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A maturity model for connected worker factories

Understanding the digital maturity of your factory, and creating a roadmap towards truly digital shop-floor operations.

Executive Summary

Manufacturing is a unique sector where digital transformation hasn't progressed like it has in the rest of the business world. In a majority of factories, work is still done manually, often using pen, paper and tasks are performed by individual operators' who know what needs to be done only from experience. For those who have taken steps to implement digital applications, many (around 70%[1]) are stuck in pilot purgatory, or sitting on a lot of data that has no clear action tied to it.

Unfortunately, due to competitive pressures and the era of consumerization, manufacturers might be the most in need of digital transformation from a production efficiencies and cost standpoint. To survive, they need to produce more product at less cost, eliminate waste, and maximize value from their workers and equipment. They also must be agile in their operations to meet fast-changing consumer demands and a world of customization. In order to make this pivot, they need cultural buy-in from the workers -- one of the biggest barriers cited by executives.

In our history of working with plants to digitize their shop floor operation, we've found common challenges and themes holding them back from realizing actual measurable improvements in a reasonable timeframe. We saw this as an opportunity to develop a digital manufacturing operations blueprint that addresses the blind spots and ultimately, improves Overall Equipment Effectiveness (OEE) in plants. After many successful engagements, we believe plants can benefit from our worker-centric and single platform approach, which has shown to increase OEE, improve quality, reduce resolution times (and associated cost), and improve worker satisfaction – all in an impressive timeframe.

This report characterizes in detail our four pillars of a worker-centric digitization strategy as well as the evidence to support why this approach is essential to realizing value from digital transformation investments. The maturity models should help you pinpoint exactly what level of maturity your own operation is at within each area, so you can then identify points of weakness and prioritize specific opportunities for production efficiencies, cost savings, and worker satisfaction. This report should ultimately help manufacturers get the foundation of their operational model right before investing in digitization of the same. By establishing a strong MOS, factories are positioning themselves to accelerate digital transformation within and across multiple plants.

We'll conclude by sharing our three key principles for success, which are in part, the result of lessons learned through experience working together with plant leaders and operator teams in implementing a digital manufacturing platform.

We hope this report acts as a primary reference for plants to map out practical steps to digitize one small function or process at a time in a way that scales up to achieve big results.

Happy reading!


Safety Officer

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Introduction

Many manufacturers are struggling with the transition to Industry 4.0, but why? In our experience, a large number of them don't know where or how to start. Some have made investments in a plethora of technologies that don't actually work together, and others thought the best approach was to connect their machines to a network in hopes the data would reveal actionable insights. What is still missing is full digital support of an operator's working day on the shop floor. Consequently, plants arent seeing the anticipated benefits of their digitization investments, and they're struggling with the cultural shift required from workers to realize the benefits.

As factories continue to invest in their quest for Industry 4.0, it's important to pause and understand where they currently stand in order to map out the right next steps (ideally, before they make any further investments). Becuase, if you don't have the foundation of your manufacturing operations right, it doesn't make sense to digitize it.

What is industry 4.0?

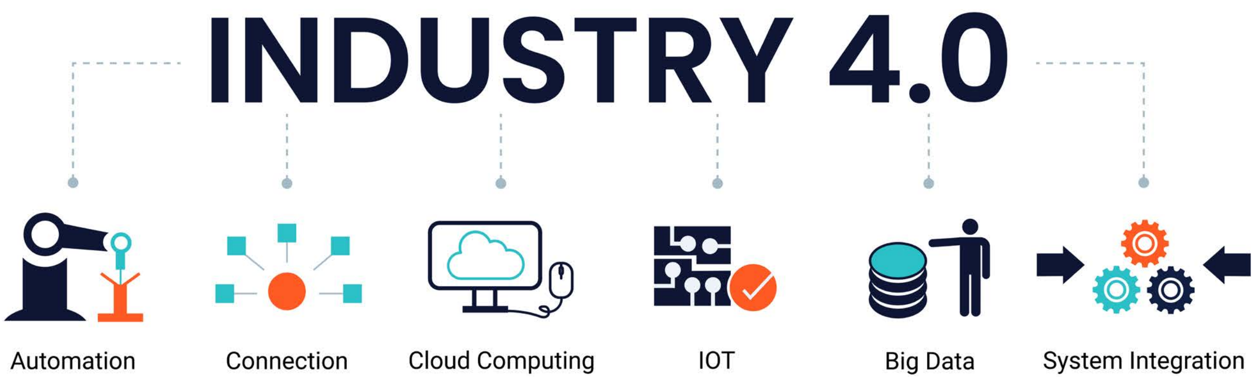
Industry 4.0 refers to the new era of manufacturing where factories leverage today's smart technologies, automation and robotics to produce goods better, faster and cheaper. All of it entails people, technologies and processes being connected to a network of sorts. The term itself can cross over with "Factory Digitization", which we'll use frequently throughout the report.

The concept of Industry 4.0 is made up of multiple pillars, but at a high level, it can imply a factories' transition to an operation that uses 1) Autonomous Systems, 2) IoT, and 3) Machine Learning. Some 4.0 models list additional technologies (i.e., robotics and 3D printing), but in any version of the 4.0 model you find, connectivity, automation and intelligence are the common themes. It's important to note that this report will focus on an Industry 4.0 approach that has a sharp focus on the needs and potential of the human worker, and not pertaining to peripheral technologies (i.e., robots).

There's no one way to achieve an Industry 4.0 operation, and while every manufacturer goes about it a bit differently, the maturity models and figures in this report aim to help manufacturers of all types – and at all stages in their digitization journey - get the foundation right.

The journey to industry 4.0

The investments and efforts required for factories to evolve toward Industry 4.0 are monumental.



It also takes careful planning to figure out what type of technology investment(s) will best support all existing plant operational practices of TPM, 5S and Kaizen, etc. This report should equip plant leaders with the information and perspective to identify which areas are holding them back, and how, pragmatically, to improve operations (and Overall Equipment Effectiveness) using a Digital Manufacturing Operating System. This maturity model should enable plants to assess the maturity of how they handle the people, process, governance, data, and technology components within the four foundational pillars that power a Manufacturing Operating System (MOS). And, by assessing to improve overall operational practices, it should be a much easier path to a digital shop floor.

Why is factory digitization important?

It's no surprise that over 90% of industrial companies[2] are investing in digital factories. Improving efficiency is the main reason for the investment, and **companies expect their investments to pay off in efficiency gains of 12% over five years**[3].

Factory digitization is impacting manufacturer bottom lines in every way you'd expect, and more. Study after study shows that implementing digital tools results in faster and cheaper production. Worker efficiency improves. Waste levels drop and quality improves. Plants experience less unplanned downtime. Workers are safer, and the overall culture is happier. With the right strategy, plants won't end up with unusable data lakes.

Historically, manufacturing operations have been done by hand, using pen, paper, and old fashioned verbal communication to accomplish a task or resolve an issue. The experience required to perform more complex tasks was stored in the minds of seasoned

employees who were heavily replied upon to show up for key-man tasks. Unfortunately that generation of workers is about to retire, as nearly one-fourth of the manufacturing workforce is age 55 or older[4], which means a labor shortage is right around the corner. The incoming wave of millennials, who were raised in a world of digital devices, will make the task of attracting new talent challenging for manufacturers. Manufacturers haven't exactly left that antiquated era of work behind, so the rush to revamp ways of work to attract new talent will be noticeable. A recent report from Capgemini shows that nearly 40% of plant processes[5] are still paper based, and this opens up the possibility for errors that are much more likely in manual task execution. This number is even higher in the U.S., with **49% of manufacturers stuck in pen and paper mode,** according to Deloitte[6]. So the situation hasn't exactly improved much over the course of the last five years.

The digital platforms that will lead manufacturers into Industry 4.0 replace those antiquated methods with automation, standardization, intelligent data handling and search capability, and most notably, connectivity for operators to manage and perform work in onWe digital and mobile interface. Mobile will be at the heart of how operators work and consume information to perform their jobs as the generation shift takes place in the coming years.

Overall, factory digization promises to optimize production and improve the worker experience in a way that reduces overall production costs and improves quality. With an easier, digital way of working, job satisfaction will improve retention in an era where factories are competing over talent.

The urgency behind digital transformation

With regard to the bottom line, **companies expect digitization investments to reduce costs by 3.6% and increase revenues by 2.9% per year**[7] .

But the benefits realized in research of manufactures who have implementation digitization strategies successfully are staggering. A group of industry-leading manufacturers are digitally transforming how they operate their business, using different capabilities of Industry 4.0. The benefits realized include 30-50% reductions in machine downtime, 15-30% improvements in labor productivity, 10-30% increases in throughput, and 10-20% decreases in cost of quality[8].

In addition to reduced costs and increased revenues, digital transformation can positively affect everything from workforce satisfaction to reduced waste, and even quality improvements – which bolsters customer satisfaction.

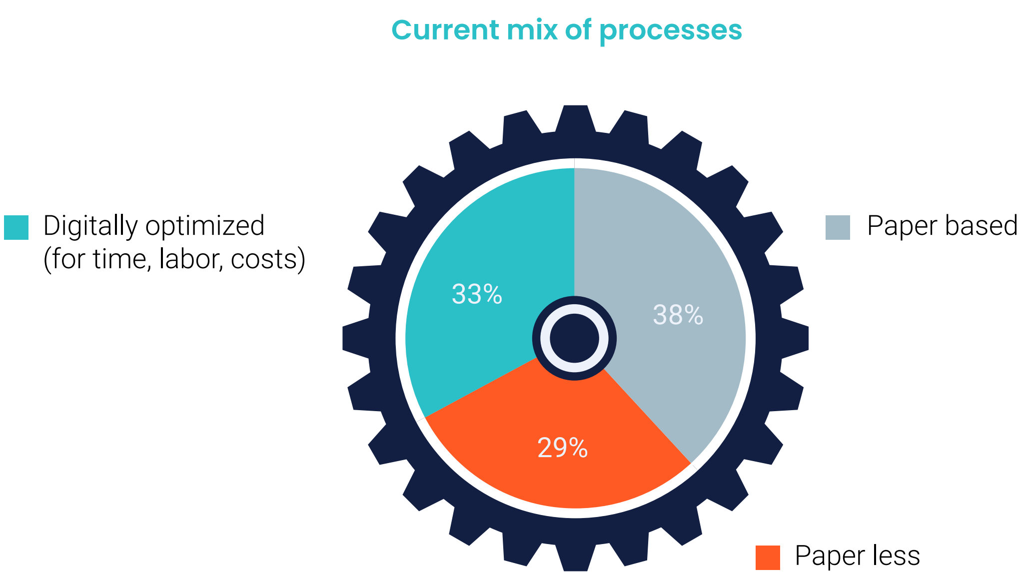
While the expected ROI of digital factory investments is within two to five years[9], using the approach and operator-centric approach outlined in this report, we've been able to recognize significant gains within the first year.

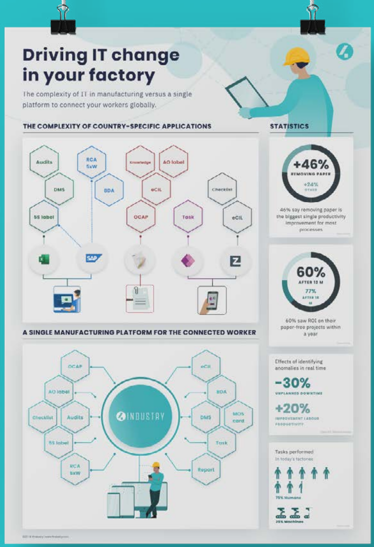
Our vision for factory digitization

While factory digitization has taken on many definitions, we see it as establishing a solid Manufacturing Operating System (MOS) framework, and only once you have that, transforming that into a digital operation of the same (a Digital MOS).

Factory Digitization involves so many different elements, and while IIoT, machine learning and autonomous systems can function fine as individual initiatives, we see often that without an established D-MOS, none of them work together or leverage the data and functionality of eachother to produce actual or worthwhile results to justify the technology investments. The intention of a D-MOS as part of

Figure 1 - Organizational journey to attain operational excellence





Driving IT change in your factory

Replace your fragmented factory application stack with a single platform to provide a uniform user experience across all of your (4.0) manufacturing systems and software.

Download infographic

What is a digital manufacturing operating system?

A Digital Manufacturing Operating System is a system of which your entire manufacturing operations are captured and managed from, using digital tools and information. Most factory floors today have a very fragmented and busy tech stack, but not always one system to manage it all from. This is where a (single-platform) D-MOS becomes key.

The digital aspect of Manufacturing Operations Management (MOM) and a Manufacturing Operations System (MOS) is more recent, but the MOM/MOS concepts are ages old.

A D-MOS is simply a digital version of a MOS, which is a system used by plants to house every aspect of manufacturing operations in a system of engagement, record, logic and action.

While we identify ten different columns (or modules) in the sample operations model in figure 2 there are four key pillars that act as the foundation of the operating system. These four pillar modules that provide the foundation for manufacturing operations include:

- Task management
- Knowledge management
- Autonomous Maintenance
- Safety management

If you can do these four things well, you're likely to have a better-than-average OEE. Below, we'll define each module in detail as well as the influencing factors for each, and their potential impact on shop

Figure 2 - Sample model for digital manufacturing operating system

People	Training	Standardization & Improvement		Production		Quality Management		Maintenance	Autonomous Maintenance	Environmental, Health & Safety	Task Management	Supply Chain Management
Onboarding	Skill Matrix	Centerlining	Changeover & SMED	Production Scheduling	Material Management	Exception Management	Change Control	Preventative Maintenance	Defect Handling	Incident Management	Project Execution & Control	Consumption Management
Talent Acquisition	Training Requirements	Audit	Lessons Learned	Workforce Scheduling	Daily Control Systems	Inspection / CCP	Investigation	Corrective Maintenance	Abnormality Management	Inspection	CAPA	Inbound Material Handling
Career development	Classroom Training	5S	Operational Standards	BOM Management	Equipment Management	Statistical Process Control	Performance Monitoring	Condition Based Maintenance	Equipment Documentation	Operational Controls	Task Control	Outbound Product Handling
Recognition	Online Training	Work Instructions	PDCA	Recipe Management	Order Execution	Golden Rules	Product & Packaging	Spare Management	5S	Business Continuity Management	Task Execution	Material Tracking
Offboarding	On the job Training	Value Stream Map	Kaizen	Product Dispatch Management	Factory Reporting	Sample Management & Control	Genealogy	Inventory Management	Cleaning	Reporting & Metrics	Task Planning (Schedule & Condition)	Warehouse Management
Career Development	Training Process	Poka Yoke	Process Mapping	Production Intelligence	Energy Management	Batch Tracking	Q-RMP Assessments	Work Order Execution	Lubrication	Permit to Work	Intelligent Task Assignment	Rework Management
Gamification		FMEA	DMAIC	Change Management	Process Intelligence	Test Execution	Reporting & Metrics	Breakdown Elimination (BDA)	Inspection	Risk Triggers	Workflow System	Logistics Management
		Start-up / Shutdown procedures	Root Cause Analysis			Regulatory Documentation		Maintenance Planning	Equipment Benchmarking	Safety Audits		Material Ordering
			Standard Operating Procedure					Maintenance Definitions		Risk Assessments		
								Historic Data		BBS Observation Management		
								Performance Reporting & Metrics		LOTOTO System		

- Task Management
- Knowledge Management
- Autonomous maintenance
- Safety Management

Task management

Task management is defined as an efficient way of managing the work performed by an individual or team of operators.

On the shop floor, there are many different personas performing all kinds of tasks. To name a few, there are Operators who typically perform cleaning, inspection and lubrication tasks, Technicians who work on Continuous Improvement initiatives and maintenance tasks, and Safety Officers that perform Risk Assessments and Investigations on incidents.

Many of these tasks are performed in de-coupled systems, and every department has its own. However with concepts like Autonomous Maintenance for example (explained later in this report), you want operators to be more wholly responsible for their area or equipment, and thus be able to perform simple tasks that Technicians would normally perform.

Ideally, a task management application should streamline and simplify the act of work for operators, provide visibility for managers into the way work is performed, and reveal opportunities for production process improvements. It is the practice of identifying, assigning and executing tasks in an efficient manner, and all in one place. It is the single source of truth for work that needs to be or was performed on a routine or as needed basis. Strong task management empowers operators with the right information and repeatable, standardized processes in the palm of their hand. This module also includes the notion of collaboration (chat and exchange information with colleagues) embedded into the steps of task execution. On the management side, task performance data is collected and can be analyzed for continuous improvement.

Today's task management model should resemble, to some degree, how millennials consume mobile applications and services outside of work. In other words, digitization of task management should be similar to how we order services quickly and easily via mobile device, in our personal lives.

Recommendations:

- Make it mobile accessible
- Consolidate all areas of shop floor task execution to take place in one system
- Allow operators to suggest improvements within the task
- Enable worker collaboration in the task management interface

Influencing factors:

- ***Digital interface:*** Mobile access allows workers to execute and manage tasks from wherever they are on the shop floor.
- ***Scheduled/auto task assignment:*** Allows workers to see what they need to do before they even start their work day, eliminating the need for meetings and waiting around.
- ***Standardization:*** Define specific steps that should be taken to perform a job so that they are reusable and can scale across plants – this helps with quality.

- ***Ability to connect tasks to knowledge:*** Eliminates all the time operators waste finding information (or someone with experience) required to perform a task. It also reduces errors.

Impact on business:

- Worker efficiency
- Production cycle times
- Cost per unit

Human error causes 23% of unplanned downtime[10] in manufacturing. That's 2.5x higher than in other sectors. Standardized work procedures presented in a step-by-step fashion help reduce the risk of errors.

In a mature task management application, plant personnel should easily be able to:

- Define work steps to be followed that will reduce errors (with templates, for easy execution)
- Plan tasks (based on Schedule, Manual or on Machine Running Conditions)
- Execute tasks (and register results)
- Automate tasks (perform workflows based on the results, or lack of, new actions)
- Enable collaboration between workers
- Generate reports (a single plane of glass providing complete visibility of all the work being done in your plant)

Figure 3 - Provide step by step work instructions

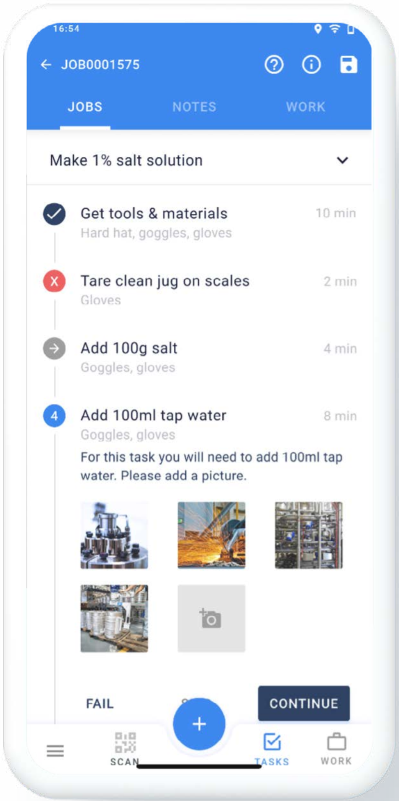
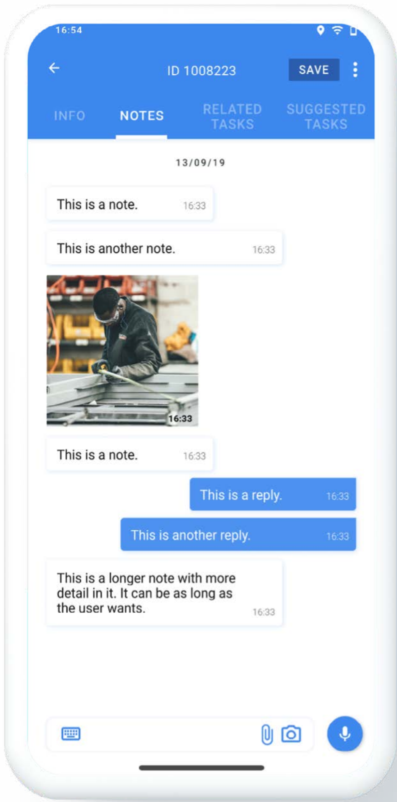


Figure 4 - Enable collaboration between workers



Knowledge management

Knowledge management implies a connected database of all the information workers need to perform their jobs effectively and efficiently. The term Knowledge Management can be interchanged with “information” and “digital work instructions”. A good knowledge management practice would entail a searchable database including (but not limited to) work processes, machine manuals, best practices, training and incident resolution steps, and acts as the primary source of information for operators performing tasks and operating machinery. A mature Knowledge Management system would allow operators to easily share information between eachother, and add or update information already existing in the database.

Recommendations:

- Set up one single database, available everywhere (mobile, desktop) and always up-to-date (only the latest approved version is listed)
- Information should be shared/accessible across multiple plants (one way of working)
- Content and materials in database are actively managed (version control, approvals, periodic review, automatic publication of RCA results, etc.)
- Connect knowledge base to idea management / continuous improvement functionality

Influencing factors:

- ***Culture of knowledge sharing:*** This is essential for user adoption. The workers must want to use, contribute to, and improve the entire knowledge database for it to add value.
- ***Accessibility:*** A good knowledge repository has all information together in one system, and is easy to access (from anywhere, any time, or any device). Good search functionality should exist so it’s easy to find what you’re looking for.

Impact on business:

- Quality
- Reduced waste
- Faster resolution times

A PSbyM Process Industries Performance Study[11] found that only 70% of worker roles are documented with skills requirements and job instructions — leaving many employees without direction.

Autonomous maintenance

The ability of plants to connect production line assets (IIoT), and monitor them in a way that can trigger notifications, actions/tasks based on pre-defined circumstances. Autonomous maintenance allows plants to define machinery conditions that are outside of the norm, and trigger actions to promptly correct the situation, which may or may not require human intervention. In any case, autonomous maintenance sharply reduces the occurrence of downtime.

Recommendations:

- Connect all asset sensors under one roof: SCADA, MES, IoT, etc.
- Assign context to mobile notifications depending on severity, equipment, worker locations, etc. to ensure you notify the right person, the first time
- One database of deviations for the whole company makes it easy to share knowledge = fix deviations faster by using previous deviation lessons learned from other plants
- Enable step-by-step digital execution of RCA / 5Why / 5W1H processes (preferably via mobile device) and make these a standard and required step in response to a production issue

Influencing factors:

- ***Scheduled/preventative maintenance –*** Having the ability to schedule maintenance and push the tasks to operators on a defined frequency is a great way to 1) extend machine life and 2) prevent breakdowns from occurring.
- ***Machine learning:*** The presence of machine learning (a key element of the 4Industry platform) can eliminate the need for human intervention. A D-MOS with machine learning capabilities can take plant maintenance to the next level by prompting corrective measures (pre-defined by operators) all on its own, or recognizing the initial signs of an issue and preventing it from happening at all.

Impact on business:

- Less downtime (and reduced cost)
- Operators freed up for more valuable work
- Extended machine life

Predictive maintenance can reduce machine downtime by 30%-50% and increase machine life by 20-40%[12], but poor maintenance strategies can reduce a plant's overall productive capacity between 5 and 20 percent[13]

Visibility and insights to improve deviation management

Figure 5 - See an overview of scheduled and planned tasks

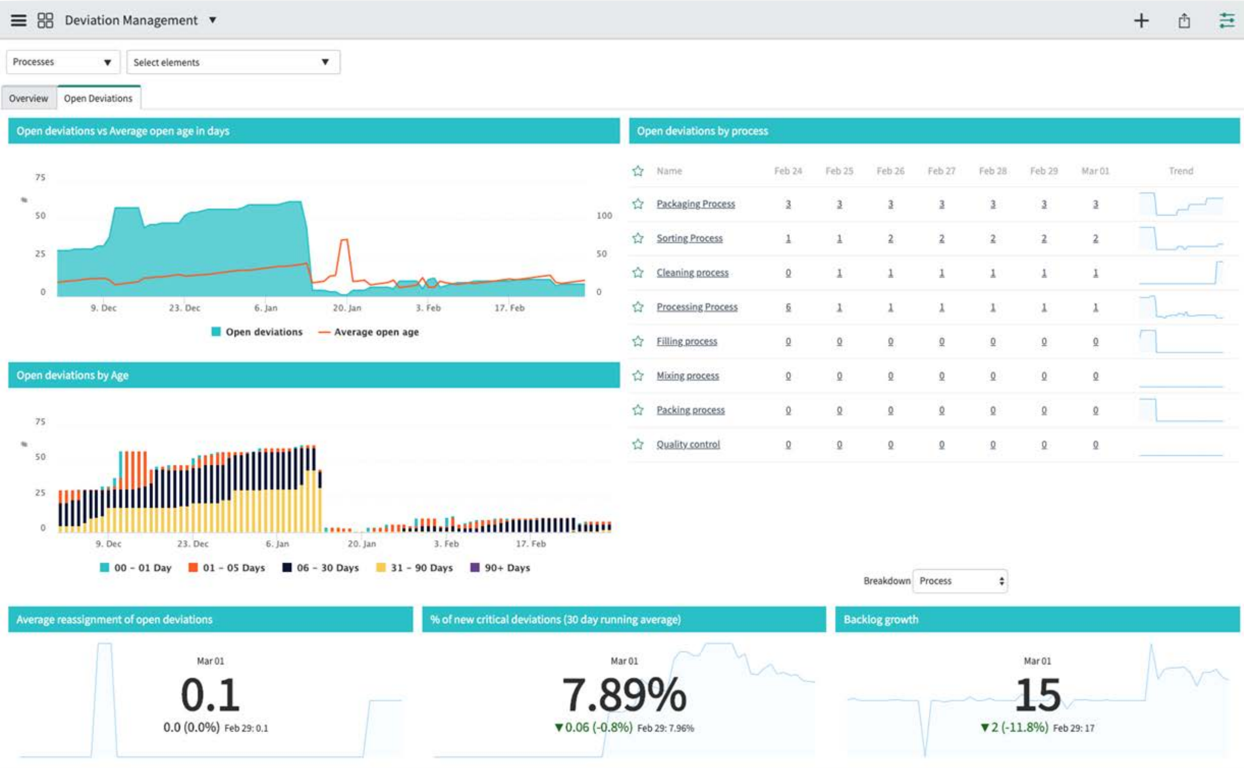
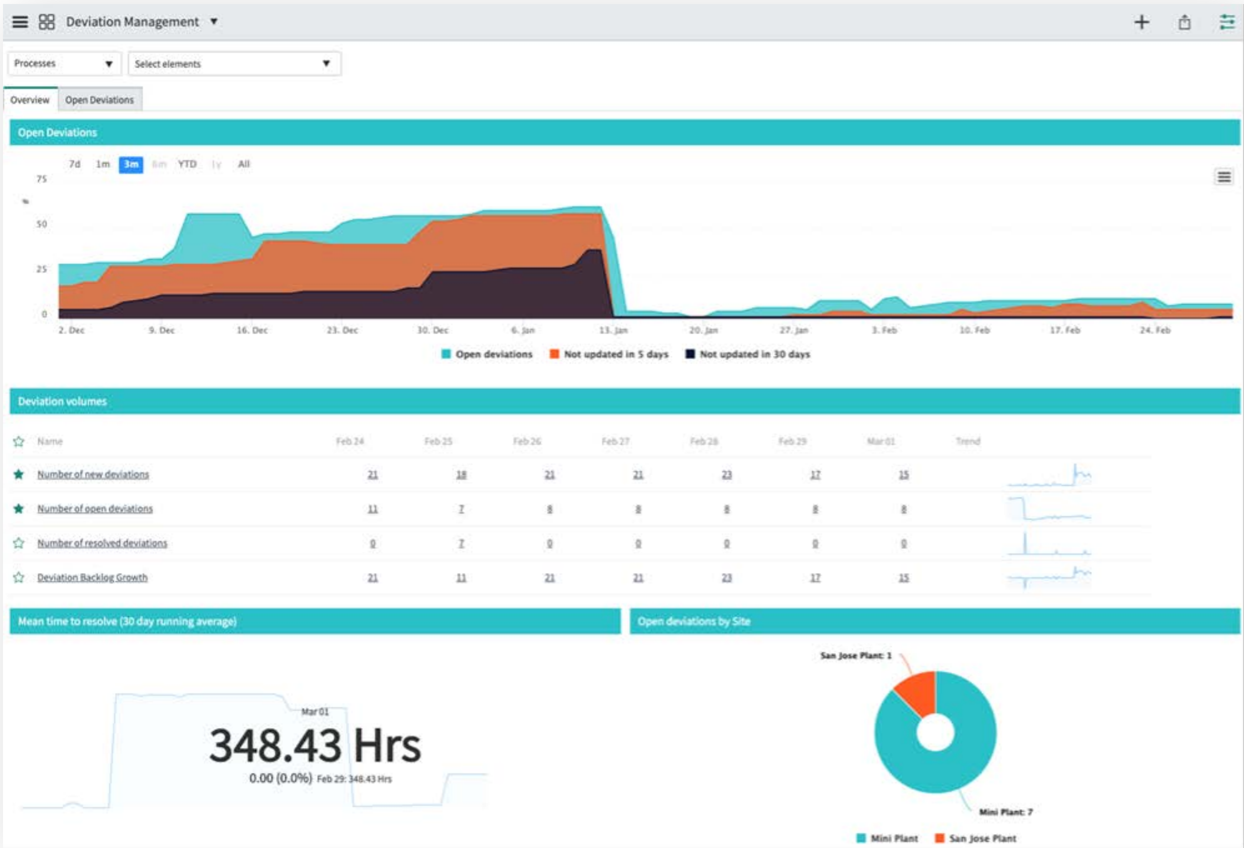


Figure 6 - Easily create new tasks and see an overview of all planned task detail, criticality and stakeholders



Safety management

A good Safety Management practice entails establishing defined (and standardized) work procedures that aim to eliminate or reduce the risk of incidents happening. It also entails clearly communicating the safety requirements (i.e., a face mask applied) and the verification of safety measures being followed, by inserting them into work procedures as defined steps within a task. Safety management can also include interactive steps within a task for operators to confirm they've taken a specific safety precaution before proceeding to the next step, or a certain area, etc.

Recommendations:

- Be able to register safety issue anywhere and quickly, without disrupting work
- Ensure Corrective and Preventive Actions (CAPA) / countermeasures are linked to tasks
- Share a safety issue's lessons learned with the wider team (and/or other plant locations) to improve global safety measures
- Insert safety advisories in everything people do: system utilization, job execution, area entry, etc.
- Implement digital work permits for unusual tasks or especially external contractors

Research found that a majority of manufacturing employees identify safety and hygiene (94%) as top enhancers of their happiness on the job[14].

Influencing factors:

- Culture of safety
- Proper training
- Automated safety checks (Digital work permits, LOTO)
- Safety procedures defined at task level
- Safety Procedures embedded in work instructions

Impact on business:

- Happier workers (a positive culture of safety)
- Incident costs avoided
- Uninterrupted production
- Less days missed due to injury

Now that we've outlined the four pillars which make up the framework of a D-MOS, you can see that the gears to make them work (in a way that produces value for the plant) all rely on the connected worker.

A D-MOS can only be successful with the right strategy and involvement of the workers who need to manage it. It must be set up with purposeful and practical use cases, defined by the workers themselves. As a result, workers feel involved in the movement to 4.0, and the data collected from their work activities is much more likely to be actionable.

Next, we'll discuss what the connected worker entails, and why it's the core strategic element for factories who want to achieve the benefits of an Industry 4.0 operation.

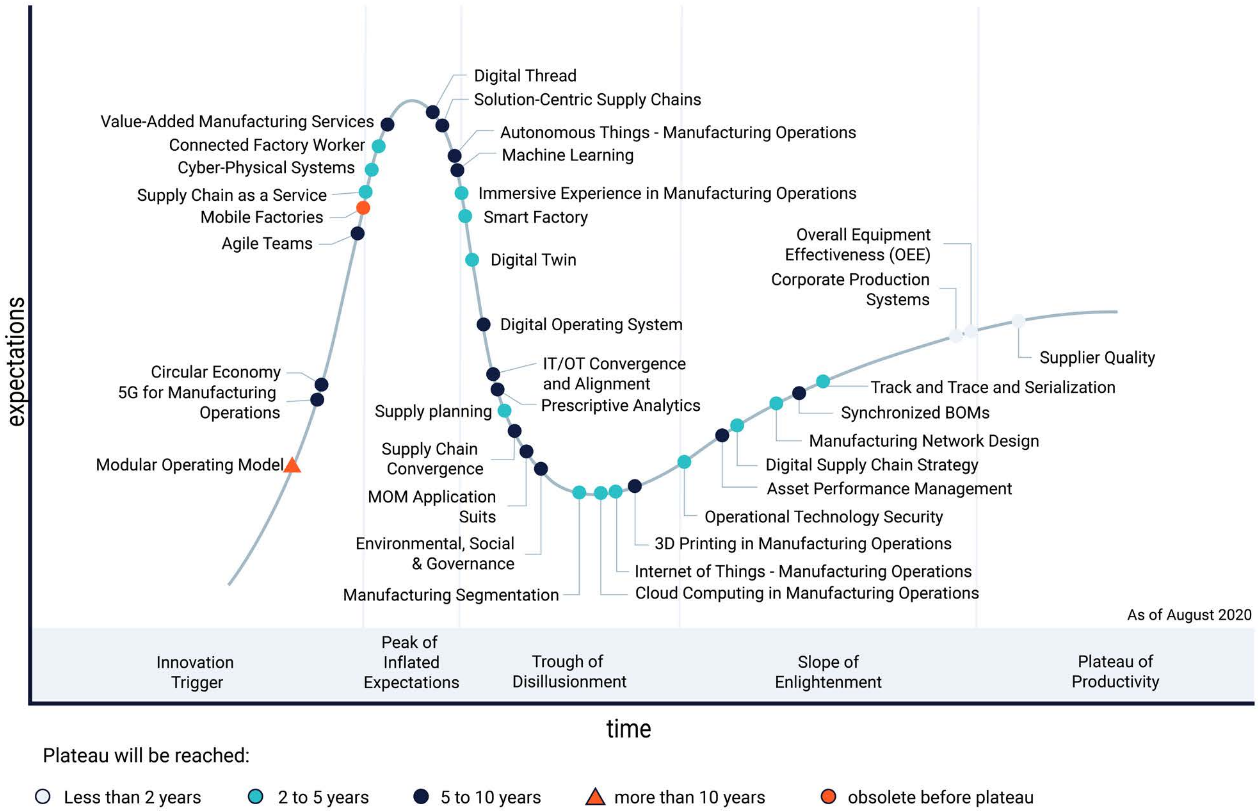
What is a connected worker?

A connected worker is an operator who is connected to his or her peers, factory assets and systems, as well as the information required to perform work via digital technologies. Being connected to a network, the connected worker's actions also feed information back to the system which can reveal bottlenecks, inefficiencies, or other opportunities for improvement.

The Connected worker, by Gartner's definition, is a factory worker who is "capable of using various digital tools and data management techniques to improve and integrate their interactions with both physical and virtual surroundings. They are able to make faster and better decisions that enable and optimize a process or set of processes that they participate in."

It's important to note that the connected worker hype is coinciding with the turnover of the aging workforce in factories. The generational shift will make connected worker tools essential to draw new talent as the millennials step into the shoes of retiring factory workers who have always done things on pen and paper.

Figure 7 - Gartner's hype cycle for manufacturing operations strategy, 2020



Source: Garlner
ID: 450325

Impact of the connected worker

Connected worker tools enable operators to work smarter. In our experience, the impact of workers who have on-demand access to knowledge (articles, SOPs, countermeasures or checklists, etc.), and especially the ability to collaborate with eachother, is significant and near immediate. **McKinsey estimates that a 20-30% productivity gain15 can be achieved through digital collaboration.**

The pandemic has put a magnifying glass and a rush on the need for workers to be connected to keep essential tasks moving, even if they have to be controlled remotely or unable to meet each other in person. Connected workers give factories the ability to assign and manage work from anywhere, as well as the ability to perform certain tasks without the need to be physically present.

A few metrics that shine light on the value of the connected worker:

1. ***Resolution time*** – the path to faster incident resolution has a few components – 1) operators are notified of issues in real time, and thus are prompted to resolve the issue as soon as (or before) it occurs. 2) Operators have instance access to knowledge articles, SOPs, corrective measures and more, which gives them the information they need to take action right away. A smart system could even recognize the signs of a reoccurring issue and suggest a solution before the operator has to look for it. 3) The ability for operators to chat and collaborate with eachother when they don't have the experience or information to solve the issue themselves. Being able to chat with engineers and supervisors can help operators resolve an issue he or she might not be familiar with.
   - Resolving an issue faster is key when an hour of downtime costs factories an average of $260,000.00[16].
   - Mean time to resolve [issues] at one of our customers went from 28 to 6 days using connected worker solutions.
   - By identifying anomalies in real time and providing automated RCA, a manufacturing facility was able to reduce unplanned downtime by 30% and improve labor productivity by 20%[17].

2. ***Travel time (and associated cost)*** – one plant that implemented connected workers on a single DMOS platform experienced a 24% decrease in engineer travel time. What used to be a heavy travel schedule was reduced to 1-2 days a week, and workers were able to focus more on Continuous Improvement initiatives as the information they used to travel for was now available via digital tools.
   - A recent LNS Research report found that 35% [of industrial companies] established remote access to scale subject matter experts who can no longer travel[18].
   - Maintenance workers waste around 21% of their time traveling to different areas in the factory, and an additional 20% waiting for instructions[19].

Embedding collaboration into maintenance processes can reduce maintenance-applicable spending by 10-15%. But the effects are visible in other KPIs as well20.

- OEE: Reduced downtime increases OEE by 2 to 3 percentage points.
- Wrench time: The amount of time workers spend performing value-added tasks versus increases by approximately 5- 10%
- Maintenance cost as a percentage of replacement asset value (RAV): Annual maintenance spend as a percentage of RAV can decrease by approximately 5-10%

3. ***Happier (and loyal) workers*** - Talent acquisition and retention is going to be a huge initiative for manufactures as we enter an era where their long-time employees are retiring and a new wave of millennials and Gen-X make up the majority of the workforce.
    - These workers expect the same mobile, task execution experience at work that they have outside of work (imagine how easy it is to order a meal on Uber Eats and visualize retrieval and execution of dwaily work tasks to match that user experience)
    - Being able to drive the continuous improvement efforts will help cultural buy in – one of the biggest barriers to digital transformation in plants.

4. ***Continuous Improvement***
    - Connected workers provide actionable data. When work activity (i.e., the time it takes to perform a common task) is tracked on a global level, it's easy for plants to look at that data and find bottlenecks, and opportunities for process improvement.
    - Connected Workers are also more likely to drive Continuous Improvement efforts when it's an inherent part of the task they're performing (if you insert a suggestion box into the steps within a digital task flow, the chances operators will contribute suggestions for improvement is much higher).

A key success factor to achieving an effective connected worker is involving the worker in the building of digitization use cases. The key to designing purposeful use cases is to take regular daily tasks of operators, and make them simple, automated and intelligent. Operators can guide digitization efforts to stay focused on the work that actually needs to be done versus the infinite universe of opportunities to connect things just for purposes of capturing data. All too often, we see manufactures have done a nice job of capturing data, storing it somewhere as if it is a goldmine, and then the organization doesn't know how to make use of it. Simply observing the routine actions of your connected workers will produce more actionable data.

At this point, hopefully it's clear that a D-MOS is completely centered around the needs of the worker, and should be stood up on the four aforementioned pillars to unleash the potential of Connected Workers as it relates to Continuous Improvement.

But there's also a technology aspect to getting it right. The technology a D-MOS runs on has to be agile and nimble to keep up with the pace of change or operational shifts that come out of continuous improvement efforts or even an evolving tech stack, and we should note that a D-MOS is most effective when implemented on a low-code platform. This is the best way for manufacturers to 1) keep their digital manufacturing operations framework future-proof, 2) be able to continuously improve their production processes based on data, and 3) have the agility to easily evolve with changing market needs.

Low code platforms for factory agility

What is a low-code platform and where does it fit into your current IT stack?

A low-code development platform provides a development environment to easily create and build upon applications through graphical user interfaces (think visual screen with drag-and-drop building blocks) and simple configuration.

Why is low-code the best option for manufacturers?

The low-code option allows for easy design, creation and customization of user interfaces, work processes, data visualization and logic unique to plant worker and production line needs. This is a smart and pliable option for a manufacturer who wants to digitize unique worker and production processes very specific to their own plant and industry -- it allows plants to take their existing work processes and digitize them to make them easy.

Alternatives include a pro-code platform which requires deep expertise and hand-coding skills, or a no-code application which typically doesn't allow for customization – something most every manufacturer needs.

A no-code platform doesn't allow for any customization, and this is not recommended for manufacturers. No-code requires plants to adjust their processes to fit a static application or workflow, and this can be really tricky. It often results in a big investment followed by an overhaul of the pilot when it hits a dead end. No two factories operate the same, and with the level of variation in worker and production processes across different industries, a no-code platform really limits the value manufacturers can realize from digitization.

In sum, a pro-code platform can be overwhelming and complex to create and build upon. A no-code platform doesn't allow for the customization manufacturers need to suit their unique industry space. A low-code platform is perfect for plants who want to digitize operations with the ability to easily build and adjust as time presents new opportunities for improvement.

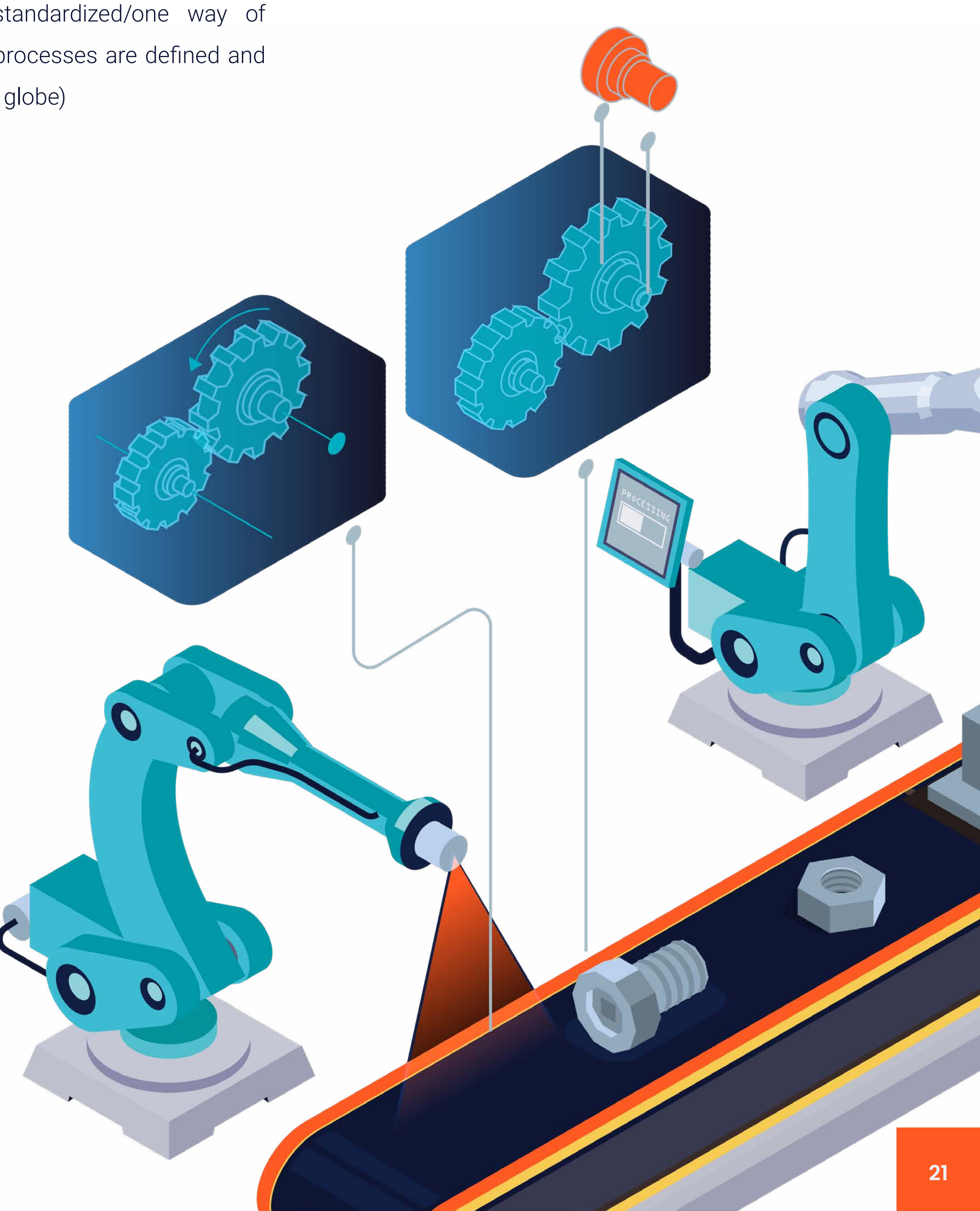
Don't invest in a solution you have to change your business processes to fit - go with a low-code, flexible, and agile platform that can instead be tailored to the ways of work unique to your plant, and that can help you grow along with your digitization journey.

Factory operation maturity

There are 5 different categories that define the maturity of your plant operations (across four different pillars). Each level has general characteristics, and later on, we'll dive deeper into what that category looks like for each of the 4 modules within a DMOS (Task Management, Autonomous Maintenance, Knowledge Management and Safety).

Some factors considered to help define where plants sit across the categories of maturity include:

- Standardization (a standardized/one way of work where efficient processes are defined and adhered to across the globe)
- Operator access to standardized, relevant, up-to-date, on-demand knowledge
- Digital task execution (digital workflows and work instructions, versus pen and paper)
- Task Automation (via IIoT monitoring and rules engines that trigger tasks to happen when needed)
- Continuous Improvement practices
- Connected plant Assets & Workers
- Actionable and purposeful data collection



Factory operations: the maturity levels

Unstructured

Work is done manually and with no frequency, routine or structure. Work execution relies heavily on personal experience. Data collected from processes and assets is unintentional, without purpose and unused. Improvements are done only via one-off initiatives. No knowledge is kept in an organized fashion and issues are addressed reactively.

Sporadic

Random production lines and/or work processes have structure in terms of established methods of task management and issue handling (a breakdown, safety incident, etc.). Only some data from task execution or asset performance is collected, but it's not structured, systematic, or actionable.

Systematic

The plant has a system in place for how work is done, but it isn't automated and it isn't connected. An overall methodology like TPM, WCM, or Kaizen is adhered to and evident in the majority of working functions. Workers in one plant are likely to perform tasks with a standardized way of work, but it's not standardized at a multi-plant or global level. Work is done via traditional methods of pen and paper, with some digital aspects involved (i.e., maybe the task completion details or result of a machine failure is entered into a computer after the fact for tracking purposes).

Digitized

The majority of operator work and plant asset performance is tracked and managed via digital tools. There are likely a lot of different tools implemented at this stage, but they don't all synch and integrate with eachother which creates new challenges. There is room for improvement in terms of process efficiency, worker collaboration and the ability to make improvements based on data insights.

Intelligent

It is rare that a plant has achieved this level of maturity, but these are the leaders who managed to take all the right turns in their path to Industry 4.0 (becoming a Smart Factory). These factories have a standardized and purely digital way of working on one single platform or achieved a successful integration of various applications. They are able to use the majority of data collected for purposeful improvements, and have seen production and quality improvements due to more effective and efficient workers. Workers in "Intelligent" factories are also likely to be more satisfied with their jobs due to an easy and simplified way of work where they can spend more time on value add and CI areas versus maintenance and repetitive, manual tasks.

Assessing maturity across four pillars of your MOS

Maturity matrix: Task management

A plant's Task Management is maturity score is based on their method of planning and assigning tasks, the ease, integration and simplicity of tools used to execute tasks, the availability of standardized job procedures, and finally the presence of easy acces knowledge available to operators executing tasks, within the task execution interface.

	UNSTRUCTURED Tasks aren't managed centrally at the plant level	SPORADIC Some tasks are managed in a centralized way	SYSTEMATIC Tasks are managed regularly in a central common system	DIGITIZED Tasks are managed in a digital system	INTELLIGENT Task management can be done from anywhere, is integrated across all systems
PLANNING	Tasks are not managed centrally; some projects are	Overarching tasks are centrally managed, but details are left to each group Tasks are managed locally on physical boards	Tasks are centrally managed using a common board All tasks are added to the board (i.e., a Kanban board), many of them added manually, pulled from other systems Central board is used to plan work at the shift level	All tasks can be managed from a single digital system An external system can send a task detail to the Kanban board, but some workflows require the tasks to be manually updated Tasks can be assigned at the worker level in addition to group level	Any kind of task can be managed and accessed within a single, mobile-enabled platform Any external system can send and receive task detail Tasks can be automatically assigned based on skills, duration and availability
EXECUTION	Tasks are done in an ad hoc manner, relying on worker experience Step for a given task are known in operator's head (by memory or experience)	Some tasks are predefined at the beginning of the shift Some tasks are part of a broader workflow represented by a decision tree (for example) but not always followed, nor are they routinely updated	Users have a list of assigned task distributed at the beginning of the shift Workflows are defined manually in each task (like a decision tree at the end of an SOP, for example) Follow-up actions are done ad hoc or reported at the end of shift	Any user can access the list of assigned tasks, including non-planned activities like deviations Simple workflow automation can be defined. Based on the task result (ok/fail), another task can be created Follow-up actions or ideas can be registered during task execution	A worker can directly access a task detail within the same application or with deep-linking Task outcome can lead to a workflow, creating other tasks and/or entries of any type Data registered during task execution is contextualized (which tasks, who, when, etc.)
AUDITS	No central management of audits, everything is done locally	Only a small group of people know how to build or execute audits Only a select few audits are defined globally Audit versioning is not managed	Any approved worker can build audits with little or no training Some audits are defined globally, but then altered for local usage Audits are defined, approved and archived systematically	Audits are digitized with text & videos, and can be executed on mobile devices Commonly-used audits are defined globally and used locally with no changes Versioning is done automatically by the system	Audits contain text, images, videos and/or inputs that can trigger workflows All audits for the company are on a single platform, so locations can share them All audits for the company are on a single platform, so locations can share them
WORK INSTRUCTION	No central management of SOPs, everything is done locally	External party or specialized workers build SOPs Only few SOPs are defined globally SOP versioning is not managed	Any approved worker can build an SOP with little to no training Some SOPs are defined globally, but then altered for local usage SOPs are defined, approved and archived systematically	SOPs are digitized with text & videos, and can be used on mobile devices Main SOPs are defined globally and used locally with no changes Versioning is done automatically by the system	SOP contains text, images, videos and/or inputs that can trigger workflows All SOPs for the company are on a single platform, so locations can share them Approval is based on intelligent rules

Maturity levels

Unstructured

We notice when task management is in the unstructured phase, operators do not have an exact plan when starting their shift or day. Tasks are performed on an as needed basis and the information needed to perform the task is either in the memory of an experienced operator, or searched for every time it's needed. Because proactive task scheduling doesn't exist, tasks fall through the cracks and something like a routine maintenance task could get left out of the mix, and two months later, results in a breakdown.

Sporadic

Operators are aware of essential tasks that need to be performed via some kind of plan or reference, but not all tasks are captured and outlined as need to be done on a scheduled or routine basis. Tasks are done using reference materials from all different forums and sources rather than one centralized knowledge base with standardized processes and information. Some teams are more organized than others, which results in inconsistencies and misaligned expectations throughout the plant.

Systematic

Tasks are centrally managed and there's a clear understanding of what needs to be done on a shift/daily/weekly/monthly or annual basis. Regular reviews are conducted on incident occurrences as well as plant machinery and worker productivity. Tasks are executed using manual tools like pen, paper and excel, which is not helpful to the next operator who goes to perform the same task. It costs a lot of time and effort to maintain information in multiple different formats (excel or paper) or across multiple systems.

Digitized

Tasks are executed using automated and standardized workflows that help guide an operator through a job quickly with on-demand steps and information to complete the job right, the first time. Task assignment and execution is managed in a digital interface, but often times the systems of action (task management versus maintenance, ERP, MES, etc.) aren't connected. Manual work is required to keep everything up to date between systems. It's also common that the task management system where a task is assigned is not the same system in which the actual work is performed by the operator (where he/she can access the SOP and click through the steps to complete the task). Job performance data is captured, but not necessarily analyzed for continuous improvement purposes.

Intelligent

Task management, assignment and execution is done digitally and in a single application/interface. Data from plant machinery, work processes and operator performance is tracked in a dashboard reporting fashion that exposes trends and opportunities for continuous improvement. Workers have bought into the process of contributing to the feedback loop, suggesting improvements to ways of work in real time.

Use cases

Common challenges	Digital opportunities
Unclear who does what during a shift/Unclear what still needs to be done	Using visual task boards to assign the task to the right person and have a clear overview of who does what
Lead time on assigning new tasks	Assignment can be done digitally and a notification will be sent when a task is assigned to a person
Difficult to plan tasks ahead of time(for the whole year)	Using a digital schedule task plan will automatically generate tasks based on a time schedule

Figure 8 - See an overview of scheduled and planned tasks

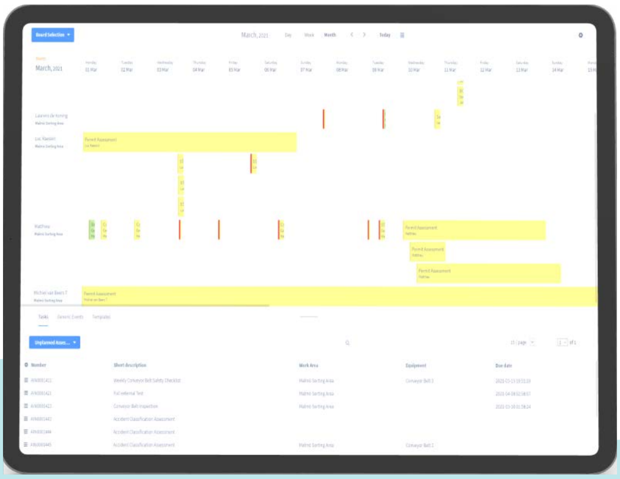
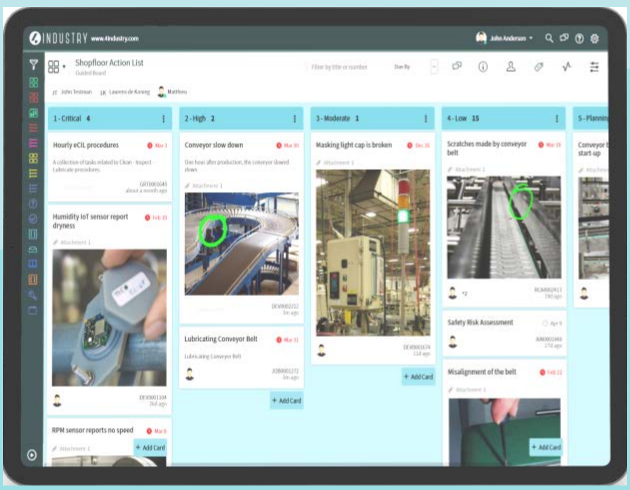


Figure 9 - Easily create new tasks and see an overview of all planned task detail, criticality and stakeholders



Maturity matrix: Knowledge management

The maturity of a plant's knowledge management is judged by their practice of developing and standardizing knowledge (information) to aid workers in performing tasks, and their method of storing that information in a centralized and easy-acces repository. Finally, mutrity takes into account the ease of which workers can consume the information (i.e., searchable via mobile device).

	UNSTRUCTURED No Knowledge Management, everything is in employees' heads	SPORADIC Knowledge is sparsely defined in different systems and formats	SYSTEMATIC Knowledge is defined and approved using one format	DIGITIZED A digital system contains the knowledge of one plant	INTELLIGENT Knowledge is managed at the company level (al plants) in one repository
DEVELOP	Knowledge articles are not maintained	Overarching tasks are centrally managed, but details are left to each group	Tasks are centrally managed using a common board	All tasks can be managed from a single digital system	Any kind of task can be managed and accessed within a single, mobile-enabled platform
	No feedback is collected for existing knowledge items	Tasks are managed locally on physical boards	All tasks are added to the board (i.e., a Kanban board), many of them added manually, pulled from other systems	An external system can send a task detail to the Kanban board, but some workflows require the tasks to be manually updated	Any external system can send and receive task detail
STORE	Knowledge articles are not maintained	Overarching tasks are centrally managed, but details are left to each group	Tasks are centrally managed using a common board	All tasks can be managed from a single digital system	Any kind of task can be managed and accessed within a single, mobile-enabled platform
	No feedback is collected for existing knowledge items	Tasks are managed locally on physical boards	All tasks are added to the board (i.e., a Kanban board), many of them added manually, pulled from other systems	An external system can send a task detail to the Kanban board, but some workflows require the tasks to be manually updated	Any external system can send and receive task detail
CONSUME	No central management of audits, everything is done locally	Only a small group of people know how to build or execute audits	Any approved worker can build audits with little or no training	Audits are digitized with text & videos, and can be executed on mobile devices	Audits contain text, images, videos and/or inputs that can trigger workflows
		Only a select few audits are defined globally	Some audits are defined globally, but then altered for local usage	Commonly-used audits are defined globally and used locally with no changes	All audits for the company are on a single platform, so locations can share them
		Audit versioning is not managed	Audits are defined, approved and archived systematically	Versioning is done automatically by the system	All audits for the company are on a single platform, so locations can share them
STANDARDIZE	Knowledge articles are not maintained	Overarching tasks are centrally managed, but details are left to each group	Tasks are centrally managed using a common board	All tasks can be managed from a single digital system	Any kind of task can be managed and accessed within a single, mobile-enabled platform

In 2019, The United States-based National Association of Manufacturers estimated that 1/4 of the US manufacturing workforce was age 55 or older[21]

Maturity levels

Unstructured

Knowledge, or the information workers need to perform a task and manage plant assets, is not recorded, and therefore not available or located in a central location that makes it easy to refer to. Long-time veteran operators are relied upon heavily for key man knowledge they hold in their head, and when they're not present, there's no record of how to perform certain tasks, so they must wait. Even worse, when your experienced veterans retire, some knowledge will be lost forever (we've heard of plant managers having to call retired people to fix a breakdown.) Because knowledge and information isn't recorded, it's not standardized, which results in workers performing tasks in a different way each time (this can cause safety risks). Pen, paper, and simple memory is the way of working in a plant with unstructured knowledge management, which results in more human error.

Human error causes 23% of unplanned downtime in manufacturing[22]. Standardization of work processes and information used to perform jobs is an easy way to eliminate errors.

Sporadic

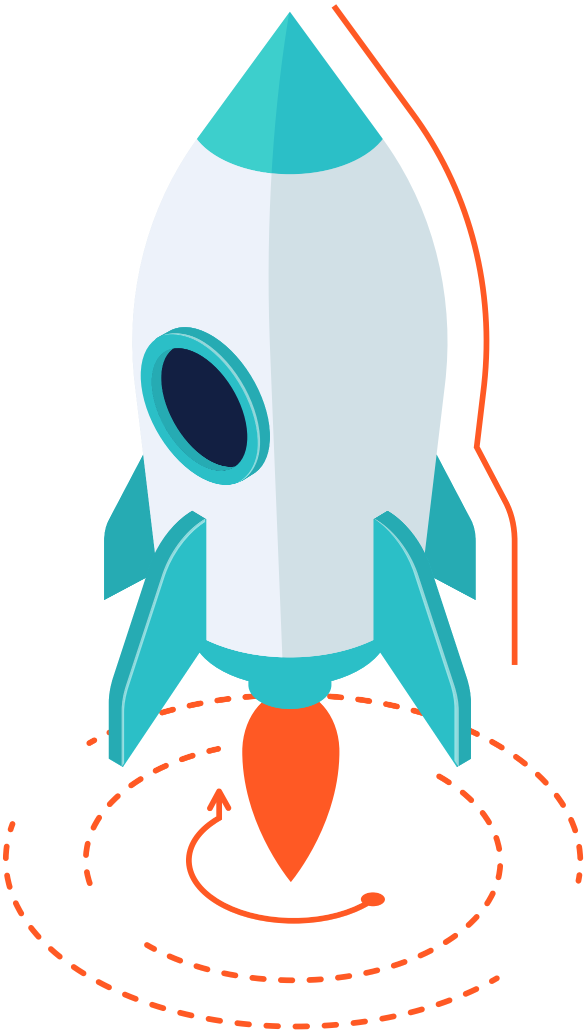
Some knowledge is recorded, and some of the information workers need to perform their jobs is available in a location or repository where operators know to find it. This means that some processes are standardized within a plant, but not in a way that scales, i.e., a Word document put together by someone hastily, and not saved in a central location where it can be easily accessed again. Some processes within a plant aren't standardized at all. Most information required to perform tasks isn't available or is only available via the minds of veteran workers. Pen and paper is still the main way of working, and is how important information is recorded for future use. In this category, workers often struggle to find the information they need to perform a task (i.e., finding a particular machine manual floating around the plant over years to fix a breakdown) and therefore the task takes longer to complete (or can't be started in a timely manner). There is essentially no standardization in ways of work between different plants and therefore it doesn't work to define, share and reuse knowledge and information as they are all working differently.

Systematic

Most all of the necessary knowledge and information required to perform jobs sufficiently is available to operators most of the time. Pen and paper is how information and tasks are tracked and recorded. Information is available on paper or via designated experts for particular task areas. In this category, operators know how to get common information and where to get it, although it might take longer than it should due to antiquated or manual ways of work (i.e., walking across the whole shop floor to get the paper procedure to restart the conveyor belt on line 7). In summary, a systematic knowledge management practice provides information necessary to perform day-to-day activities, but it is slow, adds administrative work, and is difficult to keep updated (being in various places, and on paper). It also takes a toll on job satisfaction due to the repetitive and manual nature of work.

Digitized

Key processes, manuals, lessons and information are recorded and available in a digital interface for easy and on-demand access. The knowledge base is searchable with multiple criterion (equipment, failure modes,). Operators can easily pull up information to perform tasks more efficiently (faster and better). Digitized knowledge management has brought a higher level of standardization among operator ways of work whereas everyone is accessing the same, thoughtfully-designed materials to perform jobs.



Intelligent

Digital knowledge is recorded and available in an easy-access and mobile interface, but also shareable, self-building, and intelligent, based on historical data. Intelligent Knowledge Management includes the ability for operators to improve and refine knowledge as they work, and also the ability to submit feedback and ideas for process improvement while performing tasks. The platform that sits behind intelligent knowledge management applies machine learning to recognize common issues or events and automatically present a solution to the operator based on how the issue or event was treated in the past.

By using the same Knowledge platform for every factory, large groups can foster collaboration between plants; and peoples can tap into the group knowledge and history to solve issues they are facing faster.

Use cases

Common challenges	Digital opportunities
It's hard to find documentation for a machine	Equipment manuals available on-demand, easily located through a mobile device
With so many OPLs within a factory, it takes a lot of time to find the right one	Using a digital knowledge base, OPLs are sorted by failure and equipment type. Easy access to OPLs from a mobile device that only shows relevant OPLs.
Difficult to keep the knowledge up to date when using a folder-based system (or multiple systems)	Easily update knowledge articles when they are stored and organized in one (single source of truth) system.

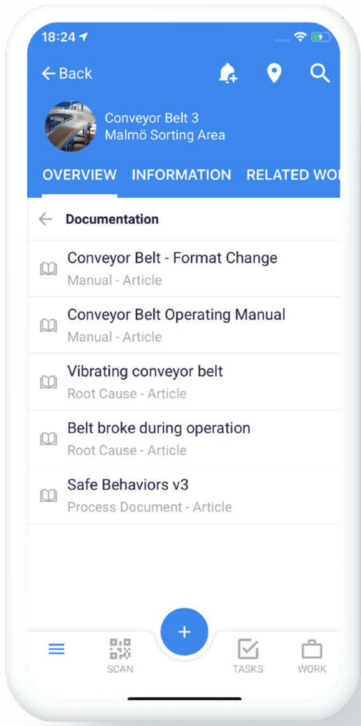


Figure 10 - Enable operators to access all equipment documentation easily, via mobile device

Maturity matrix - Autonomous maintenance

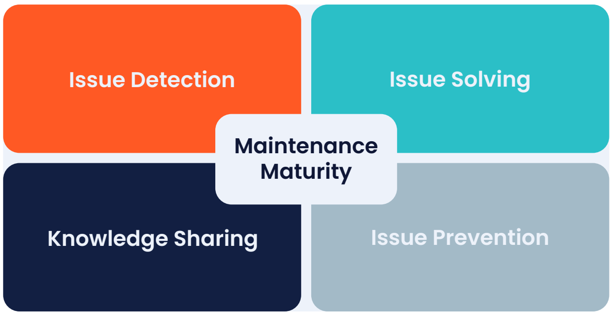
A plant's maintenance maturity can be characterized by looking at their primary means of detecting issues, how they solve them, and their ability to prevent issues from occurring in the first place. Finally, the maturity score takes into account the degree to which they perform continuous improvement activities after incident resolution.

	UNSTRUCTURED Nothing in place, only personal contributions	SPORADIC Seeds of a deviation- and data-oriented culture	SYSTEMATIC Processes like TPM in place and under control	DIGITIZED Digital benefits here but slowed by company & tool silos	INTELLIGENT Full utilization of all available data
DETECT & REGISTER	No planned checks are made, deviations discovered by accident	Regular checks are done by maintenance	Regular checks are done by production	Equipment is monitored by a local sub-system	Equipment is monitored by a central plant system
	Unsystematic communication between maintenance and production	Only production management is informed of breakdown or maintenance	Some operators are informed by a colleague in person or by phone	All operators are informed if they check monitoring devices	All relevant operators are proactively informed by mobile device
	Record is loose-leaf paper	Record is in a paper-based registry	Record is a paper-based record copied to a database w/ photos	Digital record in a standalone database with photos and pre-filled information	Digital record interconnected in company's single source of truth, w/ tracking of all actions performed
SOLVE	If maintenance cannot fix the issue, an external team is called in	The maintenance team fixes most common issues	The production team fixes most common issues	Maintenance is dedicated to proactive work; production team handles day-to-day issues	Maintenance is dedicated to predictive work; production team handles day-to-day issues and light maintenance
	No management of SOPs & Manuals	SOPs & Manuals are paper-based, stored in one place	SOPs & Manuals are paper-based, stored in various places with version control	SOPs & Manuals are digital-based with version control	SOPs & Manuals contain images, videos and links, and relevant ones are proactively suggested to workers when a deviation is registered
			Local teams can contact an expert, if needed, in an ad hoc fashion	Local teams can collaborate (chat) with global expert teams to solve a problem	Each location can access all plant locations' registered deviation history to help in solving their own
PREVENT	No regular maintenance	Regular maintenance is planned and done by maintenance	Regular maintenance is planned and done by production	Maintenance period is dictated by statistical systems, based on previous results	A failure prediction system is in place, based on sensors and historical data
	No RCAs are done	RCAs are done on paper, sporadically	RCAs are done on paper with time loss > 1 shift	RCAs are systematically done and archived digitally	RCAs are systematically done digitally. A follow-up audit is done to check if the true cause is fixed
IMPROVE & STANDARDIZE	Sporadic knowledge exchange between locations	Outstanding issues and RCA/resolution contains "Lessons Learned", which are shared sometimes within the company	A regular review of all deviations and RCAs is done within the company	RCAs are systematically shared with other locations	All locations can access each other's knowledge, data on deviation or RCAs, in their local language
	Improvements are done ad hoc	Paper-based idea registration, occasionally reviewed	Paper-based idea registration, regularly reviewed	Digital idea registration, regularly reviewed	Digital workflow exists for idea registration, implementation and follow-up, regularly reviewed

70% of the companies don't know when equipment is due for maintenance or upgrade.

Maturity levels

A plant's maturity in terms of maintenance is defined by 1) their ability to detect an issue, 2) the way in which issues are solved (i.e., defined and standardized steps), 3) their ability to share knowledge across plants, and 4) their ability to prevent issues from occurring in the first place.



Unstructured

Maintenance of plant assets is done manually - not in a standardized fashion with structured processes, and not on a proactive or planned basis. As a result, maintenance is purely a reactive practice versus preventative: fixes are put in place only when a breakdown happens.

Sporadic

An internal maintenance team exists and is able to fix most common issues with their unstructured, internal knowledge. The same team also carries out regular maintenance of equipment and maintains random records on paper. The production team doesn't participate in breakdown fixes or regular maintenance, and there's little to no connection between the two teams. As a result, there can be conflict regarding priorities between the maintenance and production teams.

Root Causes Analysis are sporadically done on paper, and outstanding issues are typically shared across the company.

Systematic

The production team is responsible for maintaining and fixing equipment with the help of knowledge from the maintenance team. Paper-based knowledge and procedures are stored in a common place, and the teams inform eachother of essential information during reviews. For major breakdowns, Root Cause Analysis is done with member from each of the maintenance and production teams. Continuous improvement ideas are collected on paper and regularly reviewed.

Digitized

The most important plant assets are connected to one or several internal systems for digital control and monitoring capabilities, like a SCADA or a DCS. As maintenance is free from day-to-day issue handling, the team can focus on more valuable initiatives, often using insights from plant asset performance data.

The production team can check monitoring devices to identify if any equipment requires attention and

What is autonomous maintenance?

Autonomous Maintenance means that the people the closest to machines (all operators) should take care of light maintenance, identify and solve basic issues autonomously. This is because operators are the one who use the equipment everyday: as such they know the machine better than anybody else. Maintenance team takes care only of biggest breakdowns and can focus to prevent breakdown from happening in the first place.

In our digital world, plant assets are connected and monitored via a tool or system that can trigger notifications and alerts upon any event that deviates from what has been defined (by plant personnel) as the norm.

easily find the knowledge document/information to solve the issue. Those knowledge documents (procedures, checklists, articles, etc.) are stored in one common digital database, used by the whole factory. Root Causes Analysis are systematically done, and results are published in the knowledge database accessible by all.

Intelligent

At this level, every plant asset is connected to a single system which monitors the majority of equipment status. This system can detect malfunctions (both from situational thresholds defined by the operators and trends) and can generate notifications accordingly. Each notification is sent to the right worker, depending on multiple criterion (work area, operators' locations, severity, etc.).

Most maintenance done is either preventive (by the production team), or predictive, (by the maintenance team, using machine learning algorithms for instance). The system also contains all digital knowledge needed to fix issues (checklists, audits, work instructions, articles, etc.) and this knowledge is shared across all plants.

Use cases

Common challenges	Digital opportunities
Manually checking the CIL tasks for the day	Digital system automatically creates the CIL task based on a plan and assigns it to a person
Completing your Deviations/Tags requires using multiple sources of input	Digital form where you can fill in the details of deviations/tags on the spot, take pictures of real life situation and relate it to the machine
Time spent on administration to fill in using paper forms	Automatically field in values in digital forms

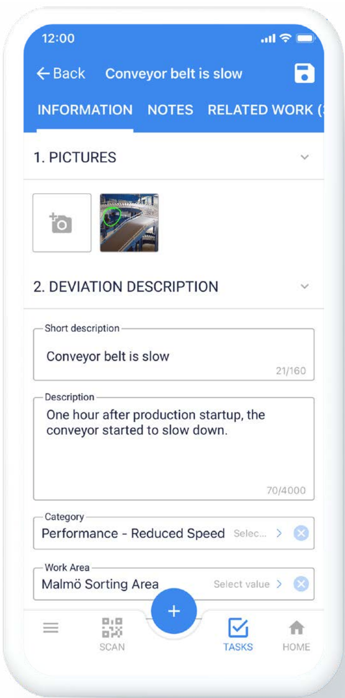


Figure 11- Enable simple mobile capture of all deviation details, including photos

Maturity matrix: Safety management

The Maturity of a plant's safety management practice takes into account their ability to prevent issues from occuring, including the presence of work permits and safety precautions embedded into work procedures. It also looks at the plant's ability to capture and analyze information from safety incidents, and how those insights/ lessons are applied to prevent future incidents.

	UNSTRUCTURED	SPORADIC	SYSTEMATIC	DIGITIZED	INTELLIGENT
CAPTURE	Only management reports major incidents	Some employees (supervisors, managers) report minor incidents	All employees can report incidents directly, using a form	Incidents are reported using a digital application	Incidents are reported in the same application used to manage production tasks
	No additional information is collected	For major incidents, information is collected in an unstructured way	Information related to incidents are collected in one standardized form	Information is collected digitally, with a form, depending on the incident	Collected information (from an incident or assessment) can be used to trigger automated workflows
	Incidents are not reviewed after their registration	Incidents are reviewed regularly by management	Incident follow-up is performed and managed (manually) by dedicated personnel	Incident management processes like escalation, tasks and audits are standardized, and handled automatically	Every workflow is automated and can be edited using a low-code platform
ANALYZE	Incidents & Analysis are recorded in an unstructured paper registry	Incidents & Analysis are recorded in a paper-based registry	Incidents & analysis are registered on paper, then copied into a digital database	All incidents & analysis are stored in one database, and are linked to assets and tasks	The same platform is used by the whole company
	No analysis is done after an incident	Analysis is done for major incidents only	Incident analysis can be created from a registered incident, and follows a defined methodology	Analysis are done digitally, allowing plant to keep analysis details forever	Result of analysis is shared across all locations, so others can learn about potential risk situations and proactively fix or avoid them
		Corrective countermeasures are applied on an ad hoc basis	CAPA are identified during analysis and are managed as tasks	CAPA are linked to analysis and their completion is tracked manually	CAPA are part of the task management system
PREVENT	No prevention processes are in place	Workers are regularly reminded of safety measures	All procedures, audits or articles include/display applicable safety measures	Some tasks require workers to complete a safety assessment first	Safety advice or audits are sent to workers depending on their skills and seniority
					Upon entering a work area, the worker receives a digital audit form for applicable safety measures
WORK PERMIT	No work permit process	A work permit process is used for long-term contractors	A work permit process is systematically used for unusual jobs or by external workers	The work permit process is digital, appropriate stakeholder(s) responsible for signing are predefined	Work permits are proactively suggested within a task based on worker skill, history and seniority
	No daily reminders	Contractors must sign a risk acceptance form upon entering the plant	Work permits are signed daily by the worker to communicate safety measures and verify acceptance of risks.	Work permit can be signed digitally	Work permit details (like hazards and countermeasures) are automatically defined according to the work area

Maturity levels

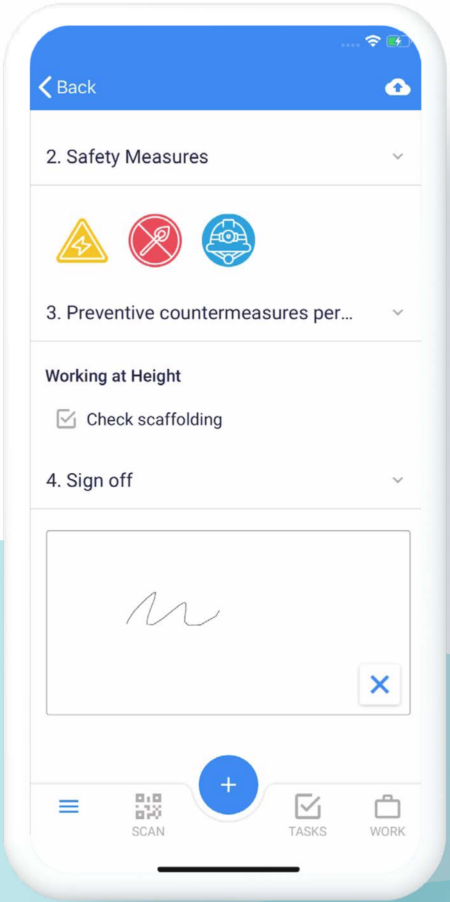
Unstructured

Safety is something workers are aware of, but it is not woven into the plant culture or specifically, operator ways of work. Occasional issues occur due to a lack of safety measures engrained into work procedures and a fundamental lack of communication around safety measures required for specific areas and tasks. Some signage exists around the plant, but workers are expected to manage safety equipment and precautions at the individual level.

Sporadic

Some worker processes have defined safety procedures that are required to be followed, but not all. The way in which safety procedures are defined, recorded and presented is random and sporadic, with some procedures communicated verbally, some presented once in initial training, and occasionally, if there is a digital working interface, presented in certain areas of digital knowledge. There is some signage throughout the plant to loosely communicate safety requirements. Work procedures are separate from safety procedures, although the two are casually expected to be applied together. Major incidents are analyzed, but countermeasures are not follow up.

Figure 12 - Digital signature verifies safety procedures adherence



Systematic

There are defined safety measures for most working procedures, and the expectation among plant leadership is that these will be followed. Safety procedures are available in different formats – signage, training, paper, some digitized, and it's understood that specific safety precautions, equipment and procedures should be applied to specific tasks. Safety is a part of the culture and therefore anybody can report an (near) incident in a standardized way. A designed person will analyze it, identify countermeasures and will enforce their implementation.

Digitized

Safety procedures exist for wmost all of factory work processes, and are defined and recorded in one primary digital interface. Workers receive proper training and have easy, perpetual access to these safety procedures and information. For some tasks, individuals can check safety requirements and procedures by the mean of a checklist before performing it. Some workers participate in incident analysis in order to prevent any safety issues.

Work permit are done systematically for external workers or uncommon tasks for internal workers.

Intelligent

The way workers are presented with the safety requirements depends on their skills and seniority. In an intelligent plant, safety procedures are well defined and integrated into the steps of established job/task procedures to practically eliminate the risk for an accident if the operator is following the defined steps to execute a job. Safety requirements around work permits, protective equipment and the like can be presented as a pop-up that requires consent or agreement by the worker before they can proceed. An example is shown in figure 12.

In an intelligent safety management plant, it's easy for plant management to see a visual overview of safety measures and worker adherence, as well as any safety incidents that may occur to collect insights on where improvements can be made to further eliminate any risk of accident. All analysis and countermeasures identified in one plant are share with the other in the company, further preventing safety issues.

Use cases

Common challenges	Digital opportunities
Lead time of incidents when using paper based processes	Quick registration of HSE related issues
Time spent to acquire multiple sign-offs at location for Work Permits	Sign-offs do not need to happen in person. It can be done from mobile device and on short notice
Unclear oversight of LMRA	Automatically trigger an LMRA and the results are sent to the appropriate people

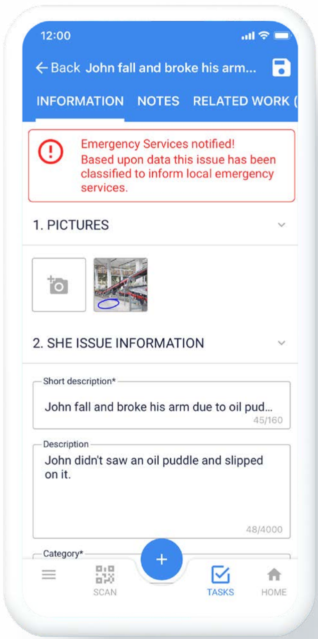


Figure 13- Enable on-the-spot, mobile capture of HSE issues

Interested in more use cases?

Download our latest connected worker use case library.

Download use case library

Where are you in the transformation journey?

The maturity assessment

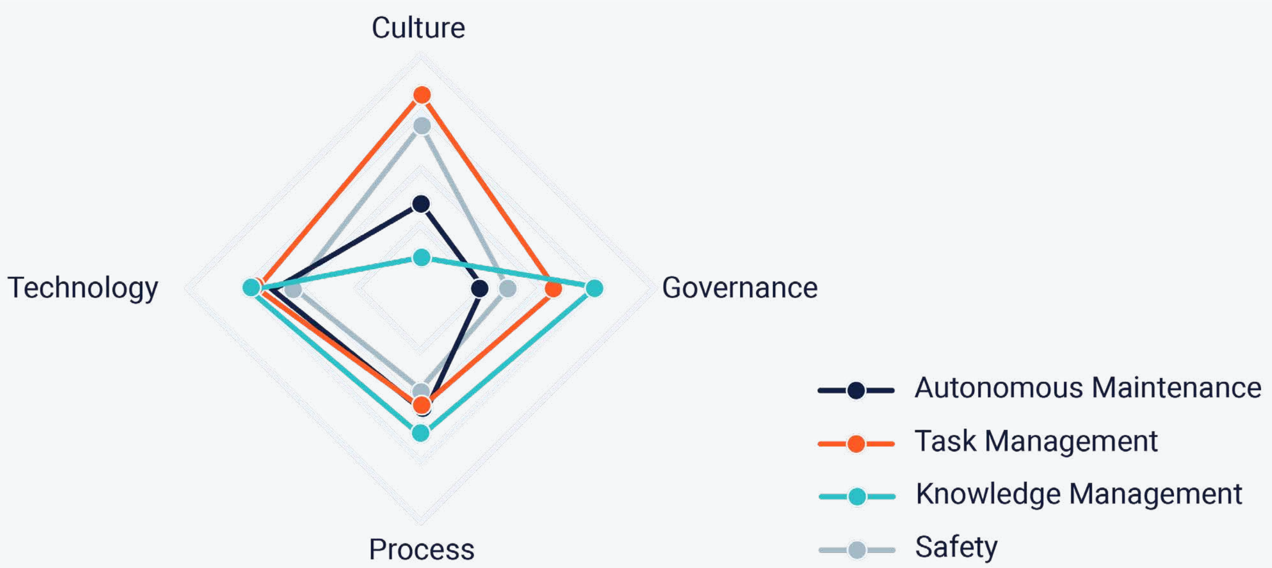
A comprehensive maturity assessment to understand where you currently are in the path to digitization is essential for determining what you (still) need to do, where to start and what your priorities should be in terms of highest value, savings or risk.

Our proprietary assessment model captures a plant's maturity in terms of culture, process, governance and technology across each of the four modules of plant operations. The method used scores each area based on a defined set of questions that are strong indicators of a plant's current state and its progress toward digital operations.

By undergoing this assessment, manufacturers are presented with a birds-eye view of their weak areas (what needs immediate improvement) and strong areas (what they're doing well). More importantly, with this report, plant leaders should gain a better understanding of the value, savings or risk associated with weakness or maturity in each specific area. At the end, we hope it calls out the most pressing opportunities for improvement or change that can result in near immediate impact on the bottom line and of course, OEE.

Below we'll highlight an example maturity assessment which we performed for a major global beverage producer.

Figure 14 - Overall plant operations maturity



Overall maturity

The biggest opportunity for this hypothetical manufacturer is around the culture of knowledge

management. While it may seem less important than autonomous maintenance and task management, creating a practice of defining and sharing knowledge will boost production efficiencies that will impact the plant's bottom line. Task management can't be truly digital and intelligent until there's substantial knowledge integrated into the process of task execution.

Their strong score in task and safety management exhibits a good culture among workers who are bought into the idea that tasks should be executed in an automated and standardized way, and who also take seriously and understand the importance of safety measures.

Contact us at info@4industry.com if you're interested in having a report created for your own manufacturing operation

Task management

In this example, the organization uses a digital interface for task planning, and it is also the primary way workers access steps/instructions needed to perform tasks. However, a digital and mobile-enabled workflow isn't completely in place for actual execution of the task. This presents a big opportunity for the manufacturer considering the data collected from operators' digital task execution reveals the most immediate and easy ways for improvement (i.e., if digital task activity shows an operator fixing the same machine twice per month, and that machine is responsible for 2 hours of production downtime each time it stops, the manufacturer can see that replacing the machine altogether is cheaper than the cost of two breakdowns).

Figure 15 - Task management

Knowledge management

Standardized knowledge is the biggest opportunity in this picture. It's apparent that workers are good at developing and storing knowledge, but unfortunately time is wasted when that process is done over and over again for the same process when it doesn't need to be. Creating one standardized process for a specific task can save an operator hours per week. The way this plant consumes knowledge is inefficient and eating up valuable time that could instead be spent on continuous improvement efforts.

Figure 16 - Knowledge management

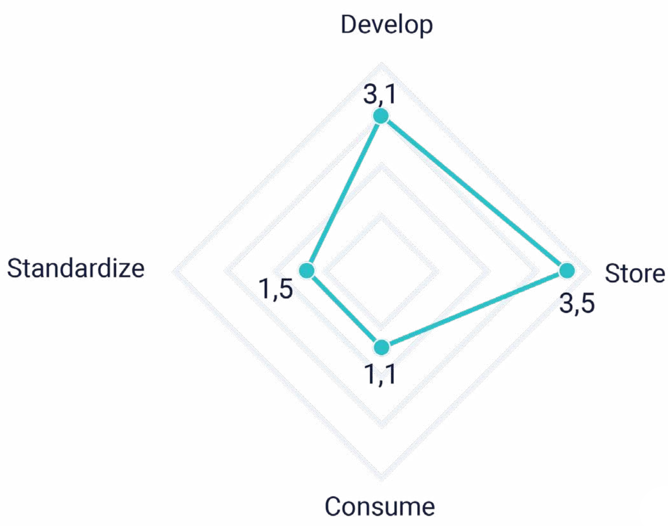
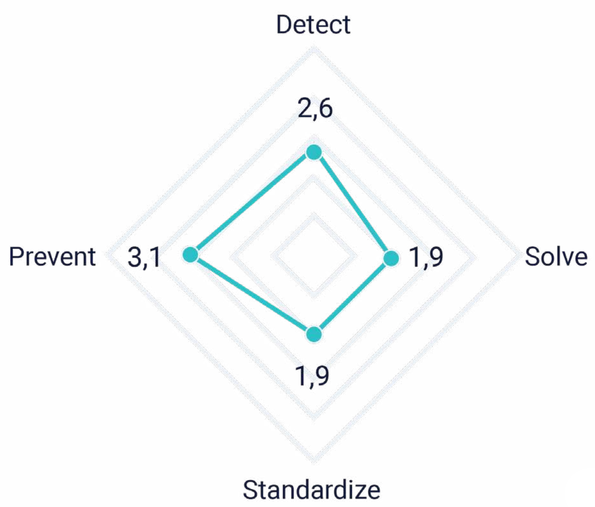


Figure 17 - Autonomous maintenance



Autonomous maintenance

In this example, it's obvious that their practice of standardizing issue resolution procedures was low, and so their ability to "solve" was also low – these are strongly correlated. On a better note, their separate and sporadic actions to prevent issues is working to some degree, but with room for improvement.

Safety management

In this example, it appears the plant places a high importance on safety, including defining safety precautions that prevent issues from happening in the first place. However, the lower score for their ability to “capture” means they don’t have a mechanism in place to track when (and how) an incident does occur. Thus, there is further opportunity to reduce safety incidents simply by capturing data from incidents and performing an analysis to implement measures that will prevent anything similar happening in the future (or at alternate plant locations).

Figure 18 - Safety management

How to accelerate your transformation to a digital shop floor

Knowing where you stand in terms of maturity today is essential to understanding your next steps. Hopefully this maturity model has helped you to identify where you are in the digital transformation journey, and the next step is in creating a roadmap (and a starting point) to accelerate it.

To that extent, we've developed a four-stage digital transformation guide (see Figure 19) that should act as a checklist to help manufacturers assess and consider all the necessary components to achieve a better end result.

Figure 19 - Digital transformation roadmap construction

The stages are as follows:

1. ***Assess and define:*** Understand your current state of digitization, learn your potential and define the roadmap to successful digital manufacturing.
    - Business Value Assessment – assess your situation vs industry best practices
    - Operating Model – define operating process, skills, roles& responsibilities and governance model to effectively work in the new situation
    - Vision & Roadmap – define your vision and create the implementation roadmap
    - Systems Architecture – define or refine the Manufacturing systems and data architecture to ensure an optimal and future-proof manufacturing system architecture

2. ***Build and implement:*** Build the solutions that fit best to your business, taking care of end-to-end implementation, ensuring successful implementations:
    - Project & Change Management – successfully deliver solution, including user adoption, go-live support
    - Solution Design & Build – build the end-to-end solution according to scope
    - Solution Configuration and Deployment – configure users, equipment, processes and make system available to users
    - User Training and Coaching – make sure all users understand how to do their work better in the new situation

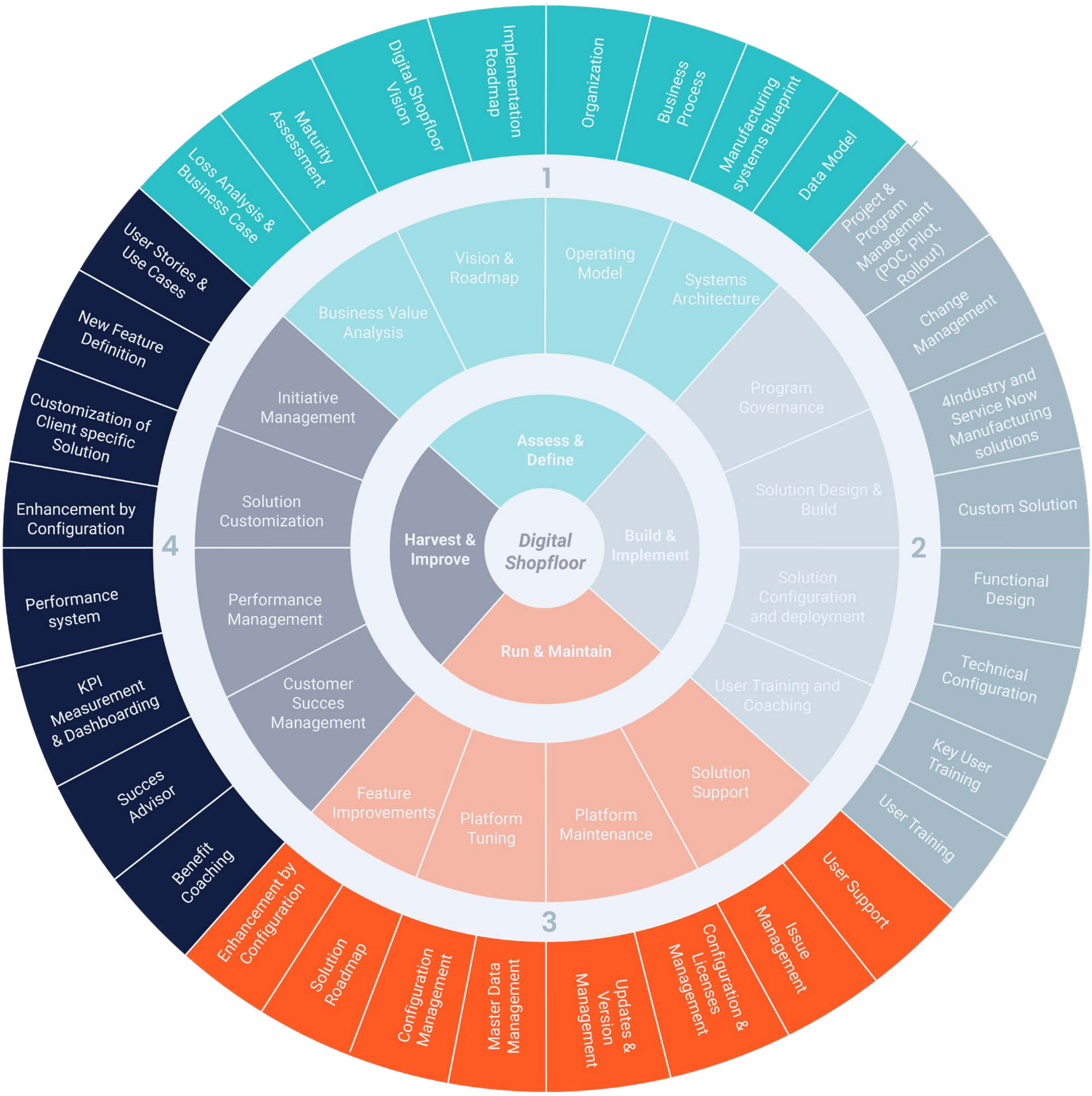
3. ***Run & maintain:*** To ensure solutions are running with optimal availability and performance, the following is needed:
    - Solution Support – provide user support for issues, questions and feedback
    - Platform Maintenance – keep the platform running in a healthy way by system administration tasks
    - Platform Tuning – ensure optimal user experience while remaining cost-effective
    - Feature Improvements – provide best solution by configuration optimization and deploying new features.

4. ***Harvest & improve:*** Build the solutions that fit best to your business, taking care of end-to-end implementation, ensuring successful implementations:
    - Project & Change Management – successfully deliver solution, including user adoption, go-live support
    - Solution Design & Build – build the end-to-end solution according to scope
    - Solution Configuration and Deployment – configure users, equipment, processes and make system available to users
    - User Training and Coaching – make sure all users understand how to do their work better in the new situation

This is not a lightweight initiative and requires dedicated focus. We recommend assembling a team to manage the strategic, functional and technical elements required in each stage of constructing a roadmap, as shown in the outer layer of the graphic on the next page.

We strongly recommend sourcing a partner that has experience, use cases and reusable assets to manage deliverables in the outer-layer to make transformation a bit smoother (and faster).

Figure 20 - Roadmap construction tasks



Once you have a roadmap outlined, we recommend staying true to a few key principles to guide the transformation in a way that produces measurable outcomes in a reasonable timeframe. We've found this approach helps achieve quick-wins, and gives the transformation momentum in terms of cultural buy-in and executive support to expand the wins achieved.

Start with the worker

Focus on actual worker needs in terms of how you could make their work easier. Humans still perform 72% of shop floor tasks, and this is where your initial digitization efforts should be focused.

Take the time to find out what your workers need to do their jobs more effectively and efficiently, and set up a task management interface (ideally accessible by mobile, so it can go anywhere with them) to address their needs.

Before you endeavor to connect machines to a

According to a recent study by Accenture, 60% of operators cite dealing with outcomes of data gathered as a major challenge[23].

network, use the information collected from worker activity to observe how work is performed and look for trends that uncover immediate opportunities for improvement. By analyzing worker activity, you'll immediately be able to see bottlenecks, i.e., which machines are repeatedly breaking down with the same issue, or which jobs are taking workers an unreasonable amount of time to perform.

You can gain a surprising amount of insight into your plant operations – and opportunities for process optimization - just by observing daily worker activity and asking workers what could be improved. We recommend starting here, and not worrying about connecting all of your machinery with IIoT or sensors until you've achieved some small wins through the data collected from operator task execution. We'd even suggest achieving some wins in this observation phase before digitizing knowledge (SOPs, machine manuals and the like) to enrich the task management interface.

Don't reinvent the wheel and design new use cases that are digital – implement simple use cases to digitize task execution for routine daily jobs that already exist.

It's important to mention we've met many manufacturers who thought it made sense to connect their machines as a starting point to digitizing the shop floor. The workers weren't bought in, and they also didn't know what to do with the data that had been collected, because it had no defined purpose that tied to value creation. We can't stress enough the importance to focus on collecting data intentionally, only where you have a purpose for how it will be used (ideally, things that can move the needle in OEE).

Involving operators in the strategy and deployment process of digital transformation makes them feel personally invested and an integral part of the transformation. As mentioned throughout this report, behavioral and cultural shift is the biggest barrier to success, so looping the workers in at the outset greatly increases the chances of success.

According to a recent study by Accenture, 60% of operators cite dealing with outcomes of data gathered as a major challenge.

"Do not let data outweigh operator intuition"
- McKinsey

Think big, start small.

Manufacturers are quick to think IIoT when they get the green light on a big investment to digitize operations. What we have found to be a more successful path is putting that stage of connecting assets to a network and implementing sensors in the backseat, and instead focus in on how your workers are performing tasks and what are key patterns and issues they identify in the process.

For example: Which machines are operators constantly fixing? Which line of operators is seeing the most quality defects? Which tasks take the most time to complete? How long does it take for a maintenance engineer to arrive after a breakdown notification?

By digitizing operator workflows, you can send all of the above data collected for all of the above scenarios back to a dashboard that captures what the actual workers are observing, where they're spending their time and what parts of that are repetitive or manual - this is how you find opportunities to automate or standardize a process that can make an immediate difference in worker productivity.

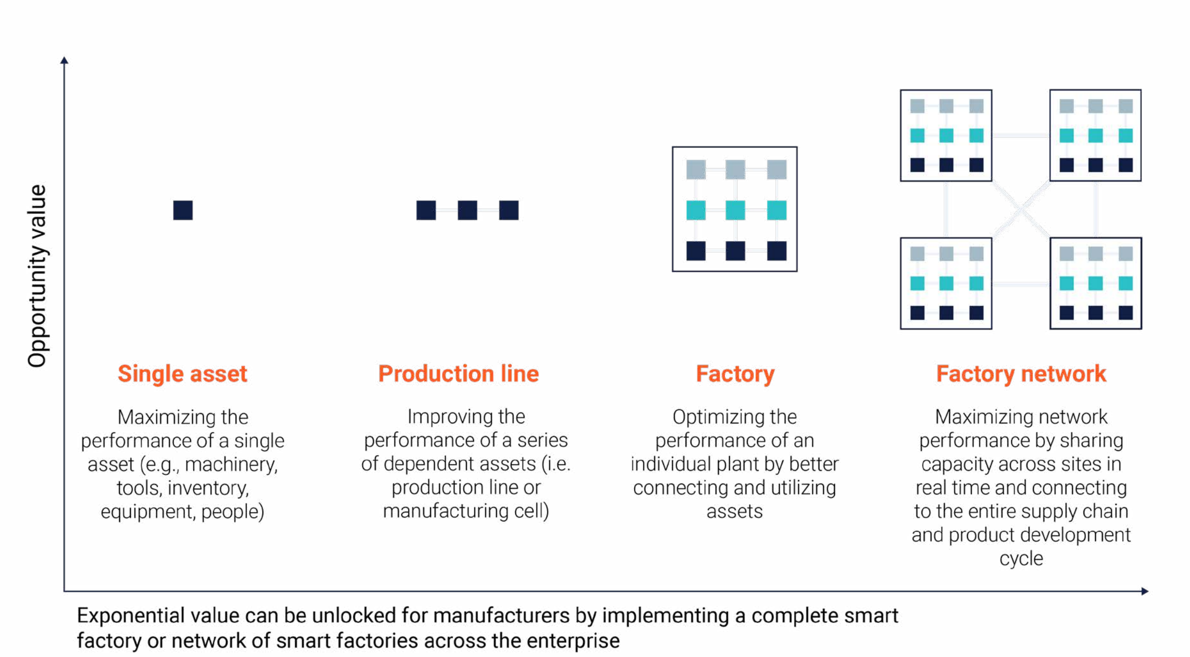
> *Real-life example: Using digitally enabled operator performance management, a Hitachi plant in Japan was able to reduce production lead time by 50% (with no impact to quality).*

This is how plants achieve small wins and start seeing numerical results that impact the bottom line. Now, you can take what you've done to optimize a process (or prevent an issue) and apply it to another area of the factory, another set of machines, or another team of operators – and later on, multiple factories around the world.

As the Deloitte graphic shows below, it's best to start with one process and achieve a win, then apply it to a full line, and then take it to factory-level -- then you can expand it across plant locations, if its showing value. In this fashion, standardization starts to develop on its own.

Deloitte insights - The smart factory: Starting small and scaling to unlock value[25]

Figure 21 - Starting small and scaling to unlock value

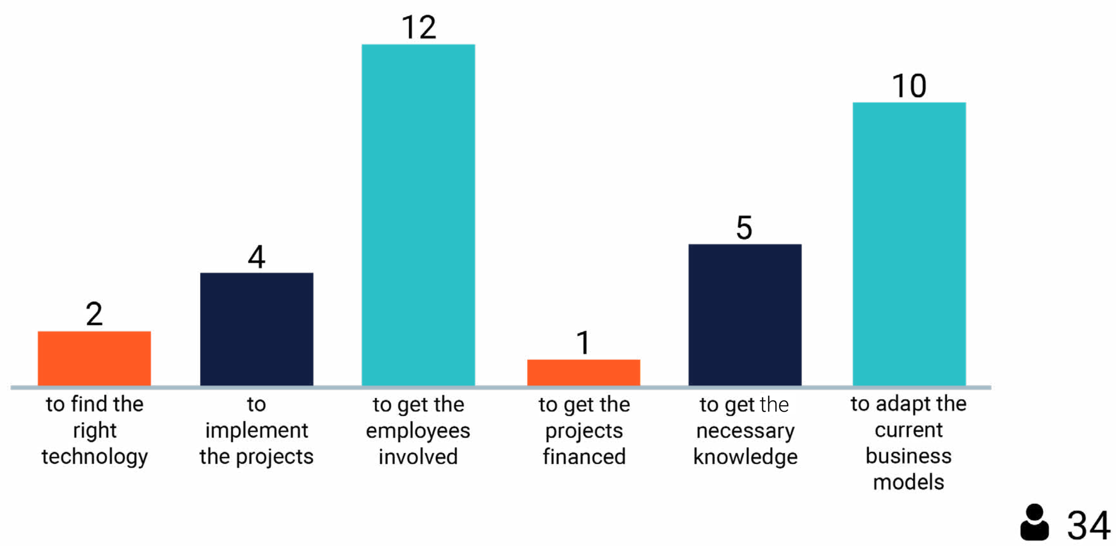


Let workers drive continuous improvement!

Only people can turn data into action, and the operators who are executing the actual tasks have the best view on ways to improve work procedures. This is another way to get cultural buy-in on digital transformation efforts -- if workers are driving the feedback process, they feel a part of the movement and are more likely to implement it.

> **Continuous improvement:** *Who's doing it well?*
> *Toyota, who has fostered a notorious culture of continuous improvement, is a great role model for manufacturers: their employees generate more than one million process improvement ideas annually, and 90% of those ideas are implemented[26]!*

Figure .22 - Workers must be involved in the 4.0 movement to have success



Poll question: What are the main challenges for Industry 4.0? Source: Phillipp Ramin, "Industry 4.0: What's in it for me?", I40.de[27]

We recommend making "feedback" a part of the workflow for jobs and tasks, with a simple way to submit ideas for improvement (as shown on the right)"

It is so important to ask for feedback and ideas in real-time. An operator is much more likely to communicate how something can be done better or more efficient on the spot (and with one easy click, in the palm of their hand) versus taking the time to report it at the end of an 8 hour shift.

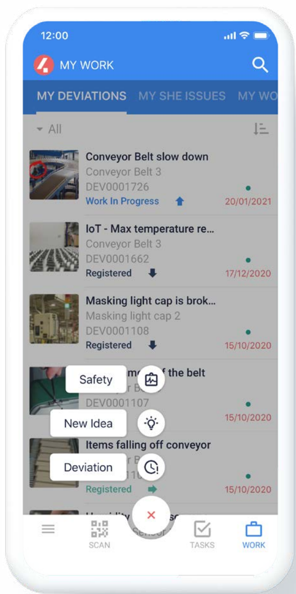


Figure 23 - Make feedback a routine part of task execution

Building a roadmap

Now that we've shared our key principles for a successful digital transformation, it's important to get pragmatic (and granular) about the plan to execute on it. Below is a sample roadmap we built out for the first stage of digitization for a global food and beverage manufacturer. The roadmap drills down a level to highlight specific steps and elements for consideration throughout the implementation process.

Notice that the roadmap starts with analysis of stakeholders and deviations. This is an easy and quick way to find out where your plant operations are encountering bottlenecks and inefficiencies. Then, in each "Process" workshop, we deep-dive to understand existing processes and how our digital solution can bring the best of both.

Needless to say, no two manufacturers (or plants) operate the same. Each one will have unique requirements and the roadmap will look different for each manufacturer, especially depending on their

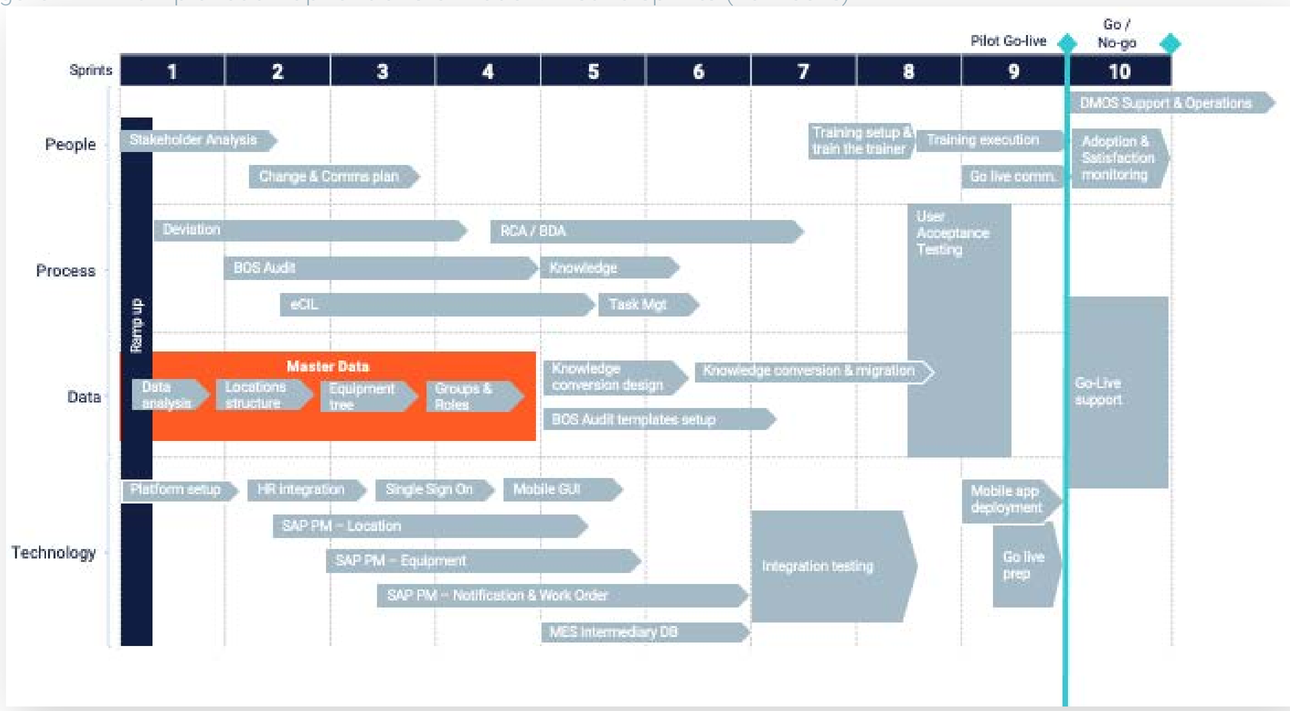
Get practical about continuous improvement

Sometimes deciding where or how to start on Continuous Improvement initiatives is so daunting, it gets pushed out.

Tip: Pick 3 small areas where you know there's room for improvement, and look closely at the work processes, line performance, % defects, etc. A few examples include:

- Over the course of a month, track what % of your machine maintenance is done before a breakdown occurs (reactive versus proactive)
- When an issue occurs, how long is a line stopped for? Track all issues for a month and take the average.
- Pick a routine line task (startup, for example) and asses the time it takes 3 different operators to complete the same task.

Figure 24 - Example roadmap for transformation: first 10 sprints (20 weeks)



current level of maturity as a starting point.

Still, it's possible to build out a "global template" from a successful pilot and apply this template into many plants for one manufacturer. Each plant will need some room to adapt, but 90% of all processes will be global, paving the way to greater plants collaboration and quick rollout.

Measuring the impact of factory digitization

Digitizing the shop floor will have noticeable impact on daily operations in terms of downtime, quality, safety, productivity and worker satisfaction.

All of these contribute to a decrease in overall operating costs, and enable the manufacturer to produce more with less, and with a high rate of quality. Worker satisfaction will improve, which will be key for manufacturers as we enter an era of their long-time employees retiring in waves.

Below, we highlight some points to show the impact of shop-floor digitization in different areas.

- ***Downtime***
    - Factories who implement digital tools for preventative and autonomous maintenance can expect to see a 23% decrease in unplanned downtime (App4mation).
    - In general, digital manufacturing can result in a machine downtime reduction of 30% to 50% [28].
    - Re-imagining the root cause investigation process through digital collaboration could create $70 million of revenue for a $10 billion manufacturer[29].
    - Reduced downtime increases OEE by 2 to 3 percentage points[30].
- ***Quality***
    - Digital lean manufacturing can improve quality between 10-35% (due to lower scrap and lead times, and higher yield and fill rates)[31].
- ***Safety***
    - The latest data from BLS[32] shows manufactures experience slightly more than a 3% safety incident rate annually, and each medically consulted incident costs around of 42,000.00[33].
    - In 2019, days lost due to injuries[34] was reported to by 70,000,000
    - Safety incidents are expensive, but the impact on employee morale is probably worse.
- ***Worker productivity***
    - It goes without saying that factories who can produce more product with less labor save cost and gain a competitive edge.
    - Digital factory investments have resulted in an average increase of 10% in production output, 11% in factory capacity utilization, and 12% in labor productivity[35].
- ***Worker satisfaction***
    - One of the most difficult to quantify, but the most important. Factories are about to experience a huge labor shortage as their long-tenured workforce retires and the new millennials make up the job talent pool. Manufacturers will have to compete with each other for talent, and digital tools should make the positions more attractive. We estimate worker satisfaction that comes from digitization of work processes can reduce turnover by a minimum of 3%.

All of these things - with the exception of worker satisfaction - can be measured in one overall metric called Overall Equipment Effectiveness (OEE).

What is OEE?

OEE, in loose terms, is a way of measuring your overall plant production efficiency. It can also be used to assign an actual numerical value to your improvement opportunity. It is calculated by factoring how each of "the six big losses", outlined below, impact availability, performance and quality. The most widely referenced formula used is: OEE (%) = Availability rate × Performance rate × Quality rate

OEE is something manufactures are sharply focused on improving because it represents major indicators of operational aspects that impact the bottom line. The issue is, many manufacturers aren't able to measure OEE, and don't know how to. It's difficult to improve what you can't measure.

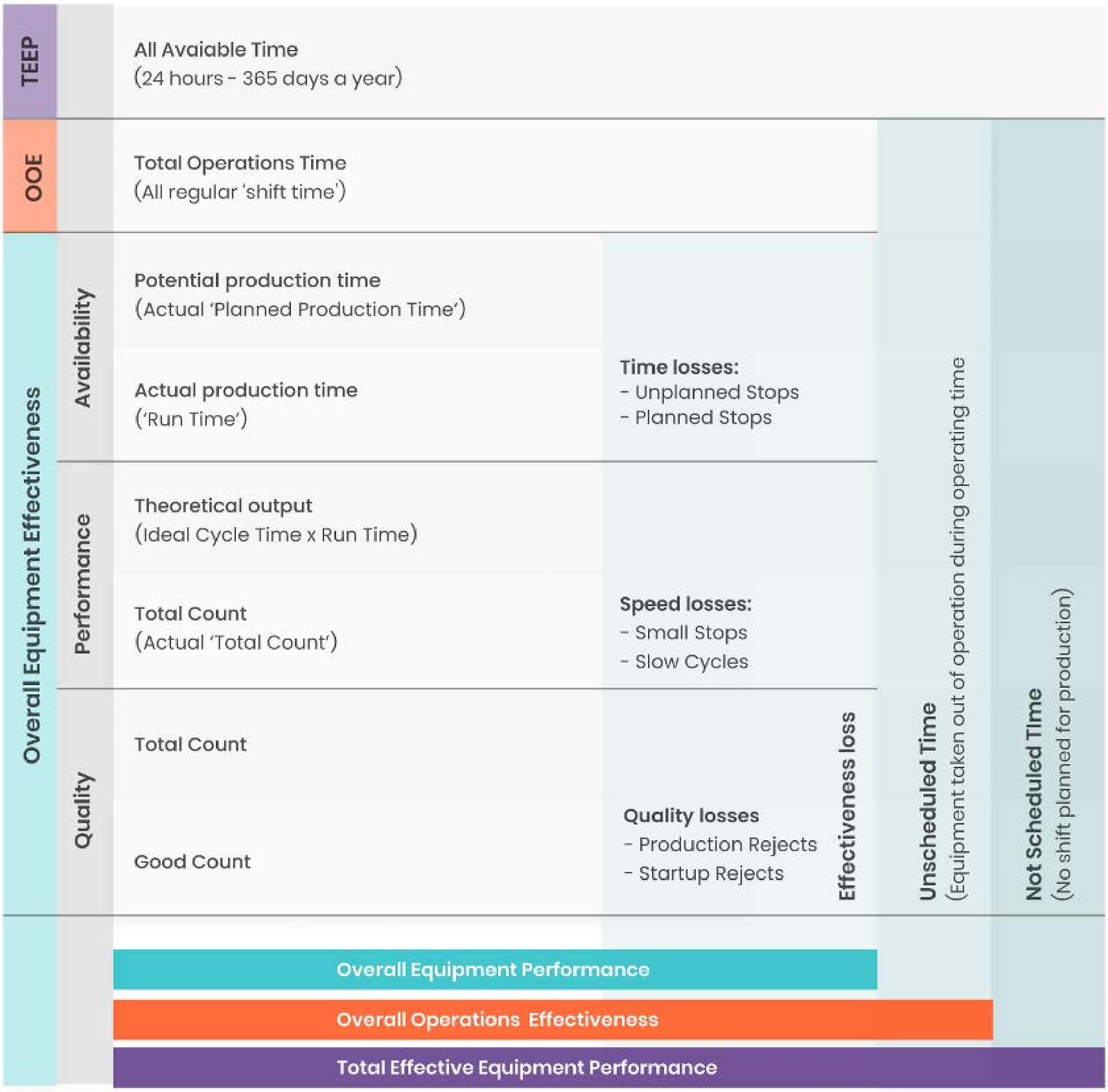
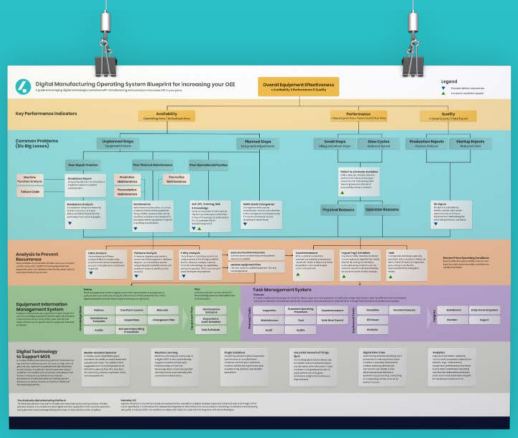


Figure 25 - Factors for measuring overall plant performance

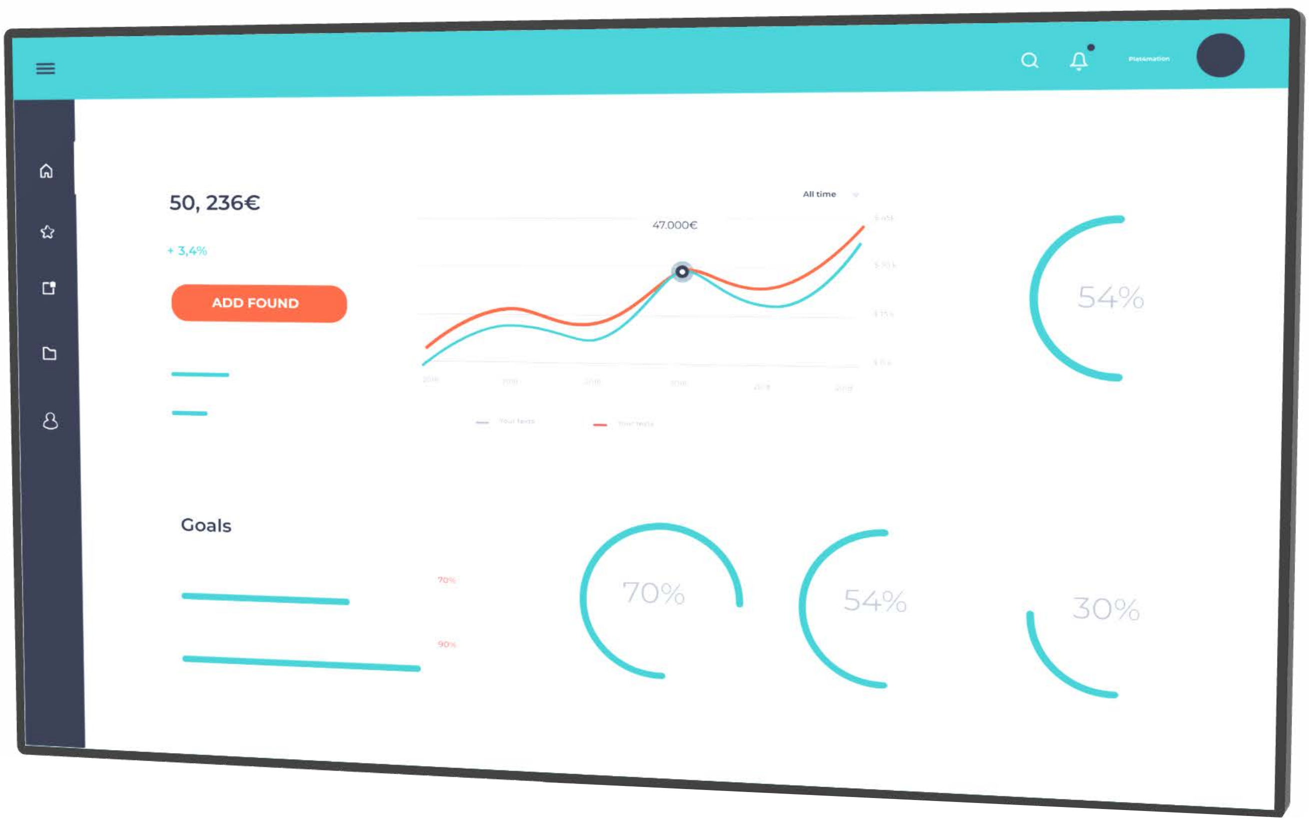


Download our OEE reference architecture if you're at a more advanced stage of using this metric within your plants.

Download blueprint

Some of the best manufacturers in the world achieve OEE of around 85%. A typical discrete manufacturer will have OEE around 60%, but it's not uncommon for plants to be operating at as low as 40%. Digitization of the shop floor can quickly move the needle on OEE (we've seen it happen in our own experience), and even an increase as small as 1% can mean millions of dollars, or more, to a manufacturer's bottom line.

Tip: Measure to know, know to improve
Being able to measure and monitor OEE is the first step in improving it. For one plant in Dubai, having a digital dashboard to monitor OEE performance resulted in an OEE increase of 15%[36].



Succes story

We work with a major beer brewer whose priority was finding a way to monitor, log, and correct production issues to reduce costs, increase OEE and improve the worker experience. They wanted a solution that empowered engineers and operators with a means to access and share information in real-time – and via mobile – to perform their jobs more efficiently. More importantly, they wanted this practice to be scalable so that knowledge, processes and standardization could be leveraged across multiple plants and geographies.

Using the 4Industry manufacturing platform, a D-MOS built on the trusted enterprise cloud platform of ServiceNow, they saw results almost immediately, including:

- OEE Improvement within 1 year
- Decrease in safety incidents
- Engineer travel time decreased by 24%
- MTTR reduction from 28 days to 6 days
- Improved Operator Knowledge & Standardized way of working
- Younger workforce took a more proactive approach and attitude towards CI

These results were achieved primarily through digitization of operator workflows, the end-to-end process of deviation management, and enabling collaboration between workers, teams and the knowledge database. All of this functionality was mobile-accessible so operators could access information, manage issues and connect with eachother on-the-go.

Conclusion

Hopefully this report acts as a comprehensive guide for how to measure the current digital maturity of your factory operations, what your next steps should be (based on your current state), and what your digital transformation roadmap should look like.

The use cases and methodologies outlined above are applicable to all types of manufacturer, and we also hope we made it clear as to how to implement changes that strengthen the foundation of your manufacturing operation, and ultimately, accelerate digitization of the same.

If we can leave our readers with only one thing – we hope this report underscores the importance of a strategy centered around the worker.

In our involvement with some very comprehensive and global shop-floor transformations, we've seen our pragmatic approach (focused on the empowering the worker with knowledge, and a simple interface to consume it within) translate to bottom line improvements within months – not years.

With that, we are excited to share our approach and lessons learned with the wider manufacturing world, and will continue to explore how digitization can improve OEE as well as the satisfaction of the workers which plant operations depend on.

About 4Industry

4Industry is a digital manufacturing operating system (DMOS) aimed at increasing your Operational Equipment Effectiveness (OEE) and providing a safer work environment. It boosts the employee experience through mobile and paperless workflows, taking your factory productivity to the next level. Based on Total Productive Maintenance (TPM), 5S, Six Sigma and Lean Manufacturing, our platform supports six specific manufacturing processes: Autonomous Maintenance, Planned Maintenance, Quality Maintenance, Early Equipment Maintenance, Safety, Health & Environment (SHE), and Focused Improvement.

Contact us

If you'd like to know more about how to increase your OEE with our smart, modular and customizable digital manufacturing platform, send us a message at info@4industry.com, give us a call at +31 (0) 30 76 02 670 or visit www.4industry.com.

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