

Improving Continuous Improvement

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# REINVENT LEAN TODAY WITH DIGITAL TECHNOLOGY



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# IMPROVING CONTINUOUS IMPROVEMENT

*Reinvent Lean Today with Digital Technology*



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## SECTION 1

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# Executive Summary

## Today's Norm: Change Now, or Lose Fast

Every single industrial organization is at risk. The competition — at home and globally — has discovered the value of digitalization to create new business models, to enable and empower the workforce, to establish new operational efficiencies, and so much more. The fact is, if you aren't moving forward and getting better you're falling behind.

The pace of technology change forces businesses to make constant improvement a core competency. With global competition, new materials and manufacturing methods, and a whole new generation of consumers and employees that have grown up around and expect technology at their fingertips, a company that doesn't have some form of continuous improvement (CI) or business process improvement approach will find itself irrelevant in short order.

That's not to say that continuous improvement is a guarantee of survival. On the contrary, CI benefits are stagnant, with most companies simply happy to achieve 1-2% annual improvements. These are the organizations that are well-positioned to leverage digital technology for more dramatic improvements. Firms that maximize their Lean, Six Sigma, or other continuous improvement programs with next-generation technologies will make faster, more informed decision-making a competitive advantage.

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**“There is nothing so useless as doing  
efficiently that which  
SHOULD NOT BE DONE AT ALL”**

**Peter Drucker (1909-2005)**, American businessman and pioneering thinker on management theory and practice.



## Today's Norm: Change Now, or Lose Fast (Cont.)

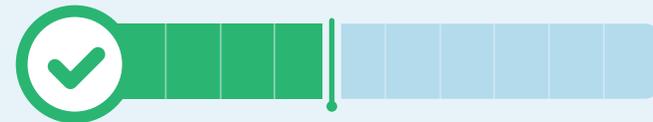
Consider this: most executives intuitively see the potential for the IIoT to enable multiple use cases, including improved asset reliability, optimized production operations, increased product quality, remote monitoring, or enabling new business models, just to name a few. In fact, 40% of companies already launched an IIoT initiative by 2017 and another 24% were in the planning stages. By adding the power and potential of the IIoT to CI, companies – and your competitors – will compound and accelerate the value on both fronts. Those who take advantage of the opportunity will outpace the market, and those who delay will find it difficult or impossible to close the gap.

Industry 4.0 strategies are no longer aspirational. There are leading organizations that invested heavily and early on; they are now poised to deliver tens or hundreds of millions of dollars of impact over the next three to five years – through cost savings, faster new product introductions (NPI), entirely new offerings, or some combination of those. We're already able to examine and learn from those early adopters – not just the upside, but which mistakes to avoid and how to overcome common challenges.

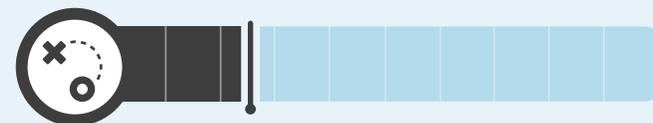
Don't be fooled into thinking that IIoT alone is enough to meet Industry 4.0 goals. To realize the all the potential benefits, companies must also apply continuous improvement across business processes, the appropriate technology and a well-trained and committed workforce.

In fact, we have not found a single company that achieved success with just technology. Nearly every one of them would likely all tell you what you already know: that shop floor technology is notoriously difficult to implement and must be combined with a mature set of people and process best practices. The common denominator for success is a commitment to Operational Excellence; it must have a prominent role for Digital Transformation success.

**40% OF COMPANIES**  
already launched an IIoT initiative by 2017



and another **24% WERE IN THE**  
**PLANNING STAGES**



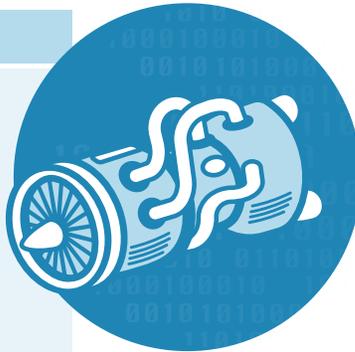
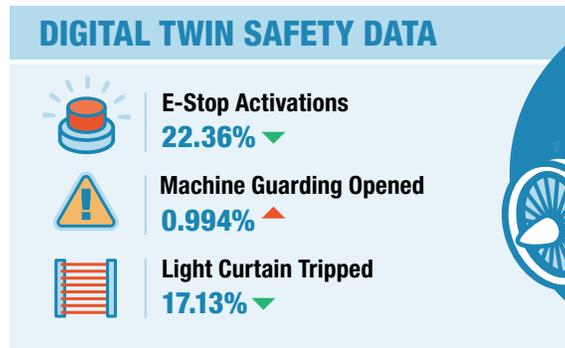
# Big Three Digital Technologies Critical to Reinvent Lean

Not so long ago, the conversation about modern innovations and technologies was entirely a separate one from those like continuous improvement, manufacturing operations management, asset performance and other disciplines. Today, it's practically inconceivable to discuss these disciplines and functional areas without considering how current innovations and technologies affect or enhance them. In manufacturing, the primary digital and IIoT technologies changing the way businesses operate are encapsulated in the IIoT platform that covers:

- Big Data
- Advance industrial analytics
- Edge and Cloud computing
- Mash-up apps

There are other important technologies that are part of the equation, like augmented reality (AR) and virtual reality (VR), that complement and extend the possibilities of next-generation factory floor user-experiences. They provide better visibility about operations and the enterprise and help humans interpret the results from the analytics applied to IIoT data and Big Data. Mobility also plays an important role, to get the information to workers when and where they need it. Applying these technologies is a core capability to realize the power and potential of the foundational elements

The IIoT, Big Data, predictive analytics, and Edge to Cloud computing are the foundation, while AR/VR, mobile and other technologies drive extensible value. Ultimately, organizations must strive to convert data to decisions, reduce cognitive overhead, and discover new ways to apply use cases.

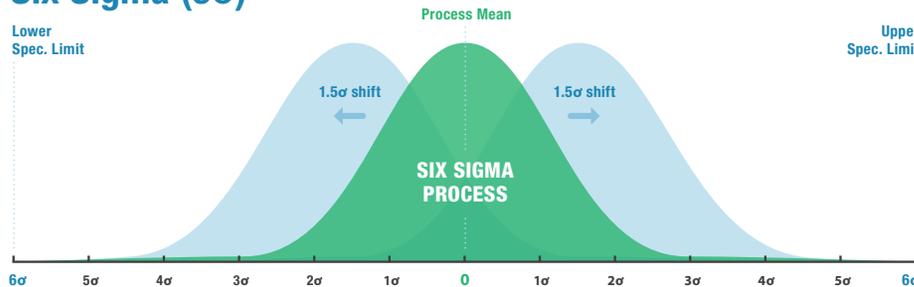


# Same Lean, Better with Digital

This ebook examines specific Lean and Six Sigma processes companies use to drive bottom-up continuous improvement. For each, we will briefly acknowledge the "traditional use," and then we'll describe how companies can apply the IIoT and digitalize processes to drive faster, longer lasting improvement. Many continuous improvement processes today are manual and paper-based. While this will certainly shift with the IIoT, we don't simply assume that everything will become fully automated. Most Lean processes are all about people; the IIoT will support the people where it makes sense, so they can continuously improve.

The IIoT combined with supporting data from Edge to Cloud and Big Data analytics is a perfect platform on which to implement Lean processes. It will make all the data from across the enterprise available and deliver key functionality such as augmented reality (AR) / virtual reality (VR) and security.

## Six Sigma (6σ)



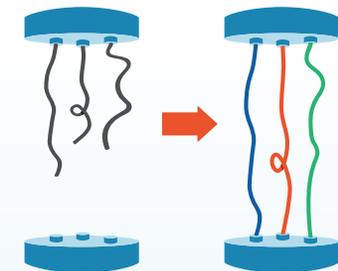
## DMAIC



## Five Whys

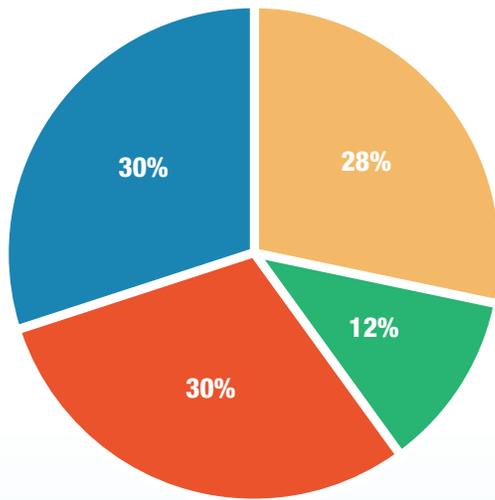


## Poka-Yoke



# Research Demographics

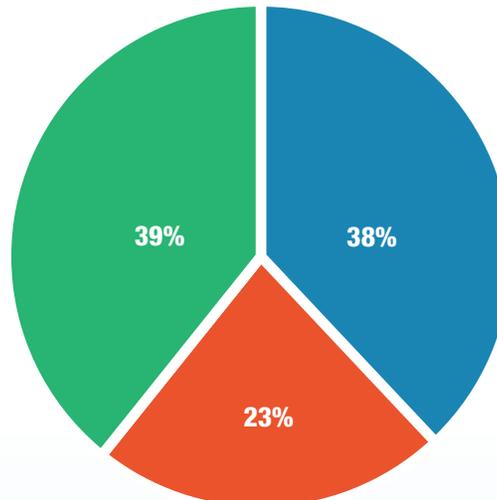
The data presented in this ebook represents over 150 survey responses through February 2018. LNS Research employs a social research model; our online format English language surveys are open to the public. Companies participate in LNS surveys to gain access to the LNS Research library, meaning survey participants are research consumers. The industry demographics of the responses largely match the demographics of the industrial landscape at large, with discrete being the largest segment, followed by process and batch industries. The research also has a broad distribution across industries and company sizes.



### GEOGRAPHY

#### COLOR BY COMPANY REVENUE

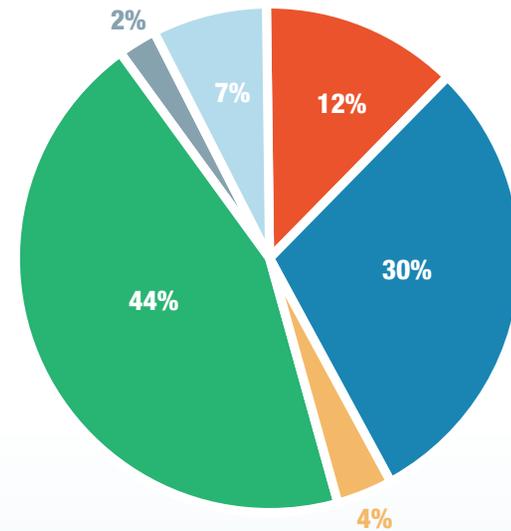
- Large: \$1BB+
- Medium: \$250MM - \$1BB
- Small: \$0 - \$250MM
- Unknown



### REVENUE

#### COLOR BY INDUSTRY

- Discrete Manufacturing
- Batch
- Process



### INDUSTRY

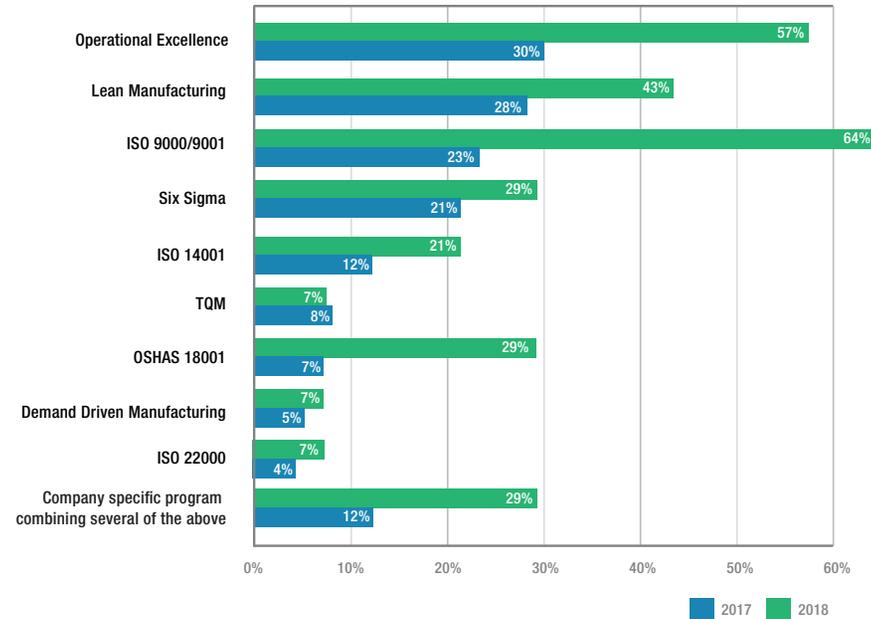
#### COLOR BY HQ LOCATION

- Asia / Pacific
- Europe
- Middle East and Africa
- North America
- South America
- Rest of the World

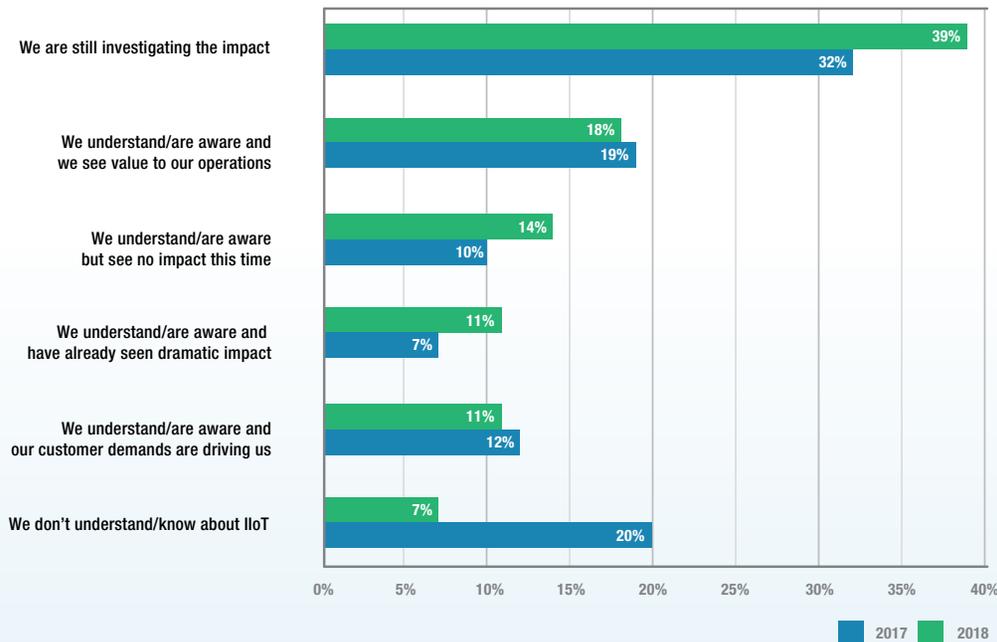
# Industry Enthusiastic About Continuous Improvement

LNS surveys include questions about continuous improvement approaches and about awareness of the impact of the Industrial Internet of Things (IIoT). It's clear that CI isn't simply "alive and well;" organizations are eager to capture the operational, financial, and competitive benefits they offer, and are investing widely. At the same time, the percentage of companies that doubt, can't quantify, or simply don't care about the tremendous value offered by Digital Transformation is dropping rapidly. As LNS continues examining these trends throughout 2018 and into 2019, we will likely find very strong correlations between continuous improvement efforts and Digital Transformation initiatives.

## Improvement Programs Implemented



## How does the IoT impact your business today?





## SECTION 2

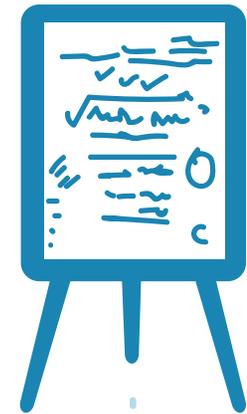
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# Transforming Lean with Digital: Faster, Longer Lasting Results

# Transforming Lean: DMAIC

## Traditional DMAIC

Define, Measure, Analyze, Improve and Control (DMAIC) is a fundamental building block of Lean / Six Sigma and the core tool to deliver Six Sigma improvements. The philosophy prescribes measuring everything, and properly define and record improvement targets. Teams use DMAIC projects when they don't know what the improvement outcomes are at the outset. For example, you wouldn't use a DMAIC project to choose a specific software package such as a manufacturing execution system (MES) when the requirements are already known, but you would use DMAIC to define an Operational Architecture if the end state is unknown at the out.

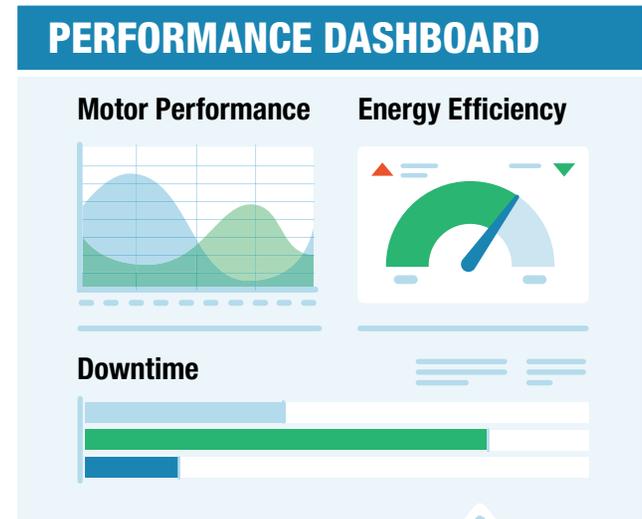


# Transforming Lean: DMAIC (Cont.)

## Digital DMAIC

In a digital world, organizations can extend DMAIC into the world of operational improvement and operational intelligence. An IIoT data model encompasses people, processes, and assets, so advanced industrial analytics can be used by individuals far beyond roles that execute standard processes and make decisions within existing define operating envelopes. Such analytics can be used by subject matter experts that are responsible for continuous improvement techniques such as DMAIC. The continuous improvement method becomes more powerful with advanced industrial analytics, so they can redefine standard processes and enhance the operating envelopes of the manufacturing processes.

LNS Research has seen instances of major quality and manufacturing issues arising due to changes within standard process and operating envelopes. The reason for this was that the impact on process performance unknown due to the complex nature of the relationships among steps or areas in the process. There are many existing tools that support the various phases of a DMAIC project, and the key to good Six Sigma improvement projects will always be the black belts that run them. Another key to successful projects is information, specifically measurements. DMAIC involves changing processes and parameters. It can only uncover and resolve complex issues with an advanced analytics tool that is exploratory and built on a robust data model that spans the value chain the project phases.



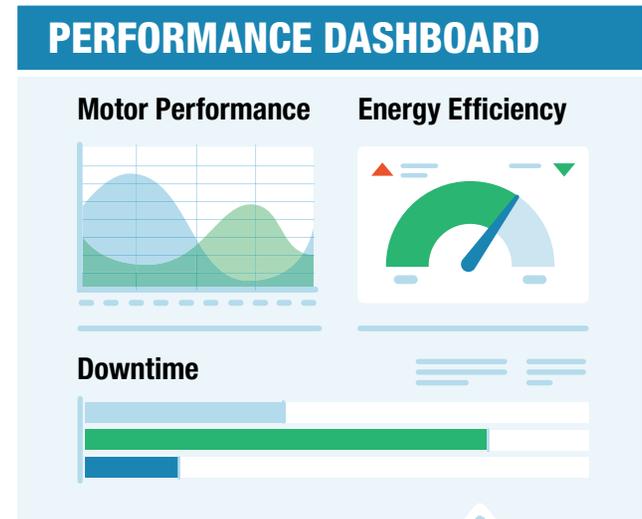
# Transforming Lean: DMAIC (Cont.)

## Digital DMAIC (cont.)

The Define phase is when the team describes the project and sets up the parameters to be measured; typical tools to analyze metrics include histograms, box plots, Pareto charts for numerical information, and cause and effect charts to address analog issues. The IIoT greatly enhances data measurement in many ways:

- Provide quick, easy-to-digest, detailed information without having to search endlessly for it. As control and supervisory data enters the IIoT platform, ever more detailed information will strengthen project accuracy.
- Enable a Digital Twin for simulation where measurements might not be available or possible.
- Measure parameters not normally accessible with smart devices and sensors. Simple IP-enabled devices are usually quick and effective.

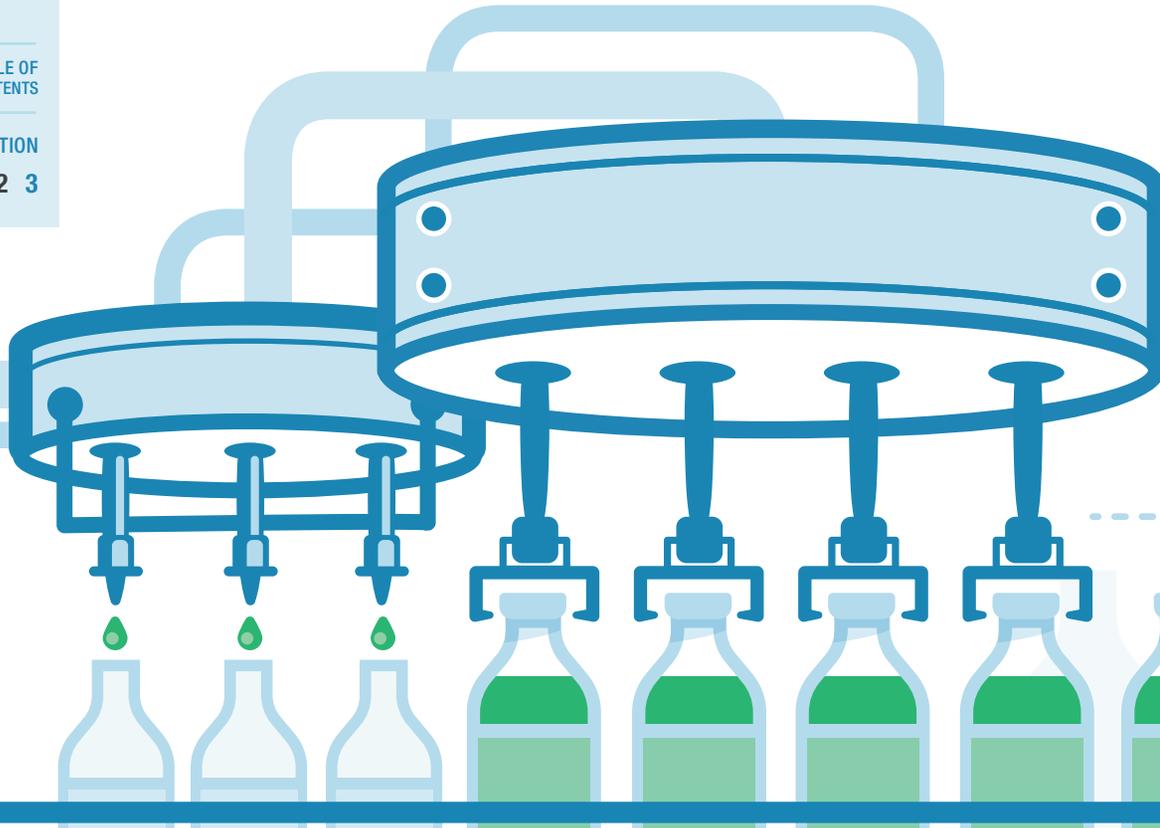
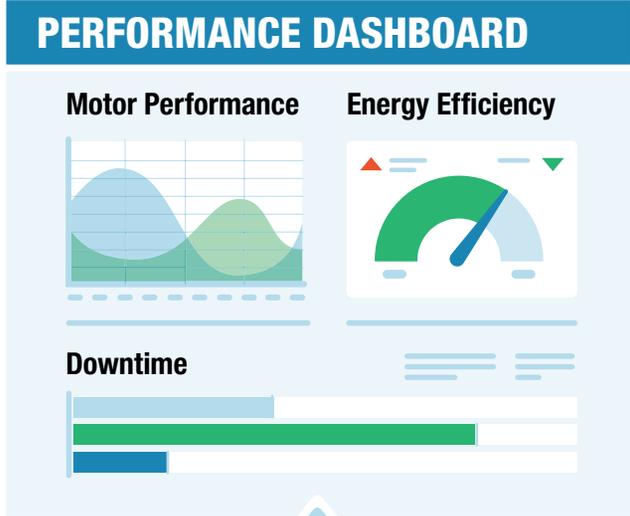
The IIoT also offers new capabilities to the Analyze phase (and perhaps also the Improve phase). Predictive analytics and Big Data from across the enterprise can open entirely new paths to solve DMAIC problems.



## USE CASE: Digital DMAIC

Manufacturing inefficiency is often an interplay of multiple parameters that cause out of spec product or poor performance. Case in point: a typical bottling plant fills hundreds of bottles per minute and has countless small motors. Companies don't typically monitor motors individually or relay machine data beyond the machine. The usual approach is break, fix/replace. Adding monitoring, getting access to internal machine data, or adding smart sensors opens a whole new world of information.

A digitalized DMAIC project to improve bottling performance can measure individual motors for each bottling head, overall line speed, and fill accuracy to determine issues, then improve and, most importantly, continue to control and monitor issues.

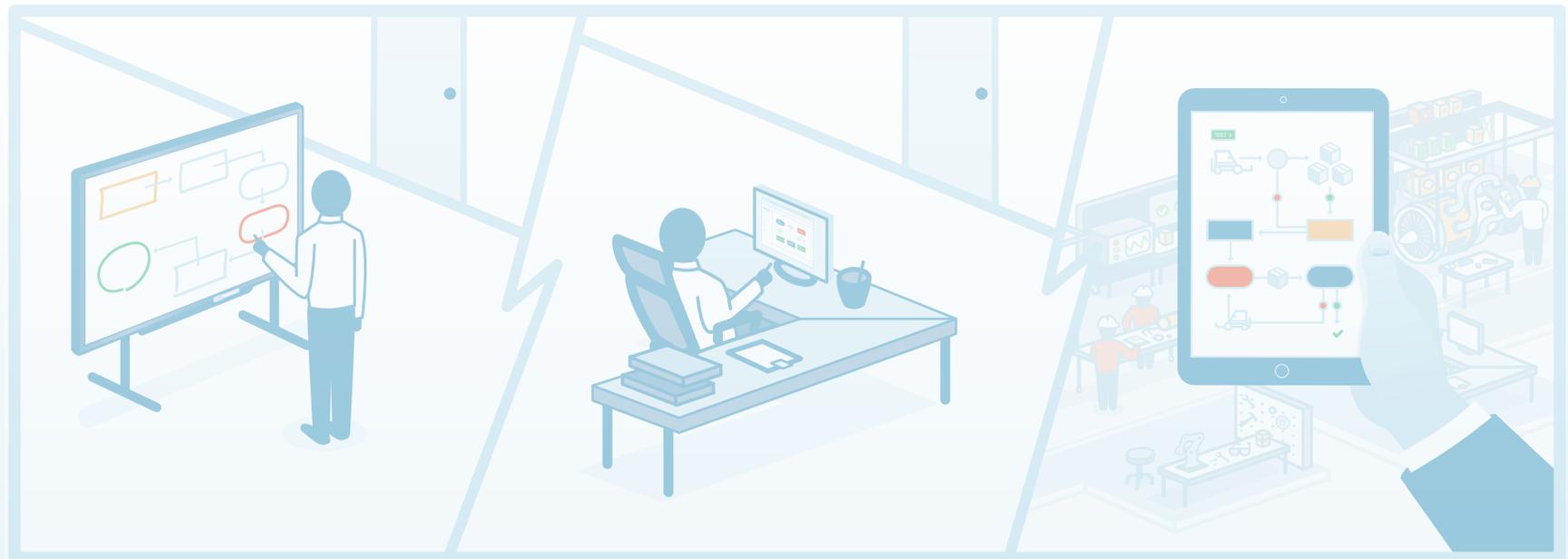


# Transforming Lean: Continuous Flow

## Traditional Continuous Flow

The goal with continuous flow is to remove waste and work in process (WIP) buffering between operations, and balance cycle time to maximize production with no loss of quality or customer satisfaction. In the past, Lean practitioners map process flows using manual diagrams on a whiteboard, flipchart or paper. Later, software applications like Microsoft Visio made the output more visually appealing, but perhaps slowed the process since there was a steep learning curve associated with them, the models were disconnected from reality, and they were hard to maintain. Furthermore, process mapping and testing was usually limited to theory and hindered by data from accounting approximations or siloed systems.

Like many Lean Six Sigma activities, the best champions and executors of continuous flow are the people on the shop floor. Operators can actually see where the backup of incoming parts occurs and can suggest ways to improve the flow between their own station and those up and downstream. Usually, there is little to no data to support changes.

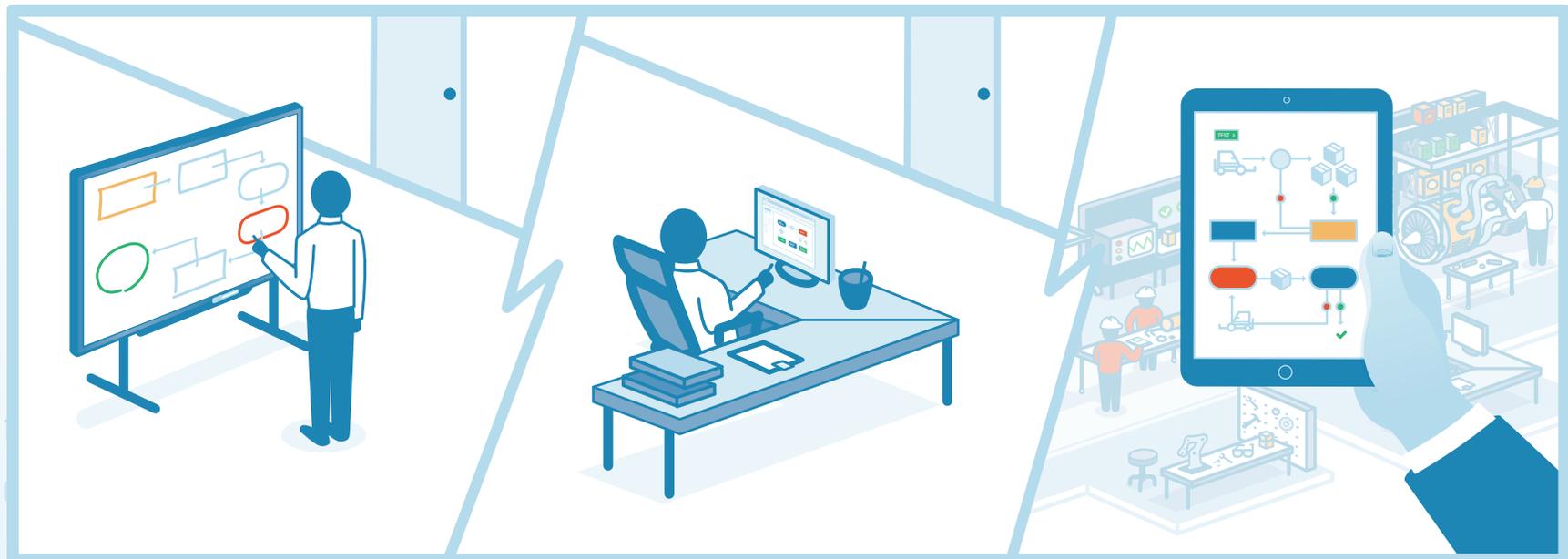


# Transforming Lean: Continuous Flow (Cont.)

## Digital Continuous Flow

The IIoT sparks new ideas in continuous flow. It's not just "more data" will improve things; continuous flow is about rhythm, coordination, and having everyone involved. Online suggestion schemes have been useful in the past, and a visual representation of reality will offer new perspectives in the future. For example, video monitoring of incoming parts allows supervisors to monitor flow and then get out on the floor when potential issues arise (See Gemba below). Communicating up and down the line between more than adjacent workstations will also help to balance flow before bottlenecks strike. However, the advanced technologies associated with the IIoT provide many more opportunities to access data and visualize production and product from new perspectives.

- Resolve difficulties and maintain flow using AR/VR. AR/VR technology is becoming mainstream and will greatly enhance operators' view of production with overlays of instructions, parts, and diagrams over the current task.
- Supercharge flow management and operator engagement and efficiency by simulating WIP using a Digital Twin of the production line. The AR experience will continue to become more realistic as the IIoT, and modern product lifecycle management (PLM) deliver Digital Twins with real-world data combined with process and product simulation.
- Enable more sophisticated and widespread collaboration and exploration to improve processes with IIoT technologies, better, faster and more data, and advanced analytics.



# Transforming Lean: ANDON System

## Traditional ANDON System

An Andon system is a means to indicate which workstation has a problem with quality, performance, material or other issue where immediate action is required. Early Andon boards were simply one or more signal lights signal lights to deliver basic notifications. Later Andon boards showed performance, often overall equipment effectiveness (OEE), or perhaps running time, depending on the process.

Andon enables the fundamental principle of the Toyota Production System (TPS), empowerment. Andon empowers operators to stop the line under their own authority if a serious problem arises. Of course, uptime is a key goal of Lean manufacturing and any operator who stops the line knows that s/he affects uptime. It's a very "public" way of taking responsibility since Andon boards are normally widely visible throughout the plant.

## Digital ANDON System

Digitalization presents tremendous opportunities to communicate in more depth with little or no additional effort. However, it's important that we don't lose the "Andon culture;" the idea is to foster open communication and individual accountability. Bear in mind that Andon is not supervisory control and data acquisition (SCADA) or manufacturing intelligence. Andon in the digital age must retain its "easy input" nature – press a button to stop the line for example. The IIoT will extend the tradition by clearly expressing the issue, and enabling access to more detailed information through mobile devices.

Andon repeaters with dive down information capabilities can be a fast way of monitoring performance from operator to plant manager, without extra investment in MES and other costly solutions. Digital collaboration tools allow fast information sharing across the line and allow others to quickly investigate and address root causes, while the operator that activated the digital Andon addresses the specific issue at hand.



# Transforming Lean: Five Whys (Root Cause Analysis)

## Traditional Five Whys

Five whys is a spectacularly simple and effective way to dig down to find manufacturing issues. Repeat “why” five times and you should be able to discover the root cause of a problem.

Problems that benefit from this type of analysis are often initially dealt with through “quick fixes.” Applying rigor with a team approach is the only way to unearth root causes. The traditional skill belongs to Lean and Six Sigma masters — knowing which questions to ask is far from intuitive, but well-executed five whys meetings are often the best way to uncover the real problem.

## Digital Five Whys

Advanced analytics is one of the key components of the IIoT, especially in the areas of asset performance and predictive maintenance. Root cause analysis is closely related to these topics, and we foresee a strong future market for IIoT-based tools for performance improvement and problem-solving. Artificial intelligence (AI), deep learning and neural network-based analytics will transform problem-solving throughout the factory.

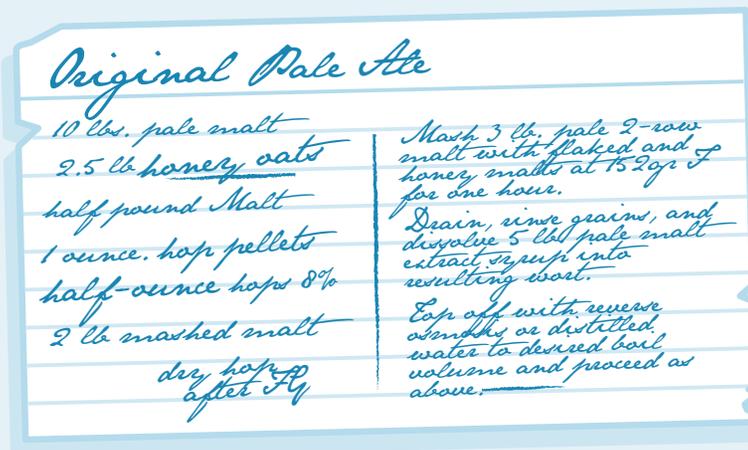
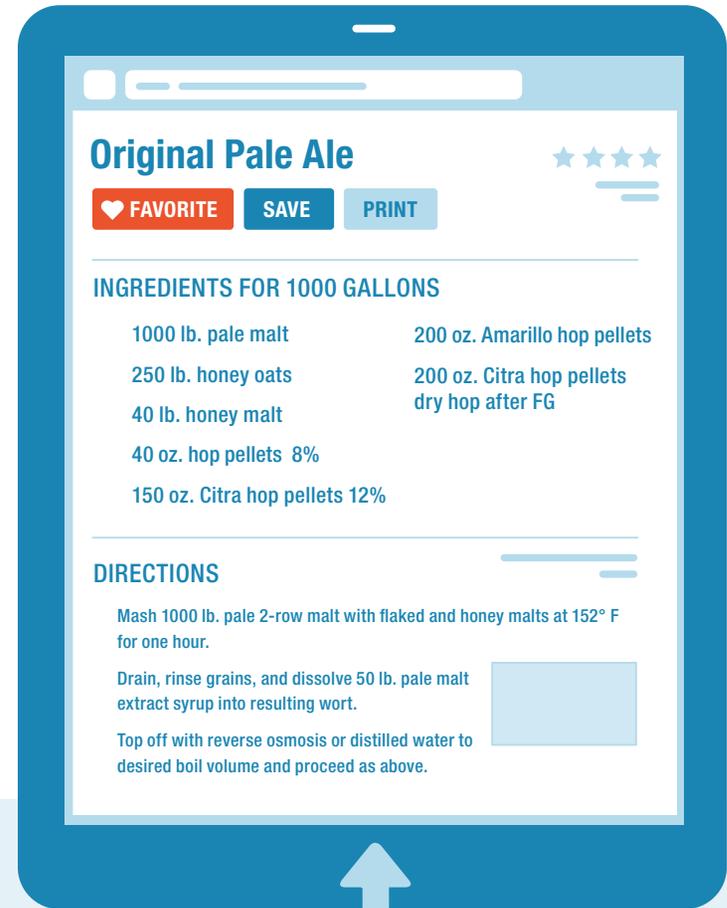
A key to future success is not to jump into advanced software without first considering the problem at hand. “Intelligent” software requires guidance to apply the correct techniques to each problem. In particular, a robust data model of the product and processes should be built before trying to apply IIoT analytics. Sometimes, using five whys might address a problem better than technology, so Lean Sensei’s and Six Sigma Black Belts need not fear becoming obsolete.



# USE CASE: Digital Five Whys

Anyone that has ever home brewed beer knows it can be a touchy process, fraught with seemingly mysterious relationships between live cultures, bacteria, time, temperature, ingredients, equipment, elevation, and much more. Given all the possible sources of variation in recipes, sometimes even top brewmasters can make mistakes. One of the largest craft brewers in the US recently engaged in an IIoT project using machine learning (ML)/AI and historical process data to solve a batching problem that was resulting in a major quality issue and the loss of entire batches.

The brewmasters thought the problem was the relationship between pressure and temperature; it turned out to be an issue with the timing of batch processes determined by natural variances in yeast. Using ML/AI, the brewmasters built a model to alter the recipe and optimize batches on previously unknown relationships. With the new process established, they eliminated lost batches for this quality issue and recaptured two weeks of extra capacity per lost batch.

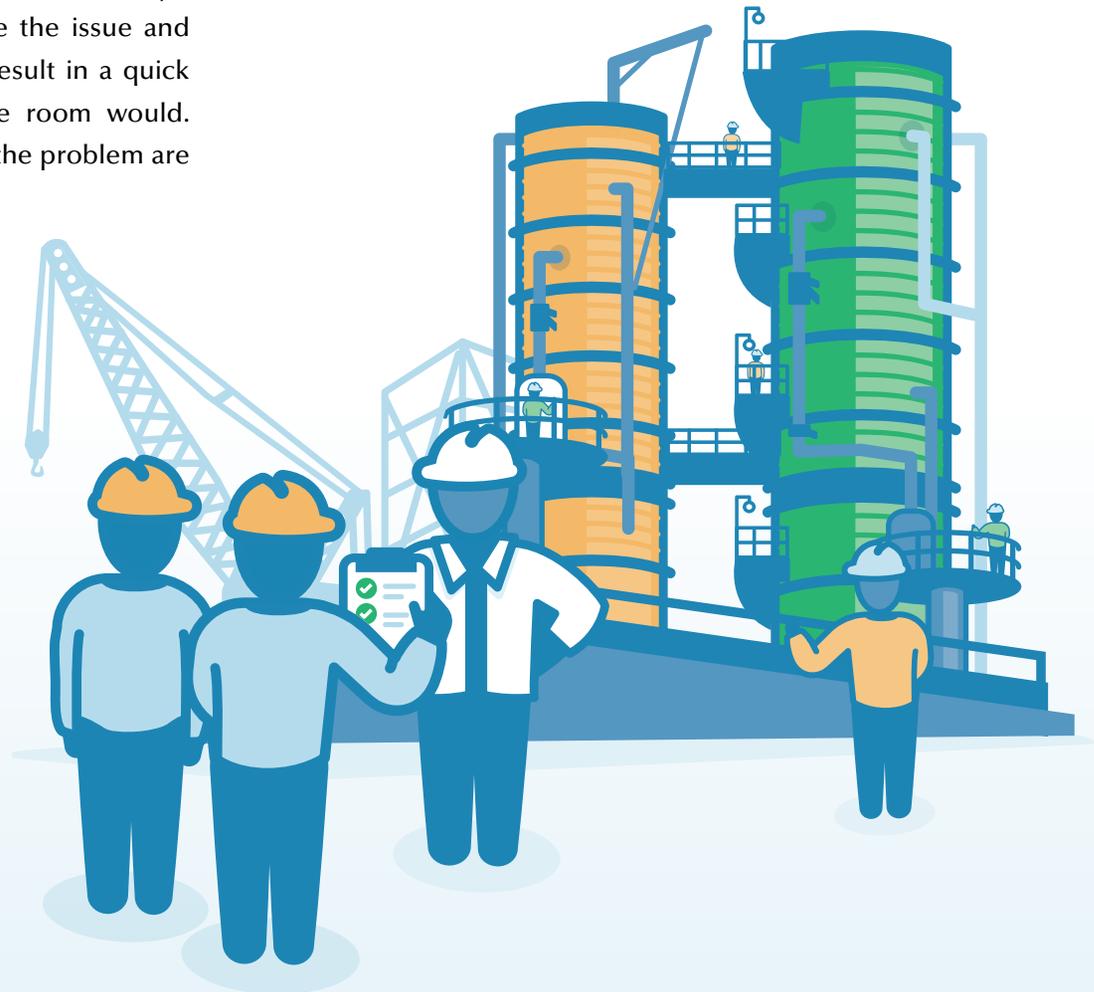


# Transforming Lean: Gemba (and Gemba Walk)

## Traditional Gemba (and Gemba Walk)

One of the great characteristics of the Toyota Productions System (TPS) is its practical outlook on people and their jobs; Gemba (現場, also Genba) and the Gemba walk is a strong example. Gemba simply means “the shop floor, where production takes place” and the Gemba walk is the act of walking the floor to observe production and work. This might seem a somewhat trivial activity but like many continuous improvement processes, helps people get to the heart of issues early and correctly. If a production issue causes delays, discussing it on the shop floor where you can see the issue and discuss it with the operators is far more likely to result in a quick solution than a planned meeting in a conference room would. Furthermore, operators directly involved in solving the problem are far more likely to accept changes.

A Gemba walk is not “management by wandering around.” It will only work in a culture of cooperation and wanting to do better. It doesn’t need to be the place where all problems are solved but does provide for collecting evidence for problem analysis.



# Transforming Lean: Gemba (and Gemba Walk) (Cont.)

## Digital Gemba (and Gemba Walk)

Genba and the Genba walk get a whole new outlook with the IIoT, but they must retain the cultural benefits of the process. VR and especially AR are emerging technologies that enhance the Gemba walk. An overlay of performance and manpower data on top of a real-time view of production helps Gemba walkers get a more accurate understanding of the state of production and the staff. A Digital Twin offers a view of every detail of the production system and the product. In a complex manufacturing environment, the Gemba walker can engage plant floor technicians and talk at a detailed level, with a fully up-to-date view of production.

One unique benefit of the digitally-enhanced Gemba walk is the need for fewer subject experts to cover multiple plants. With the changing workforce and fewer available subject experts, a single expert might have to provide coverage for several plants. An AR/VR system will become indispensable. The idea of remote Gemba, with a single individual to walk multiple lines from an offsite location might also become a reality.

In addition to AR/VR, the Gemba walker can benefit from location-specific technologies such as near field proximity sensors so that his/her digital system knows where s/he is at any time; the expert won't need to take any action to have fully up to date and location-aware information.

The Gemba walk in a digital world can bring great benefits, but users must ensure it doesn't hinder the key goal – communication with operators on their terms and in their locations. It would be easy to put a large screen in a meeting room and for all the managers to get together to scour the factory for issues before going out there – that is not a Gemba Walk and will not deliver the benefits of shop floor communication as Gemba walk does.



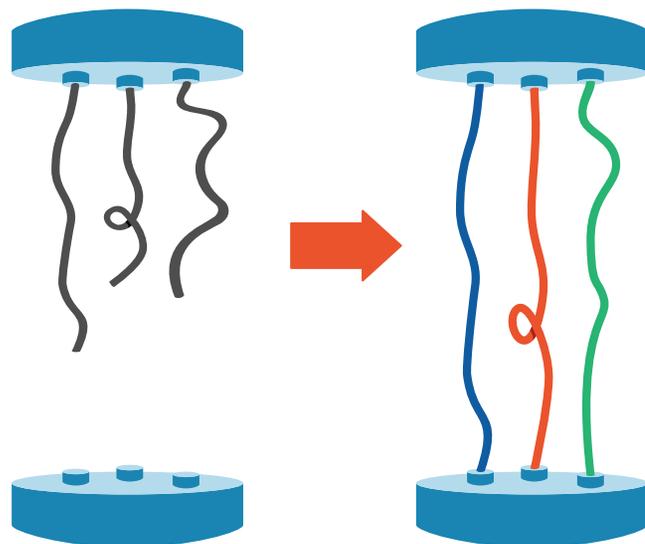
# Transforming Lean: Poka-Yoke

## Traditional Poka-Yoke

Poka-yoke (ポカヨケ) is yet another simple but valuable tool in the continuous improvement armory; it's a Japanese term that means "mistake-proofing" or "inadvertent error prevention."

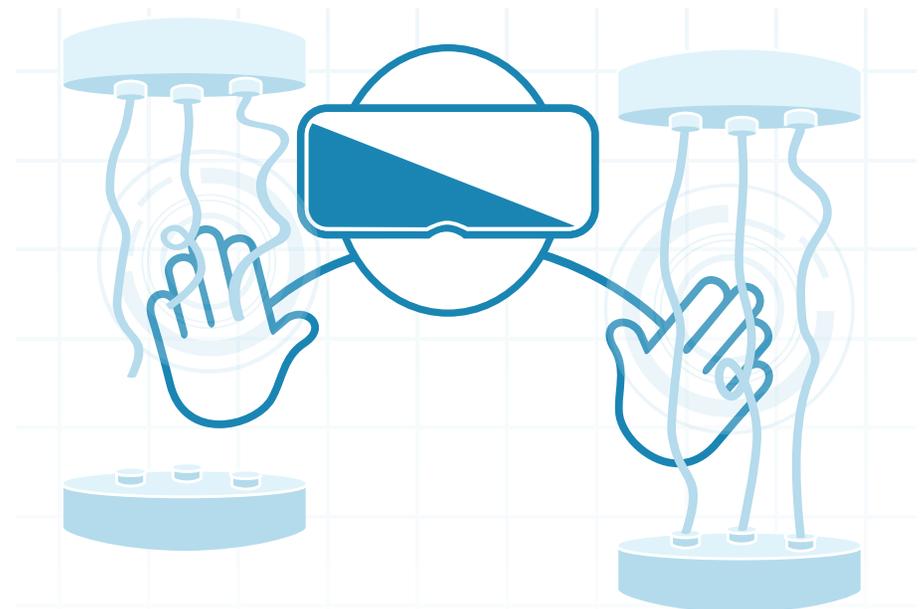
This technique zeros in on simple changes to processes that will help to avoid errors. In manufacturing, Poka-yoke is considered the first step towards truly error proofing a process. To error proof, you must design a process in such a way that it is impossible to make inadvertent errors.

When a production process often yields defects, poka-yoke techniques can be used to reduce overall defects. The changes are usually highly cost-effective, often come from operators suggesting small changes, and reduce errors in the overall process. One of the limitations of poka-yoke is that scaling solutions can be difficult; making the same change in another plant might not yield the same result.



## Digital Poka-Yoke

The Digital Twin is an excellent place to conduct poka-yoke. Testing against specific standards in the digital world is easy. The advent of Manufacturing Process Management (MPM), the design and management of the production process from the product design, opens new avenues for poka-yoke. Process designers can use product information to ensure that the transfer from design to production rigorously uses poka-yoke rules. Teams can error check each process step in the virtual world before implementing in the plant, and conversely, poka-yoke changes made in the operating production process can be sent back to the Digital Twin and the MPM system for error testing.



# Transforming Lean: OEE and Other Operations Metrics

## Traditional OEE and Other Operations Metrics

If you ask plant managers from ten sites across the same company how they calculate overall equipment effectiveness (OEE), you'll likely receive ten (or more!) different formulas. What's more, few if any of those formulas are "wrong." That's because until very recently OEE has been calculated on-premise using the specific systems and data available to each site. Manufacturing doesn't differ only from company to company; people, processes, and technologies vary greatly from one site to another across an enterprise. As a result, it has been difficult or nearly impossible to establish an apples-to-apples view of operational performance across multiple plants, making it difficult to share best practices and problem solve beyond each plant.

## Digital OEE and Other Operations Metrics

Digital Transformation offers a way to solve the conundrum of this tricky metric. To be effective, it must be calculated using consistent data and a single version of a formula but adjusted to compensate for individual asset, process, and plant differences. Companies can then compare similar assets across their plants and even from third parties to uncover previously unknown root causes, test the effects of change, and evaluate what drives OEE performance and profitability. OEE sometimes takes on the aura of a religion — get your OEE up at all costs. We must remember and focus on the fact that OEE and other operations metrics drive key financial metrics, and in the IIoT world evaluate OEE and other metrics alongside financial measures so that operators and other staff can directly drive financial performance.



## USE CASE: OEE, Gemba, and Poka-Yoke

Any facility that is FDA regulated is familiar with the daily (perhaps less frequent with extended run) ritual of clean-in-place (CIP). A fast and efficient CIP process is one of the ways a facility can quickly improve OEE and gain immediate increases in availability. An effective CIP process is also one of the areas where these companies can dramatically decrease or increase the risk associated with product safety.

Typical CIP processes are not quick, efficient, effective, or well documented. Companies usually manage the CIP process locally through HMI/SCADA systems, and record results either manually or in data historians. The process must hit time, flow, temperature, and concentration targets and the line is presumed clean and ready for production, with perhaps some swabs as spot checks for contamination.

Rather than simply running the process and assuming cleanliness, the IIoT presents the opportunity to analyze, measure and predict actual cleanliness across many plants. Gemba walks reinforce the analysis by measuring in place and feeding information back into the cleaning algorithms. Poka-yoke further extends the value by error-proofing measurements and to foolproof updating CIP processes.



# Transforming Lean: Standardizing Work (with Kaizen, Continuous Improvement)

## Traditional Standardized Work (with Kaizen, Continuous Improvement)

Standardized work can be a slightly contentious issue in manufacturing companies, possibly because it's not always well understood. Standardized work is a snapshot of three things:

- Takt time, the rate of manufacturing on a production line
- Sequence of what needs to be done
- List of equipment and parts needed to achieve the sequence within Takt time

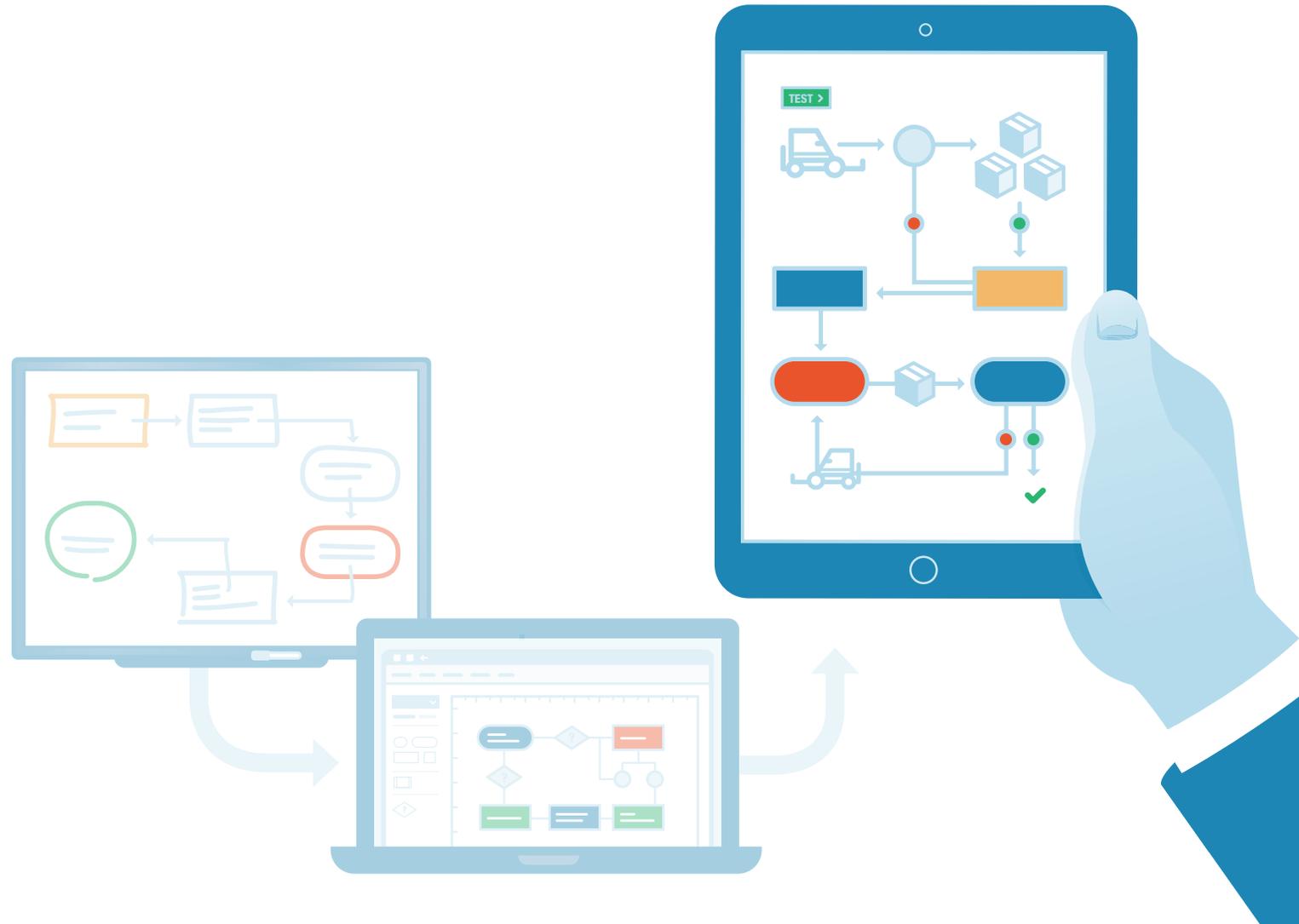
The fundamental goal of standardized work is to maintain improvements made through Kaizen (continuous improvement), and therein lies the confusion. Standardized work changes all the time, which makes it a bit of a misnomer and not that obvious for "standard" process. The key is that all improvements should be incorporated into the standardized work so it is a continuously changing view of the best way to do things.



# Transforming Lean: Standardizing Work (with Kaizen, Continuous Improvement) (Cont.)

## Digital Standardized Work (with Kaizen, Continuous Improvement)

In a digital world, the benefits of standardized work can be spread across plants, the Kaizen can also be shared, and improvements to the process can be automatically incorporated into the process definition, the digital standardized work. Ultimately, the whole culture and concept of Lean come together as Kaizen and standardized work are integrated with MPM and the digital production process.





## SECTION 3

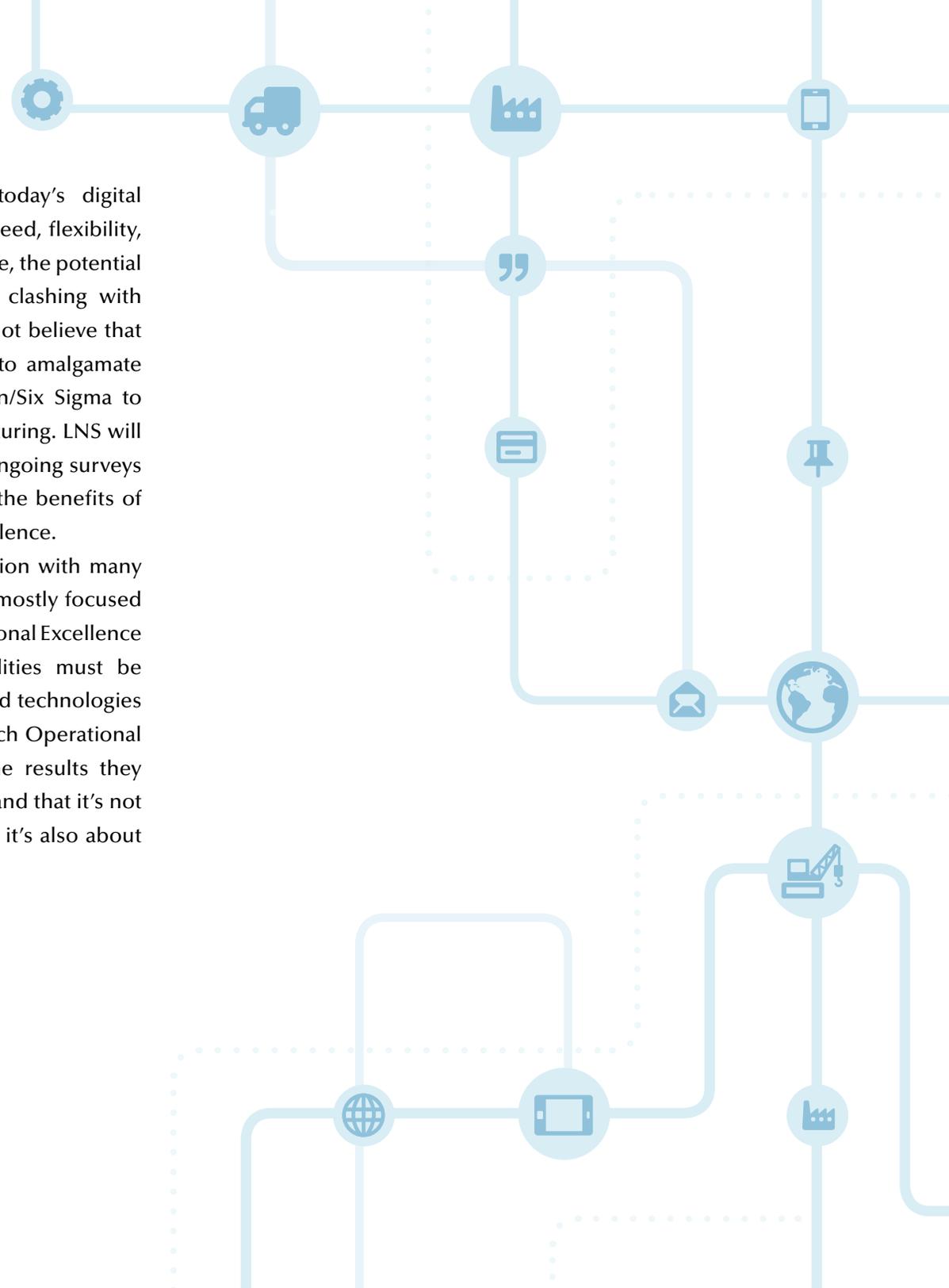
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# Recommendations

## Digital Transformation Means More Than "Technology"

Industrial organizations are eager to leverage today's digital technologies to take advantage of unprecedented speed, flexibility, and precision in decision-making. Not for the first time, the potential for change in computer integrated manufacturing clashing with traditional methods is a reality. LNS Research does not believe that this has to be a clash, rather there is opportunity to amalgamate the best from IIoT-focused manufacturing and Lean/Six Sigma to ensure high quality, speed and flexibility in manufacturing. LNS will continue this research as we collect new data from ongoing surveys of manufacturers and will continue to demonstrate the benefits of modern and traditional focus on manufacturing excellence.

LNS Research is working on Digital Transformation with many program members, and to date, the effort has been mostly focused on technology. As we move into an IIoT world, Operational Excellence with its culture and change management capabilities must be included to affect change. At the same time, advanced technologies can enhance and change the way companies approach Operational Excellence and Lean. For companies to achieve the results they want from Digital Transformation, they must understand that it's not just about transforming how we execute operations, it's also about transforming how companies improve operations.



## Recommendations

Manufacturers that are already using Lean, Six Sigma and other continuous methodologies should take these steps to get started:

- Define Operational Excellence projects to move from a Lean world to an IIoT-driven Lean world. When managing Lean projects, Sensei's should be thinking about how they can enhance project results with a digital architecture.
- Build a robust data model of the first plant (and products) to use with digitally enabled Lean. This is achieved with an effective Operational Architecture that is the starting point for an IIoT platform.
- Train Lean Six Sigma experts in advanced digital methods, and ensure they are key players in transformation workshops. They might have a lot to learn, but certainly, a lot more to offer.

Lean is alive and well in the Digital Transformation world and a key message to remember: continuous improvement and world-class manufacturing is as vital in today's digital environment than it has been over the last few decades. From the marketer's perspective, the disposable product may be with us to stay, but manufacturers still want to build the best.

### Authors:

**Andrew Hughes**

*Principal Analyst*

[andrew.hughes@lns-global.com](mailto:andrew.hughes@lns-global.com)

**Matthew Littlefield**

*Principal Analyst*

[matthew.littlefield@lns-global.com](mailto:matthew.littlefield@lns-global.com)

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