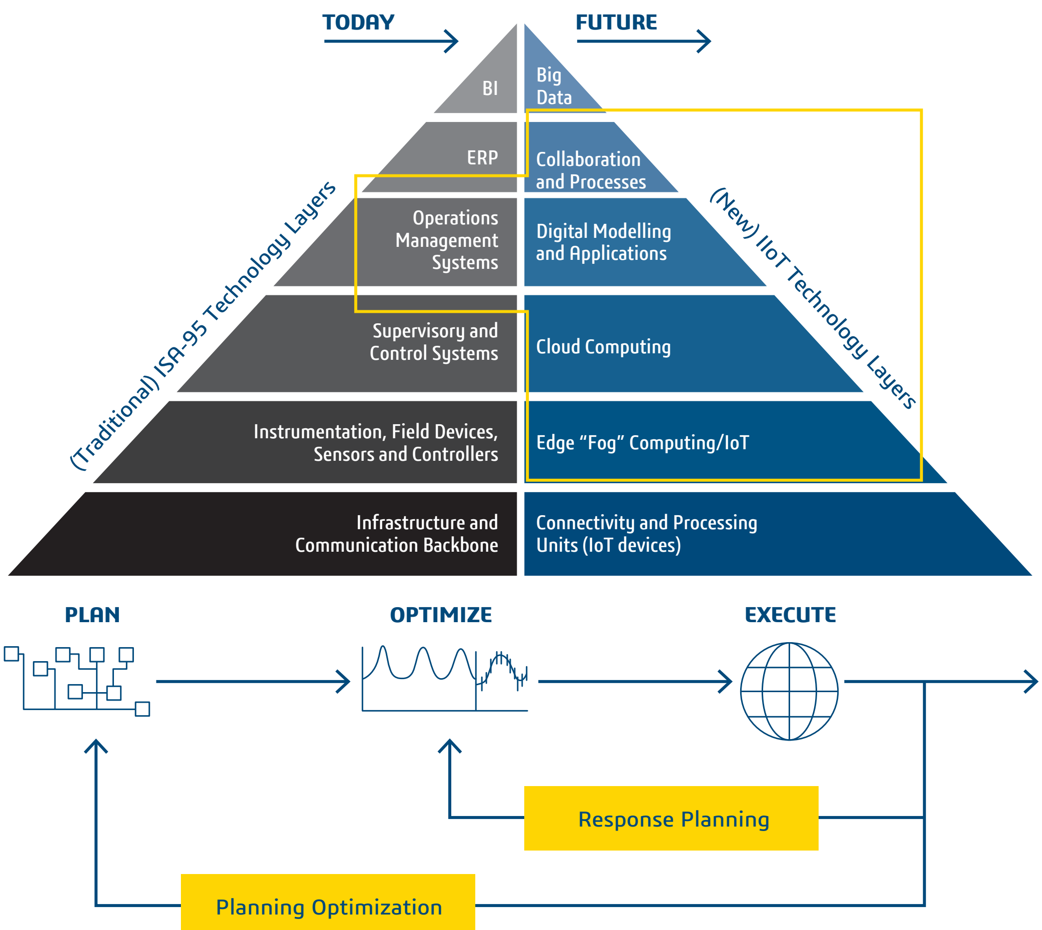

Figure 5
With this new architecture, Pull process is not confined to single-domain events within the four walls of a factory. It is now possible to transform how traditional Lean Manufacturing is being implemented.

Challenging Lean

Historical Pull techniques developed within the context of Lean Manufacturing has led to a number of presumptions on how to apply Pull. However, these common beliefs were established without taking into consideration any of the above mentioned Smart Pull capabilities. Let's examine some of these more closely.

Presumption 1: Before applying Pull, organizations need to be mature in Lean, extending the time it takes to succeed

It is said that Toyota took 20 years to make their Kanban-Pull system work. Before successfully applying Pull to the production process, Toyota developed a Lean culture, succeeded in Single-Minute Exchange of Die (SMED), institutionalized production leveling, and established a continuous production flow. While each of these factors is important to achieve long-term success, today's Smart Pull solutions can significantly reduce the time-to-value of Pull implementation.

Case 1: Accelerating business transformation at a corrective lens manufacturer

A manufacturer operating in a highly competitive consumer goods segment is a global producer of corrective lenses. One of their key business drivers is lead time. Minimizing customer wait time is directly correlated to higher customer satisfaction. Before implementing Pull, this firm's production processes were Push-based where the primary driver was simply to maximize output. As a result, processes were out of sync, and led to significant queuing of materials between operations. The average production lead time was over three days.

Their Smart Pull solution now includes logic to calculate how lenses of different diameters can optimally fit into Kanban-labeled containers and to determine the optimal sequence for production. As a result, production lead time was shortened by more than 25 percent, right after the Go-Live of their Pull solution. During the transition from Push to Pull, operators were not in the habit of following the rule that jobs were pulled by Kanban signals. Real-time monitoring and feedback of Kanban status was found critical to accelerate the transformation process. Subsequently, this manufacturer successfully reduced lead time by almost another 50 percent while increasing volume and product mix by almost fourfold. This solution has now been successfully rolled out to 15 plants across the globe.

Presumption 2: The primary purpose of Pull is to eliminate inventory and overproduction

Lean Manufacturing was originally developed to eliminate waste, initially observed in the US automotive industry. Overproduction and inventory are the primary kinds of waste; other types include excess movement, waiting, transportation, processing, and defects. While Pull techniques are very effective to control material flows and reduce inventory, they can be used to tackle other, more pressing challenges.

For example, the cost of material and inventory in a pharmaceutical manufacturing environment is typically not very important. It is very common to leverage excess inventory to ease more imperative logistic challenges. In this case, Smart Pull techniques can be effectively leveraged to accelerate approval processes, speed up response times to quality events, reduce critical machine downtime, and improve profit velocity rather than to reduce inventory.

Case 2: Achieving operational excellence at a heavy equipment manufacturer

A heavy equipment manufacturer made a strategic investment by building a model factory at a plant in Europe. A BPM platform for manufacturing operations management was implemented supporting Pull processes to reduce machine downtime. Repair orders are now automatically triggered by machine downtime events and then sent to repair and maintenance staffs. Intelligent rules have sped up diagnostics of machine issues and minimized repair part shortages, significantly improving overall throughput without the need for further machine investment. This solution is now being rolled out to other plants across the globe.

Presumption 3: Pull should be implemented without reliance on computers

Lean Manufacturing was developed when computers focused on centralized planning and scheduling. Material Requirement Planning (MRP) was invented in the US during the 1960s. From the 1960s to 1990s, computerized planning has evolved considerably. MRP, MRPII, ERP, and then Advanced Planning and Scheduling (APS) are all trying to leverage the calculation power of computers to come up with an optimized plan. This plan basically consists of starting and finishing times for hundreds and thousands of tasks in manufacturing operations. It was the operations manager's responsibility to ensure the execution of the 5 M's processes (Man, Machine, Material, Method and Measurement) obeyed the optimized plan that was generated by the black box of a computer.

This use of computers ran against the philosophy of Lean, which encourages Genchi Genbutsu or "go and see first-hand" over reliance on a computer's black box approach. Ohno, however, was not against the use of computers. He believed that computers could help to realize his vision, but the kind of computer technology that he needed was either not possible or too expensive at that time.

Today, computing and information technology has advanced considerably from Ohno's day. With smart tags such as RFID, each unit of product can now carry all the information regarding its own manufacturing and logistic process. Leveraging context- and location-awareness capabilities, necessary information can be delivered to operators and workstations at the right time and place without creating any excessive burdens.

"Computers could relay information to each process when it is needed. Setting up the computers, however… is not only expensive but often unreliable… In business, excess information must be suppressed. Toyota suppressed it by letting the products being produced carry the information."

—Taiichi Ohno, 1988

Case 3: Institutionalizing Lean globally at an industrial equipment manufacturer

An industrial equipment manufacturer has a high level of Lean maturity at one of its excavator facilities in Asia. Material released to the four fabrication and final assembly lines are triggered by Pull signals downstream, generated by the completion of excavator units. This is a type of CONstant Work in Process (CONWIP) process that regulates the maximum Work in Process (WIP) in the loop, to avoid WIP explosion. The implementation of these Pull processes is fully automated and paperless. Smart logic optimizes sequences to balance production loads, as different units entail different configuration options. The material feeding sequences to workstations is also controlled by Smart Pull. In this way, material is made available at the right station at the right time, even if every unit on the assembly line has different material requirements. This manufacturer successfully rolled out this solution to five other facilities, each with different Lean maturity levels.

Without the use of computing technologies, it would not be possible to handle the complex load balancing optimization and sequence dispatching that is now required within manufacturing processes. Manually handling sequences with paper Kanbans would greatly reduce operational agility. The use of a BPM platform with Smart Pull cannot only improve operational flexibility and responsiveness, but also enable fast, global rollouts of Lean best practices, which was previously not possible.

Best Practices to Use Smart Pull

Now that we have seen some of the actual results that can be achieved when implementing a Smart Pull manufacturing strategy, here are some best practices to accelerate response times, further reduce waste, and in the end, elevate operations to new levels of excellence.

1. Leveraging "higher order" information

Information that is collected directly from an event is raw or first-order data. Common examples include operation cycle time, completed quantity, actual cost, and others. Planning parameters are often derived from the long-term average of first-order data. Examples include standard cycle time and standard cost. Information that is seldom leveraged as part of a business process is the second or higher order statistics, derived from first-order data. Examples include standard deviation, moving average of lead times, or probability distributions of completed quantity and actual cost. Given the capabilities of Smart Pull, this higher order information can now be synthesized in real-time, and then applied to streamline performance.

Example—Smarter Replenishment

Pull replenishment of material is most suitable for materials that have a relatively stable supply and demand pattern. The application of Smart Pull can further reduce inventory by updating replenishment parameters according to the latest demand trend statistics with considerations of current supply side constraints. This approach applies well to replenish either supplier or internal line side inventories.

Figure 6 illustrates the potential benefits of Smart Pull when applied to inventory replenishment processes. The blue line shows actual inventory levels of a component material. The gray line shows simulated inventory movement, based on applying a dynamic buffer replenishment process. Under this scenario, average stock levels could be reduced by almost 70% without incurring any inventory shortage. Alternatively, a 50%+ reduction in safety stock buffer levels appears possible, when comparing a dynamic buffer (black line) with a static buffer (yellow line). This dynamic buffer is calculated based on second-order statistics such as standard deviation and moving average instead of a static trigger point used by most traditional replenishment strategies.

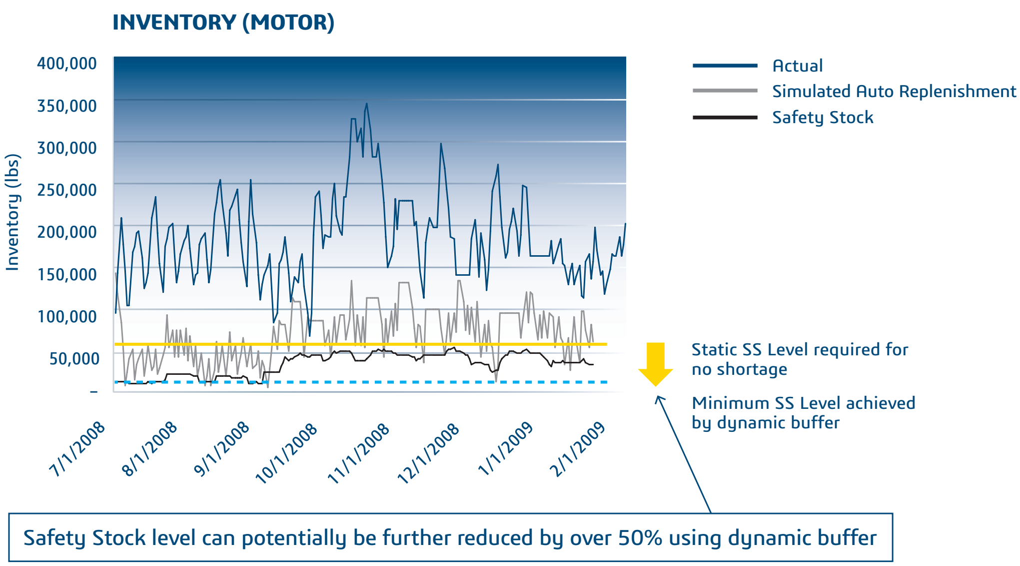

Figure 6
Smart Pull can reduce Safety Stock Levels.

2. Increasing robustness of Pull processes

Many manufacturers are challenged when implementing traditional Kanban processes. One of the reasons is that Kanban is a multi-stage Pull system—a fluctuation at one stage is easily amplified by responses from the next stage, leading to further fluctuations down the chain. Smart Pull can help to improve the robustness of Pull processes while avoiding unnecessary gyrations of inventory levels by:

- Enabling real-time visibility to Kanban status and WIP with alerts and alarms that can actively provide notification to react faster to over-fluctuation events (see Case 1).
- Providing greater flexibility with the design and effectiveness of Kanban or Pull loops; for example, a CONWIP process can reduce the number of stages in a typical Kanban loop while offering a better way to minimize the impact of fluctuations (see Case 3).
- Automating Pull process control mechanisms, based on access to the real-time status of a Kanban or WIP. For example, advanced algorithms can be implemented to actively monitor traffic jams in Kanban loops and can then adjust control parameters such as number of Kanban or maximum WIP quantity accordingly.

3. Complementing Push with Pull and vice versa

It is a continual challenge for manufacturers to optimize how Push and Pull processes can best work together. Applying intelligence to make Pull processes smart helps to overcome this challenge, based on the following guidelines:

- **Use Pull to trigger stable demand items and Push for irregular items**—This approach applies to both finished product build and component supply strategies. For example, even in an Engineering-to-Order (ETO) or special project-based type of operation, traditional Pull processes can only be used to manage the material flow of commonly used components across different products. Such components exhibit a steadier demand pattern. Smart Pull enables the mixing of Push and Pull processes within the same production operation to effectively address different material consumption patterns.

Case 4: Mixing MTO and MTS in assembly at an automotive supplier

An automotive supplier had to supply its automotive OEM customers according to the specific sequence of the OEM's assembly line. While others coped with this requirement by piling up finished goods stock and then shipping-to-sequence, this car seat manufacturer drastically reduced inventory by moving to a Make-to-Sequence (MTS) model instead. A key enabler of this advance was implementation of a Smart Pull solution that allowed not only the assembly of final finished goods, but also the fabrication of supplying semi-finished goods according to sequence. In the same production line, MTS was adopted for black color seat production whenever extra capacity is available, whereas MTO is executed for all other special colors.

- **Using Pull to improve data accuracy in Push**—Standard lead time, cost, and capacity parameters are examples of typical master data in ERP and scheduling systems that can be improved by Pull. Any significant deviation of the actual data from the standard planned quantity can be configured to update such master data automatically.
- **Using Pull to simplify plan and order management**—Planning and scheduling systems are typically used to determine start and end times for thousands of orders, including not only production and material transfer orders, but also maintenance, inspection, and other types of orders. Using Smart Pull can simplify this task. Instead of enforcing start and end time of so many orders, Pull enables operations to flow. Managers can monitor more meaningful parameters of the operations such as throughput, capacity, WIP level, and Pull trigger points. These are the parameters that the flow depends on and hence can greatly enable managers to be in control without managing detail schedules of thousands of tasks and orders.

Case 5: Letting the product speak at an industrial equipment manufacturer

At an engine plant there is, at any given time, several hundred possible configurations that could be produced. Each engine has a unique identifying RFID tag. When an engine arrives at a workstation, the unique ID is read and the corresponding routing and specifications of manufacturing details are pulled to the workstation. The operator then carries out the specific manufacturing tasks for this engine unit to build an order of one.

- **Using Pull to improve detailed scheduling**—Detailed scheduling is only accurate for a short time into the future. Smart Pull processes are an effective way to trigger scheduling that can improve planning accuracy by avoiding over- or under-frequent rescheduling.

Case 6: Adding Pull to manage dynamic, detailed scheduling

A synthetic fiber production facility has up to 70 machines running at any given time, with each machine having several spindles. While master scheduling at the machine level is conducted on a regularly scheduled interval, detailed scheduling is pulled by machine event. This is because the generation of complex manual tasks is required to support spindle level production processes, such as the preparation work for each spindle. Stop and start events of spindles are used to trigger a push-based detailed scheduling program to achieve greater labor efficiency and minimize downtime.

4. Using digital model simulation in combination with Pull

Aside from using actual data to improve traditional planning, information collected by smart sensors and devices can also be used as parameters in digital modelling to improve the next step or next shift in execution, resulting in better asset utilization, yield, and throughput. There are a wide variety of modelling techniques available for such purposes, including discrete event simulation, multivariate statistics, linear/non-linear programming, heuristics, and artificial intelligence. Many of these techniques have been available for decades, but their usage was not widespread. IIoT is quickly becoming an enabler because it streamlines the free flow of digital information between the frontline of operations and the digital modelling engine at the backend. Recent advancement in these modelling tools has led to adequate performance; user-friendly interfaces have empowered those who do not necessary have computer science or mathematical training to benefit.

Case 7: Pull-based line balancing with discrete event simulation

A telecommunication device manufacturer has its assembly and testing operations in a line configuration. The company faced a challenge of balancing the line when starting to produce mixed products, each with different cycle times. Each testing machine cost millions of dollars, so a poorly balanced line would result in low asset utilization. Each unit was provided a unique ID, which then allowed that ID to drive the production flow, similar to what was described in Case 5. The manufacturer then collected cycle time data on each unit to feed a discrete event simulator that predicts and optimizes the utilization of the testing machines before every shift. This new process lets products flow in an optimized way unrestricted by the line configuration. Asset utilization and throughput was drastically improved as a result.

5. Improving human decisions with Pull

Pull processes need not be entirely automated. In many situations, it makes better sense to add Smart Pull to enhance human decision making, especially when dealing with uncertain situations that are complex and rare. Smart Pull processes have the capability to sense large volume of real-time events and to filter and identify those that are important to the concerned individuals. Examples include the sending of active notifications to trigger worker involvement to then decide an appropriate action.

6. Making Lean "stick"

Many organizations are challenged to make Lean initiatives "stick" beyond initial success. IT tools can be leveraged to measure Kaizen results, benchmark across facilities, and globally deploy processes. Case 1 and Case 3 are classical examples of using Smart Pull processes to improve the chances that a new Lean process improvement is maintained.

7. Expanding Pull to quality and maintenance

Case 2 is a good example of how Smart Pull processes can be used to improve machine uptime and equipment maintenance efficiency. Leverage Smart Pull process to respond faster to quality events and containment requirements, which can be implemented not only at a factory, but also across a supply chain.

8. Extending Pull to supply chain partners and customers

There are many ways to expand Pull to partners and customers. These include, but are not restricted to, supplier Kanban processes, synchronization of outsourced production, and supply chain quality management. A mix of push and pull strategy is commonly used to balance the need to minimize excess inventory and to meet short lead-time requirements of customers. Smart Pull can leverage the last optimization engine technology with real-time detail visibility of the supply chain to streamline overall material flow.

Case 8: Synchronizing outsourced ETO operations with Pull

An industrial machine OEM manufacturer engineers and assembles large-scale machines according to customer order. Every order starts from design and engineering, and then passes on to several outsourced operations to produce key components. Some of the production jobs at these contracted operations are triggered by a Smart Pull process, based on the start of an engineering or production task at the OEM. This avoids shipments sent to the OEM plant too early (or too late), which is critical, as these parts can take up a lot of space.

9. Using Pull to create new customer experiences

Traditional Lean concepts focus on using Pull to improve cost, delivery and quality performance of a manufactured product. Smart Pull can go beyond the limitation of the product medium to deliver customer experiences in the form of services.

Case 9: Using Pull to create new services by an apparel material manufacturer

A Japanese secondary clothing material manufacturer has been facing tough cost competition from Chinese manufacturers. To improve satisfaction of its customers—brand owners of designer clothing lines—they implemented an RFID status tracking process on their ironing line. The RFID tags track the real-time status of each piece of clothing material as it passes through each step of the production process. This real-time status is not only used internally for performance tracking against plan, but also is shared with brand owners to improve visibility of delivery tracking. Delivery time is a critical Key Performance Indicator (KPI) for the fashion industry because goods only can sell at premium price for a very limited time. The Pull signals triggered from production line events have improved customer satisfaction by delivering a new user experience, delivered as an additional value-added service to differentiate from competitors.

Taking a Smart Next Step

In the wake of the current technological innovation wave driven by Smart Manufacturing strategies and IIoT, it is not uncommon for manufacturers to not know where to start. Some companies are investing billions of dollars to set up labs and experimental production lines for the purpose of evaluating these technologies. In this white paper, we advocate a more pragmatic approach that does not require an overhaul of your existing production lines.

So what is an appropriate next step?

To start, we recommend the adoption of a scalable manufacturing IT platform strategy that enables not only connectivity to be established for all smart devices, but is also flexible enough to support the full Plan-Do-Check-Act (PDCA) cycle that is required to benefit from such automation. Smart Pull processes can be implemented across multiple domains within manufacturing operations where real-time execution is necessary. These requirements necessitate an enterprise architecture based on an operations execution platform capable of managing each of the processes surrounding manufacturing events or activities. The volume of activity associated with these activities typically generates too many details, records, and data for most ERP systems to handle.

To achieve best-in-class performance from a Smart Pull process execution strategy, a manufacturing IT platform for execution events is required. Look for a solution that is capable of not only supporting multiple domains, but can also seamlessly integrate the necessary operations intelligence and digital modelling capabilities, which will then provide the foundation for Smart Pull process execution. Only then can you fully harness the power of Smart Pull.

Manufacturers can take the following steps to help move forward with such a platform strategy:

- Holistically evaluate your end-to-end operations processes to clearly identify what key strategic drivers are most relevant for the profitability and competitiveness of your business. Examples of typical strategic drivers include flexibility or responsiveness (can be measured by lead time and product variety), capacity utilization/Return On Assets (ROA) (especially for more capital-intensive companies), quality (especially in regulated industries), inventory optimization, and throughput. These drivers will differ in importance from one manufacturer to another.
- Review and discover how Pull can improve your most important strategic drivers; in some cases, an overhaul of your operating model might make sense; in other cases, incremental improvements will be just fine.
- Next comes the identification of what extensible and scalable IT platform best addresses your needs while offering the capability to embed intelligence into your Pull processes.
- Identify a few key short-term goals with visible returns. Larger projects are best started with a few quick wins to validate the strategy and drive organizational momentum. Upper management will then ensure future budget availability to continue your vision of adopting Smart Pull as an enterprise Lean manufacturing strategy.
- Roll out and institutionalize successful Smart Pull practices to other facilities. Be sure to take the time to publicize performance improvements, increased customer satisfaction, or whatever other key performance metrics are identified as part of the project. Just as your goal is to implement more Smart Pull manufacturing processes, ideally you will want your new solution to be "pulled" to new locations eager to achieve similar results. As success stories are shared, take opportunities to expand further, including exploration and capitalization of new opportunities brought about by advanced Pull scenarios. Continuous process improvement never ends!

ESTABLISH A GLOBAL, SYNCHRONIZED MANUFACTURING NETWORK TO SUSTAIN GROWTH, INNOVATION & GLOBALIZATION

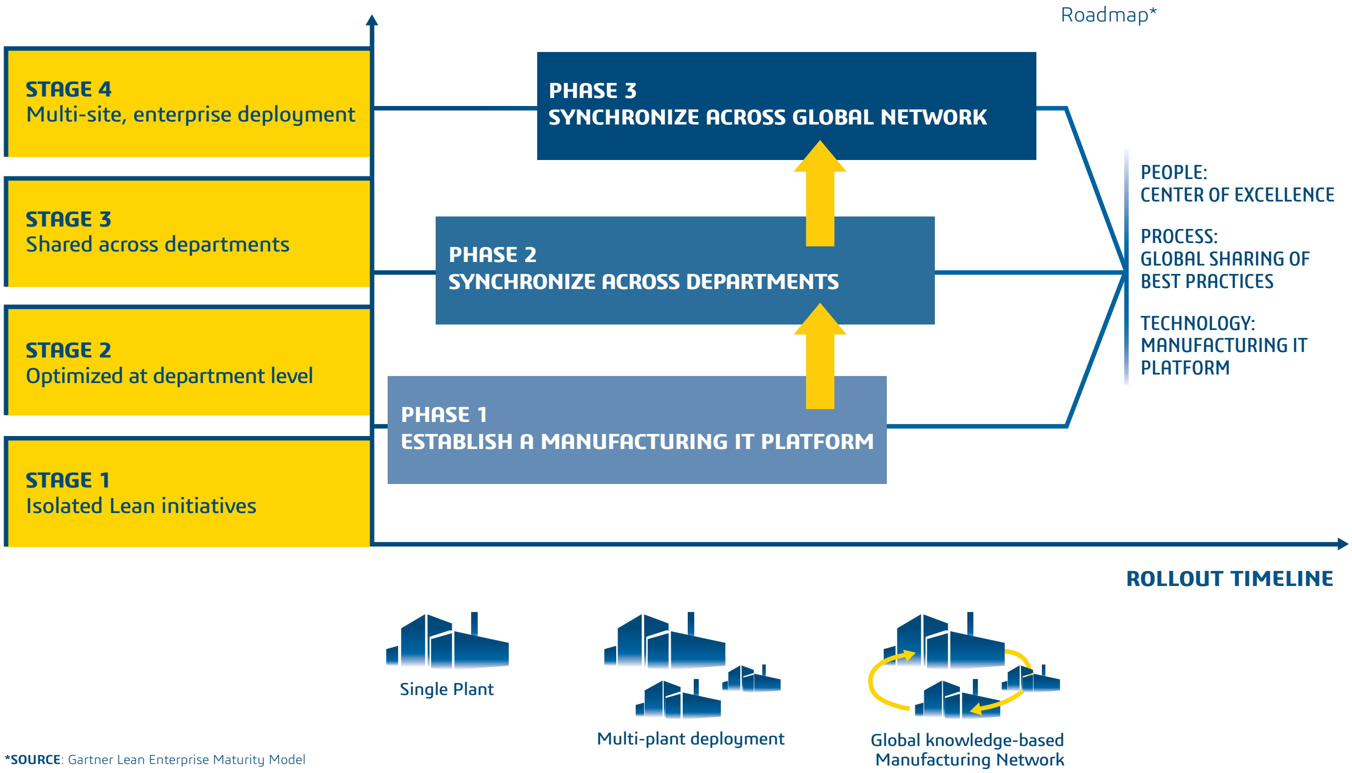

Figure 7
Manufacturing Transformation Roadmap*

***SOURCE**: Gartner Lean Enterprise Maturity Model

Conclusion

Many of the recent literature in Smart Manufacturing and IIoT have been focused on the adoption of advanced hardware such as smart sensors, robotics, or automation equipment. This white paper has outlined a framework that emphasizes digitization and business transformation, which in many cases do not rely on advanced automation, and in most cases are far more important. Such business transformation is based on a new mechanism of information flow, now made possible by Smart Pull.

The advantage of thinking in terms of the above Smart Pull concept is that it takes the focus away from technology and puts it on business transformation. Challenges and inefficiency based on Push are then presented as opportunities. Perhaps you can start asking the following questions to identify areas of opportunities:

- What kind of improvement in capital lockup or wait time has the most impact on your business?
- Can these areas be improved by Pull?
- Which part of your customer engagement or operation inefficiency can be addressed by changing from push to Pull?

Perhaps we are not far away from the day when design, engineering, manufacturing, logistics, and after-sales resources are all available as services to be called on demand in the same way Uber is disrupting the transportation industry. A consumer could then use his or her smartphone to customize an order that meets his or her special needs. All the necessary industrial resources could then be orchestrated—on demand—based on Pull to fulfill each specific order. The concept of Smart Pull is truly revolutionary given its role to help bring these business transformations to market.

A key learning from implementing each of the above example scenarios is that operations models and technological maturity are constantly evolving. Manufacturers have yet to explore the full potential of the new opportunities enabled by Smart Pull. Whether you are pursuing efficiency improvement or new customer experiences, transformation is not a one-time event but an ongoing process.

The key to sustainable success is to adopt a scalable and flexible manufacturing IT platform strategy that can support the continuous improvement and execution of such business transformation. Without such, organizations are quickly locked in to newly developed capabilities that soon could become obsolete. Factories of the future will not only be powered by intelligent robots and sensors, but also at its core, controlled by an adaptable IT application platform that is as agile and responsive as the Smart Pull processes it enabled.

For more information about the power of **Smart Pull**, visit **www.apriso.com**.

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