Industry 4.0

The Art of Intelligent Manufacturing

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Preface

No one can argue that manufacturing is one of the most important sectors in the world. In fact, I would argue that it's actually the most important. Competition has driven the industry to make transformational leaps in technology, known as revolutions, from steam-powered engines, then assembly lines, to the introduction of computers and electronics on the factory floor. And now we're on the brink of a new one - the **Fourth Industrial Revolution**.

The Fourth Industrial Revolution goes by many names - *the digital manufacturing revolution, Industry 4.0, Industrial Internet of Things (IIoT), smart factories* - and it is transforming the manufacturing sector at an unprecedented speed. As a result, it's important for manufacturers to start thinking about how it is going to impact their lives, their work, and their companies in a way that makes their jobs, and manufacturing in general, easier. Data-driven, Industry 4.0 technologies will enable manufacturers to make high-quality products at faster rates and lower costs. When successfully implemented, these systems are a game-changer for manufacturers, driving greater competitive differentiation for their business and higher product value for their customers.

Manufacturers need to start embracing the paradigm shift towards more intelligent, data-driven manufacturing soon, or risk becoming obsolete.

Why? Because the reality is, no business has actually survived a manufacturing revolution without adopting the new, emerging technology. You don't see manufacturers still running on steam engines. There isn't a factory without computers and electronics controlling their production lines or integral parts of their systems. In this regard, the digital manufacturing revolution will be no different.

What differs from earlier revolutions, is how daunting this revolution has become to manufacturers. There are so many articles and buzzwords regarding digital manufacturing, but there aren't many sources of information that provide an uncomplicated picture of what it is, how it will benefit manufacturers, and how they can start the adoption process.

With this book, I hope to give you a clear sense of what the Fourth Revolution is and what it can do for your factory. I'll shed some light on what is going to happen in the next few years and how manufacturers can start evolving and adopting Industry 4.0 technologies today. The Fourth

Industrial Revolution is built on data, and the more data you have, the more insights and improvements you can make. So the sooner you start acting, the sooner you start collecting data, the sooner you start taking this journey, the faster you and your plant will evolve, become more competitive, and make things better.

Willem Sundblad, CEO & Co-founder, Oden Technologies

The Power of Industry 4.0

The Journey Toward Perfect Production

Manufacturers are under constant pressure. They need to decrease waste while increasing uptime, throughput and quality to continue to compete effectively. Manufacturers are no stranger to disruption either, and in recent years lean manufacturing practices and automation have applied further pressure on them, even forcing some out of the game altogether.

The next disruptive phase in manufacturing is already well underway. "Industry 4.0" builds on the previous three phases of industrialization – mechanization, mass production and controls. It's an intelligent production environment enabled by an integrated platform of enterprise data systems, the Internet of things (IoT) and cloud computing.
Industry 4.0 provides insight into variables or anomalies that can cause performance issues, such as machine failures, bottlenecks or waste, and it is going to completely transform the manufacturing sector and fundamentally change the established relationship between the makers and consumers of products.

Working towards perfection in manufacturing

As a concept, Industry 4.0 opens up the possibility of “perfect production” wherein the typical challenges in the manufacturing sector – machine failures, product defects, scrap – are eliminated, helping manufacturers to operate as efficiently as possible.

This shift will lead to manufacturers becoming so efficient that they no longer rely on low-cost country sourcing to remain competitive. By bringing production closer to their customer base they not only reduce shipping costs, slash energy consumption and lower the risks inherent in the supply chain; they can also respond faster to customer demands. It's a win-win for both the manufacturer and their customers.

By building Industry 4.0 into their strategies, manufacturers will also be future-proofing their organization. Consumers are becoming increasingly concerned with buying products from companies that have solid corporate social responsibility (CSR) policies.[1] Organizations that can demonstrate low-energy consumption or a reduced carbon footprint, and have better staff welfare policies, will be the ones that compete most effectively with consumers.
In addition, Industry 4.0 goes beyond creating efficiencies. It also empowers manufacturers to create more customized products, which can help them stand out in a crowded marketplace, and improve loyalty and satisfaction among their customer base.

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Early adopters will reap the benefits

The organizations that embrace Industry 4.0 early on will benefit from a significant data-ownership advantage over their competitors. Take a look at the leading tech giants, such as Amazon, Facebook and Google. They all hold monopolies on consumer data, having built their business models on "wells of information." [2]

Manufacturers have a data-rich environment, if they can emulate the tech giants and pivot their strategy towards analytics, to make the most of their data, then they can truly exploit the rich value of Industry 4.0 to create further competitive advantages through perfect production.

The role of artificial intelligence and machine learning in Industry 4.0

Effective data management underpins one technology that will shape the future of manufacturing: artificial intelligence (AI). The more data sets computers are fed, the more they can observe trends, learn and make decisions that benefit the organization. This automation will help manufacturers to predict failures more accurately, detect and anticipate problems, and predict workloads.

To successfully integrate AI and machine learning into the workflow, manufacturers must build robust technology foundations. This means creating a purpose-built, big data architecture that can pull together data from disparate systems, such as enterprise resource planning (ERP), manufacturing execution systems and quality management software.

To maximize the many opportunities of Industry 4.0, manufacturers need to build a system with the entire evolutionary journey in mind because perfect production requires collaboration across the entire supply chain.

What's At Stake In The Race To Industry 4.0?

As Industry 4.0 gains momentum in the manufacturing world, executives are calculating the risk-reward ratio of becoming early adopters of this technology. Some are considering the cost, in money and time, against the potential gains. Others are determining whether they should wait until their competition shows definitive proof of the benefits before striking out into the largely unknown territory. Still, others, stung by the over-blown promises of overly complex and costly earlier technologies, are simply wary. All of them are working to figure out what exactly is at stake in leading or lagging behind the Fourth Industrial Revolution.

To put it simply, the answer is that the future of your business is at stake. But most executives will see that answer as too simple or abstract, if not too glib.

To truly understand the risks and rewards of being among your industry's leaders during this transformation, bring the debate down to earth. Consider one of the fundamental issues you deal with every day: the cost of poor quality and downtime.

Reducing the cost of poor quality and downtime

The daily battles that manufacturers wage to make better products and keep machines running figure prominently in Industry 4.0. Driving down the cost associated with these basic elements of manufacturing are among the most critical challenges a manufacturer must address — and for good reason.

The true cost of poor quality[3] — the sum of the costs from repair, rework, scrap, service calls, warranty claims and write-offs from obsolete finished goods — can range between 5 and 30%[4] of a manufacturing company's total revenues, with the range for a majority of companies falling between 10 and 20%.

And that's not counting the costs associated with lost customers.

This profit leakage is a staggering amount for an individual company, alone. When you calculate how it compounds through the supply chain, impacting the bottom line and ultimately the customer, the value of fixing the problem becomes clear.

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Likewise, the cost of downtime[5] reduces profitability in a variety of ways too numerous to detail here: lost production and capacity, higher labor cost per unit and inventory costs and added stress on employees and machines. When the machines are down, everyone's attention is diverted from growing the business, whether it's responding to new opportunities or innovating new products and services.

Though variable industry to industry, one survey[6] places the cost of one minute of downtime in the automotive industry at an average of $22,000 per minute. If you can reduce your downtime costs to a fraction of that, the benefits to the bottom line alone will be substantial.

Think about it. An extra 10 to 20% of potential profits would propel you to the top of your industry. More importantly, it gives you back the time and resources to cement your competitive advantage. You can lower your prices, while maintaining or increasing margins, spend time on hiring efforts, invest in new productivity-enhancing equipment, products and services and divert the savings towards developing and enhancing products.

This is what's at stake in the race to Industry 4.0.

How Industry 4.0 solves production problems

Earlier I mentioned that Industry 4.0 solutions are designed to address the cost of poor quality and downtime. But for many, the question of how these solutions do it still remains.

Simply put, the answer is data and manufacturers making better decisions through data analysis.

Industry 4.0 technologies collect factory data and surface the insights that enable manufacturers to quickly identify

the root cause of problems that result in poor quality or machine downtime. The first steps toward implementing an Industry 4.0 solution involve setting-up an infrastructure that enables data collection, storage, and analytics.

Start with the backbone: data collection. You need IoT devices that constantly gather data from the machines and sensors, in real-time. Storage Cloud computing that drives down the cost of data storage and democratizing computing power, putting the power of problem-solving into more team member's hands. Only then, select a data analytics tool that processes your machine data, detecting trends and revealing actionable insights.

As you debate how quickly you want to enter the race, don't simply think about how to adopt these new technologies. Rather ask yourself the question, "How can I solve production *problems* using these technologies?" Consider that your competitors are asking the same questions. The ones that choose to innovate will win on quality, performance, and customers. From that perspective, not moving quickly toward Industry 4.0 means falling behind your competition and risking future business.

What Is The Cost of Quality in Manufacturing?

At the end of the day, nothing matters more than customer satisfaction. Fundamentally, this sounds quite simple; make the customer happy, and all is well. Keeping customers happy and loyal to your brand, however, is not as easy as it sounds. There are many factors that influence a customer's experience. Things like proper packaging, attentive customer service, and product quality are important when trying to keep customer satisfaction high. The production of high-quality products is arguably the most important part of this process, but it isn't cheap. On the other hand, the costs incurred from having a low-quality product can be much more expensive.

The Cost of an Underperforming Product

Keeping product quality high can be an expensive expenditure to deal with. Replacing or repairing a broken machine is costly, and few people would say that it's not necessary. Ultimately, as a manufacturer, if your products are sub-par, you are guaranteed to lose customers. That is far more expensive. When it comes to losing the lifetime value of a customer because they're unhappy, there is no question about it; avoid it at all costs.

Repair and replacement costs are pretty much unavoidable, and that is why it is important to focus on effective ways to go about incurring these costs. Every year, manufacturers waste money replacing and repairing machines before squeezing out every ounce of value from the machine. This underutilization of resources isn't a financial problem as much as it is an information problem. The Internet of Things (IoT) and data analytics technology allow manufacturers to optimize the usage of their machines and save money in the long-run.

Wasted Time Detecting Bottlenecks

The most valuable commodity, by far, is time. The amount of time that plant managers spend on either searching for bottlenecks or suffering from having them at all is staggering. Without IoT devices to gather ongoing and accurate data on machines, technicians are forced to make more assumptions with less data. This increases the chance of unnecessary repairs and ultimately wastes time. It's important for plant managers to identify the source of a given productivity problem once they know it exists.

Rather than spending days or even weeks spot checking their individual machines to find the productivity constraint, a manager's time would be much better spent actually dealing with the problem. Having access to data via IoT devices empowers plant managers to get a better look at what's really going on in their factories and to solve problems that are facing their organization faster.

The Opportunity Cost of the Compound Benefit

Costs that are often overlooked are opportunity costs. Having access to big data and data gathering devices helps with these costs and because of this is an appreciable commodity. It is a long-term investment that will definitely appreciate in value. Just like most successful investments, investing early on gives you the benefit of compound interest. Manufacturers can benefit immensely by focusing primarily on data gathering mechanisms.

In the increasingly complex world, data is just another tool in a business leader's toolbox that can be used to facilitate sufficient and accurate decisions. Information gathered today will allow manufacturers to make decisions tomorrow. While other manufacturers struggle to digitize and build

While other manufacturers struggle to digitize and build a smart factory, early adopters will begin benefitting from the compound interest.

a smart factory, early adopters will begin benefitting from the compound interest. Becoming an early adopter of IoT technology doesn't have to be difficult or obscenely expensive either. If done with the right service, being an early adopter could be a phone call and consultation away.

The Cost of Wasted Material

Material waste from poorly maintained machine is another heavily overlooked cost for manufacturers. Each year, manufacturers who fail to keep strict track of whether or not their production lines are on spec lose enormous amounts of money. This can be likened to printing 100,000 copies of a flyer with an obscene typo on it; it's embarrassing, wasteful, and expensive. Miniscule quality issues like this can easily be avoided through better tracking practices or by implementing data analytics technology.

The Cost Of Downtime In Manufacturing

A crucial part in any area of business to realizing greater savings is determining the cost of downtime before an issue arises. Formally called the true downtime cost, or TDC, this measurement takes into account a variety of business support and lost opportunity costs when a downtime issue occurs. Things like a computer crashing, a machine not working, or a software program needing critical updates will disturb the natural flow of a business and lead to these costs.

Industry experts estimate that almost every factory loses at least 5% of its productivity due to downtime, and many lose as much as 20%. To determine the cost of downtime, a business must analyze every cost factor associated with the possible downtime issues. This data is usually available in most companies and can be organized according to the TDC guidelines to find meaning.

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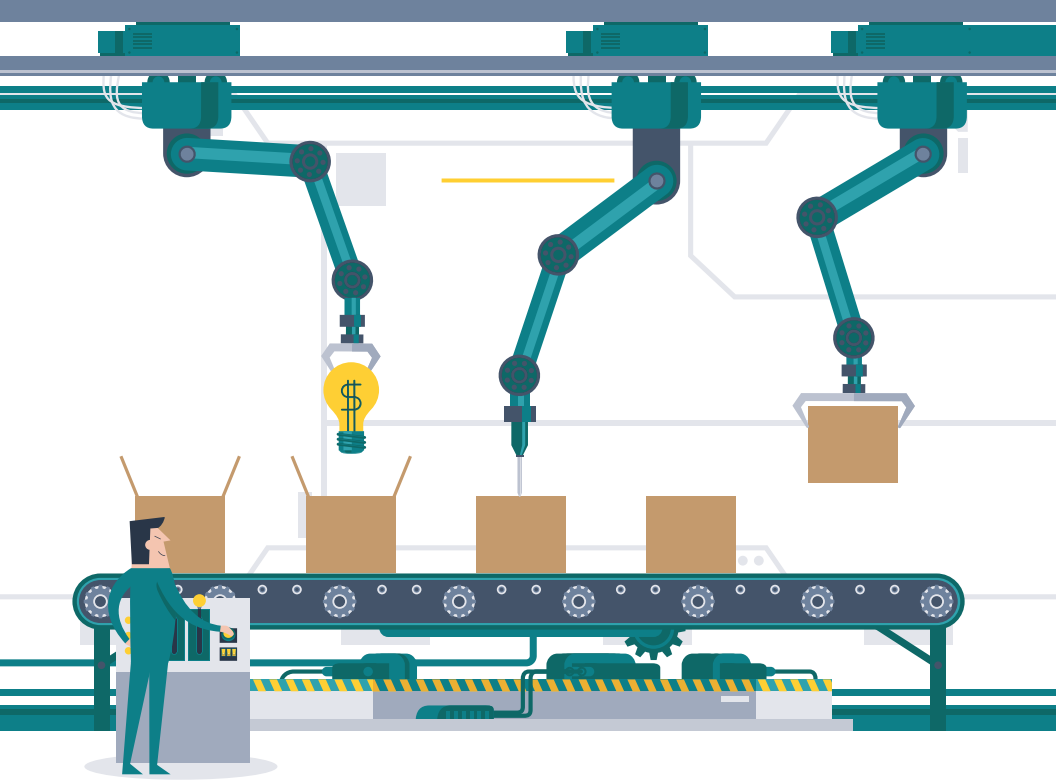

Downtime in the Manufacturing Industry

The cost of downtime in manufacturing can be pretty significant. There are many areas within the manufacturing process that become affected when a system malfunctions or does not operate at its normal efficiency. Downtime influences factors like equipment availability, labor overhead, maintenance, engineering, and production.

The cost of downtime in manufacturing is determined by looking two major classes of costs: 1) Tangible Costs and 2) Intangible Costs.

Tangible Costs

The tangible costs of downtime in manufacturing include:

01 Lost Production

Every product that a manufacturer produces represents some amount of potential profit. Whether it's pennies or dollars, these values add up over time-based on how fast each unit is produced. For example, let's say a company can produce 100 units per minute, and each of these units represents a potential of $1 of profit. For this company, the cost of downtime in manufacturing based on lost production would be $100 per minute, $6000 per hour, etc.

02 Lost Capacity

When all systems are fully operational, a manufacturing plant that is running at suboptimal capacity. It is important for a factory to plan for when there is a sudden increase in demand. When this occurs, the factory will need to operate at a higher capacity to fulfill the added business. Reducing downtime is important because it creates additional capacity for free and makes situations like these a non-issue.

03 Direct Labor

When you reduce downtime in manufacturing, your production levels go up while your labor stays the same.

This will decrease the labor cost per unit. Also, when there are less issues, employees can focus on their main task and increase their efficiency.

04 Inventory

The cost of holding inventory is typically around 10%-30% of the inventories value, per year. This means that if you have 1 million dollars of inventory, it would cost $100,000 to hold it for a year. One cause of downtime is changeover between products. Reduced changeover downtime will allow smaller lot sizes and lower inventory levels, which will lead to a lower cost of holding.

Intangible Costs

The intangible cost of downtime in manufacturing is less obvious, but can include things like:

01 Responsiveness

When downtime occurs, employees must focus on addressing these issues as their top priority. Since the cost of downtime in manufacturing is so significant, it becomes more important to solve these problems than focusing on customer service issues. For example, the TDC in the automotive industry is around $22,000 per minute!

02 Stress

Downtime can cause a lot of stress in both employees and the machines that they are operating. When a system isn't working, it can get overwhelming for an employee to accomplish their daily tasks. On the other hand, if a machine needs to produce at their maximum capacity for long periods of time, it becomes more likely that they will malfunction. People and machines perform better under less stress.

03 Innovation

Downtime can be a very time-consuming issue for a business. This takes away time from other things like innovation and creative brainstorming opportunities. It is much more important to make sure a current system is working before imagining how to improve that system's capabilities for the future.

The True Cost

Downtime is a very prevalent thing in the manufacturing industry. On average, manufacturers deal with up to 800 hours of downtime annually. The cost of downtime in manufacturing can be very significant and cost a company millions of dollars. This is why it is critical to understand the cost of downtime, and find the right data acquisition system that enables you to monitor and mitigate downtime in production.

The Human Factor

How Industry 4.0 Helps Manufacturers Solve Workforce Challenges

Stuck between a soon-to-be retired workforce and a cohort of young engineers and operators with comparatively less experience, manufacturers are in a bind. They have job openings, but can't find qualified people to fill them.

While the general public believes that all of the manufacturing jobs are going away, unemployment figures tell a different story. Since 2011, manufacturing unemployment has been lower than overall unemployment[7], sometimes by wide margins.

Exacerbating the issue is the skills gap, which means the jobs that employers need filled require skills that most of the unemployment pool doesn't have. Manufacturers need highly skilled engineers and machine operators, but often times it's those without this required skill set that are looking for work.

The result is that almost every factory I visit has open engineering positions and is struggling to run their business with a workforce that's smaller than ideal.
One of the solutions to this conundrum is technology. Industry 4.0 technologies amplify the contributions of every employee from the highest skilled engineer to the entry-level

operator, increasing their productivity[8], so manufacturers can do more with fewer employees. Here's how it helps address each aspect of manufacturers' workforce problem.

Institutionalizing intellectual property

The trouble with having a talented, older workforce is that your company becomes dependent on them to maintain your intellectual property. These employees have tremendous domain knowledge about your manufacturing processes and recipes, which is the IP that differentiates your product from your competitors. If that knowledge is not recorded, analyzed and understood across the organization, and if you don't have a process in place to effectively transfer it to young engineers, your company is at risk.

By adopting more data-driven practices and principles, you address two aspects of this problem. First, by transferring domain knowledge from the workforce to the manufacturing system, your domain experts can more effectively access and use it. This means the manufacturing system will augment the deep knowledge and skill of experienced engineers and operators, so they become even more productive.

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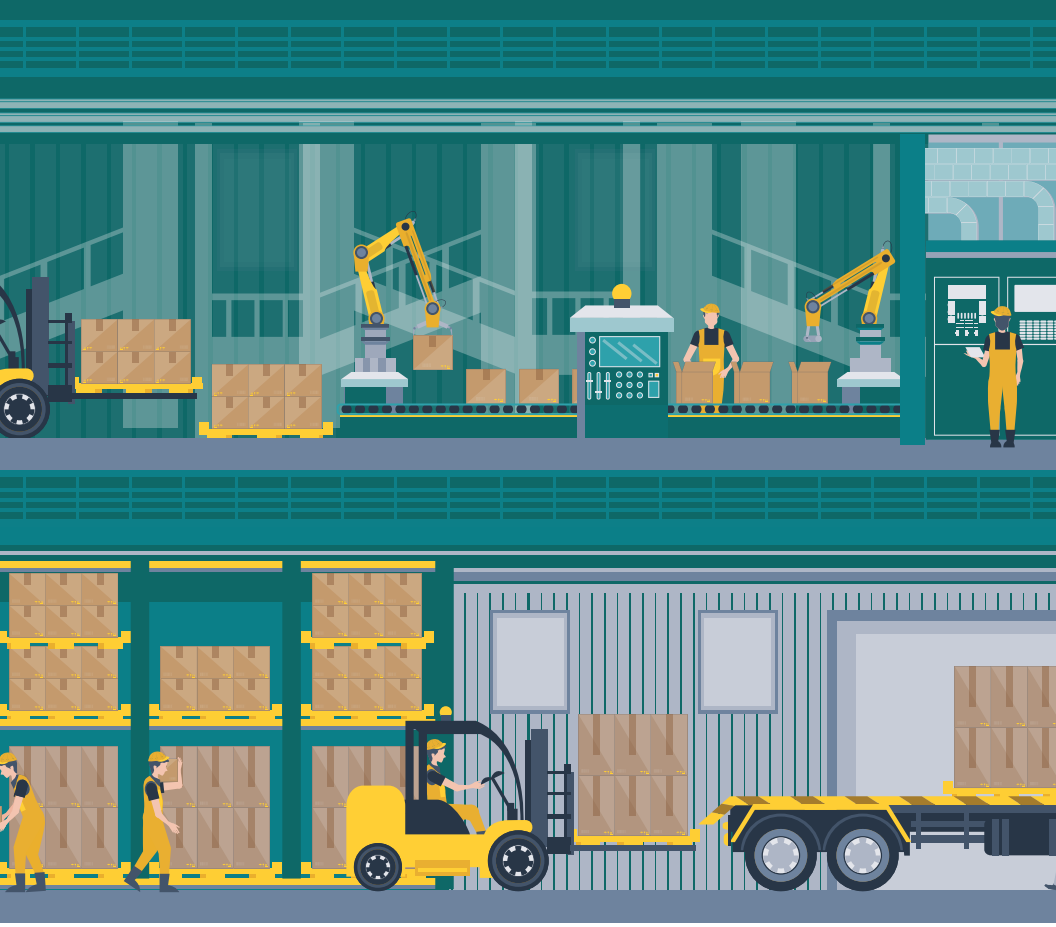


Second, once you've captured the domain knowledge and made it instantly available through advanced manufacturing systems, employees throughout the company also gain access to it, fostering a culture of data transparency.

Attracting young high-skilled talent

Recruiting young, skilled talent has become increasingly difficult as the pool of young engineers and skilled workers

seeking manufacturing jobs is unfortunately small. Most engineers are educated at universities in the cities, far away from manufacturing in both geographical distance and awareness. They aren't exposed to how rewarding a career solving manufacturing challenges can be.

But manufacturing is high-tech, and your facility must demonstrate that to potential recruits. Updating your factory tooling, automation and software with the latest industry 4.0 technologies will help attract the young talent that has grown up with digital technologies and are extremely computer savvy.

Upskilling operators

Investing in data solutions and technologies comes with a bonus benefit for the lower skilled operators on a factory floor. As domain knowledge of the highly skilled engineers and manufacturing professionals is collected and maintained in manufacturing systems, lower skilled operators gain access to it. This also addresses two issues.
First, the difficulty of learning highly specialized processes contributes to high turnover among new employees. With knowledge built into the system, new hires can learn more quickly, so they don't get discouraged and quit.

One study found that manufacturing engineers spend roughly 30% of their time looking for information.

Second, once trained on the fundamentals of the process, operators can leverage the digital technology to learn from the system, increasing their skills to the benefit of themselves and the company.

The power of first-mover advantage

Even as they struggle to fill talent gaps, manufacturers are wasting the talent they have on staff. One study found that manufacturing engineers spend roughly 30%[9] of their time looking for information. Think about that. You're paying a high salary for very skilled engineers who should be spending their time solving problems and improving processes and products. Instead they are digging through old systems that require more time to extract data.

Industry 4.0 technologies eliminate the time-wasting search, making data and information immediately available while instantly helping to address your workforce challenges.

Human-Technology Symbiosis in Manufacturing:

Changing the Discussion About Automation and Workforce

Will technology help or replace workers?

The debate within manufacturing about whether technology will completely replace people is interesting, but it's the wrong debate to be having. Technology is changing the workforce, it's a fact, and it has eliminated low-skilled manufacturing jobs in the past; but it's not as black-and-white as most arguments suggest.

Rather, the discussion should be about the concept of human-machine (or man-computer) symbiosis, the mutually beneficial relationship between humans and technology, and how machines and software can intelligently and physically increase the productivity of the systems to be more than that of human or machine alone. With the emergence of Industry 4.0 and the capabilities of Industrial Internet of Things (IIoT), the conversation should refocus on how to best transition displaced workers into the high-salaried, higher-skilled roles that are created along with the adoption of technology.

In fact, human-machine symbiosis is not a new concept. We know this from historical experience--and not just the old go-to story of the first Industrial Revolution. Accountants

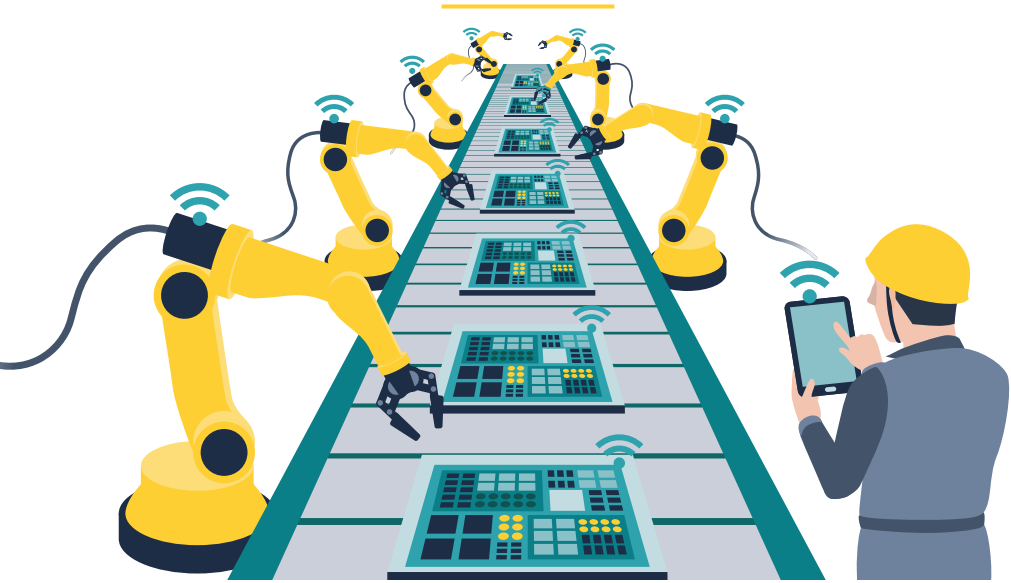
The concept of human-machine symbiosis is the mutually beneficial relationship between humans and technology, and how machines and software can intelligently increase the productivity to be more than that of human or machine alone.

have abandoned handwritten ledgers in favor of electronic spreadsheets. Product designers and architects have transitioned from manual to automated drawing tools. And few scientists and engineers use the once ubiquitous slide rule to assist with calculations. In each of these instances, technology eliminated tedious, time-consuming manual work, even as it augmented the education, skills and experience of the professionals.

Automating chess

Why am I confident that a similar transition will work for lower-skilled manufacturing workers? Consider a classic experiment, detailed by Ari Gesher from Palantir's now archived blog.[10]

Most people know the story of Garry Kasparov, a grandmaster chess champion who lost to IBM's Big Blue supercomputer. This loss launched earlier predictions about machines taking over the work of humans, creating much concern and fear. However, fewer are familiar with the results of a subsequent open chess tournament, where entrants were free to use whatever support they wanted, including any combination of humans and computers.



The “surprise” outcome of one of those competitions was that a team of two amateur chess players won the competition using three laptops designed to easily help with decision-making. This duo beat out a grandmaster chess player using an advanced, but complex chess supercomputer.

Kasparov explained the outcome in his book, Chess Metaphors: Artificial Intelligence and the Human Mind:[11]

“Their skill at manipulating and ‘coaching’ their computers to look very deeply into positions effectively counteracted

the superior chess understanding of their grandmaster opponents and the greater computational power of other participants. Weak human + machine + better process was superior to a strong computer alone and, more remarkably, superior to a strong human + machine + inferior process."

What this means for manufacturers

Historically, the equation for this type of intelligence amplification was the following: the power of the person, times the power of the machine, equals the power of the system.

The result of the open chess tournament suggests a new equation: the power of the person, times the power of the machine, divided by 1+f (where "f" is the friction of how easy the machine is to use).

This reveals the incredible power of manufacturing's digital transformation. It means that reducing the friction, or making it easier for manufacturers to use technology, will increase the output of their workforce that are interacting with computers and software. It also means that if your friction reduces to zero, and you start adding more power with data

Making it easier for manufacturers to use technology will increase the output of their workforce.

analytics, artificial intelligence, machine learning and other Industry 4.0 technologies, then you will make the most of your manufacturing operations.

Theoretically, a low-skilled operator could behave like a material science PhD, if the technology delivers to them the right insights, guidance, and prescriptive and predictive ideas, with very little friction.

For manufacturers looking to invest in technology, it means bypassing the cumbersome technologies that only the company's experts or those that have undergone weeks of training could use. Instead, choose a system that is designed to be intuitive and easy to use by anyone, whether an inexperienced engineer on their first day or a 40-year veteran who may not be a digital native.

So the big question as manufacturers adopt Industry 4.0 technologies isn't about whether technology will replace factory workers, but rather how to build manufacturing systems that maximize the performance and productivity of your workforce via human-machine symbiosis.

Beyond Digital Transformation:

How Industry 4.0 Benefits Your Customers, Employees, and Culture

It's no secret that Industry 4.0, or the Industrial Internet of Things (IIoT) has the power to drive true quantifiable change in the manufacturing industry. The immediate bottom-line production benefits are clear: fewer machine failures, reduced scrap and downtime issues, and improved throughput – to name a few. However, there are additional, less quantifiable, benefits of implementing this technology.

One trend that I've started seeing among manufacturers is the use of Industry 4.0 to create a positive, cultural shift across an organization. Think about how lean manufacturing and Six Sigma revolutionized the plant floor by turning production workers into problem solvers striving for continuous improvement. Similarly, Industry 4.0 is transforming how factory employees work, collaborate, and serve their customers.

The best-in-class Industry 4.0 solutions aggregate data not only from machines but from existing third-party systems - MES, ERP, maintenance, SCADA. The Industry 4.0 platform becomes a single source of truth for all manufacturing operations. Decision makers across the entire organization gain access to the same unified data set, rather than relying on disparate systems or manual data-collection.

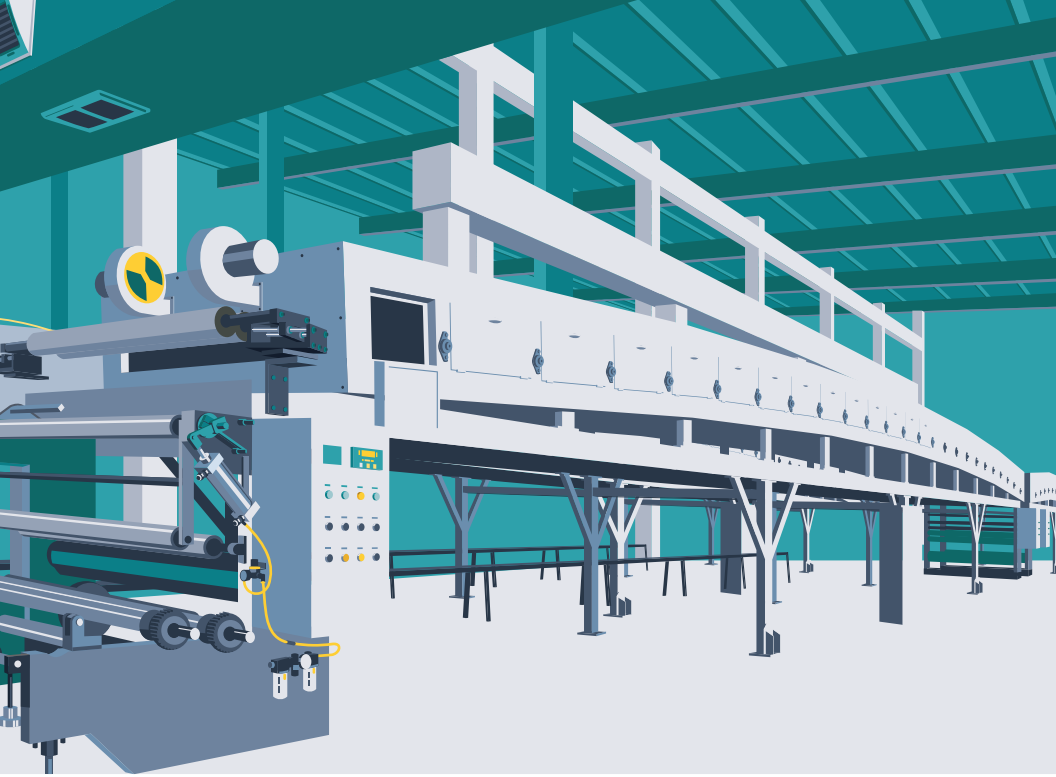
The best-in-class Industry 4.0 solutions aggregate data not only from machines but from existing third-party systems becoming a single source of truth for all manufacturing operations.

Effectively, Industry 4.0 eliminates the silos that create frustration and disagreements between employees about the source of production issues. The availability of open, connected data means that plant managers, engineers, and management can now work together to objectively solve production problems. It also results in improved customer satisfaction, increased supply chain transparency, and enhanced employee engagement.

IIoT strengthens customer relationships

More than one-third of manufacturing executives say improved customer engagement and satisfaction are among the top benefits of IIoT.[12] Since IIoT combines detailed process data with other production data sets (work orders, QA data), it enables higher levels of traceability. Manufacturers can quickly resolve warranty claims or address quality issues related to their manufacturing process. These faster response times demonstrate a level of production transparency that increases customer confidence in their supplier's capabilities.

Additionally, Industry 4.0 allows manufacturers to bring new products to market faster by reducing production lead times.



Let's take Faurecia SA for an example, the France-based car seat manufacturer invested in IIoT[13] to increase transparency into the production of their parts. The resulting traceability throughout Faurecia's production process increased their product quality and reduced the time it took to move from the development stages to full production.

In an IIoT-enabled factory, production data will also help manufacturers gain a better understanding of customer demand. Advanced systems with Machine Learning allow manufacturers to use real-time analytics from the plant floor to predict buying behaviors of their customers.[14] In turn,

manufacturers can ensure they have the right components on hand when they need it, optimizing inventory levels and reducing the potential for production delays.

High-tech solutions for a tech-savvy workforce

I'll focus on engineering: younger engineers are accustomed to using technology in their personal lives, while the top engineering talent have worked for companies that were early adopters of advanced technology. Both expect to have access to similar technology in the workplace, tools that provides fast, reliable information. Without this, they will likely avoid or leave an organization where disagreements are frequent and decision-making is slow due to outdated, legacy data-collection methods.

Industry 4.0 unlocks these data barriers and positions manufacturers as forward-thinking technology leaders. It fosters a data-driven culture where employees feel empowered to make intelligent decisions. As more manufacturers adopt Industry 4.0 technologies, companies will realize these additional benefits that may not have an easily calculable dollar-value, but are equally critical to their strategic goals.

The Future of Manufacturing

Data Is The Foundation For Artificial Intelligence And Machine Learning

Artificial intelligence (AI) and machine learning (ML) are going to have a huge impact on manufacturing. With these technologies, manufacturers will gain the computational power needed to solve problems that humans can't possibly solve. They will ultimately be able to provide *prescriptive* answers to production issues manufacturers have been asking for centuries. Namely, how do we make our product as efficiently as possible, with zero waste and the least amount of downtime.

As with most reports about groundbreaking technology, this discussion of the 'holy-grail' is way ahead of industry practices. The vision serves a useful purpose in suggesting what's possible. But with many manufacturers lacking the data infrastructure necessary to obtain real AI and ML capabilities, the journey towards perfect production can also be so abstract that it confuses the very people looking to achieve it. I'm often asked by corporate leadership, "Where and how do we adopt AI technology?"

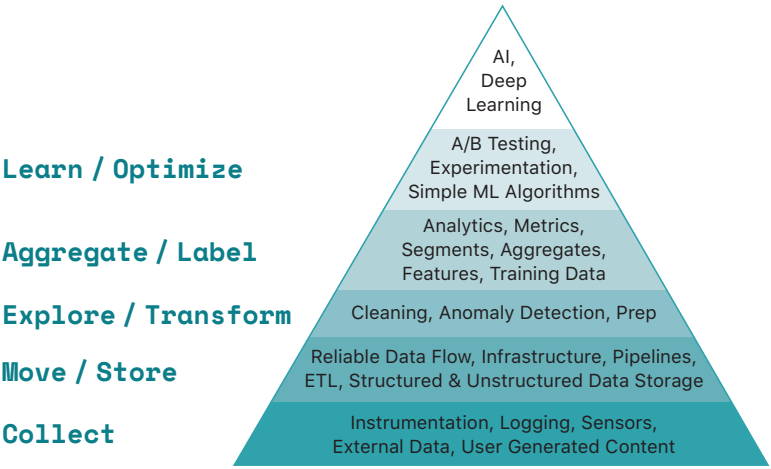
Begin with data

While the sci-fi-sounding AI scenarios highlight the technology's incredible computational power, the practical, effective applications begin with data. Indeed, data is both the most underutilized asset of manufacturers and the foundational element that makes AI so powerful. Think of Maslow's Hierarchy of Needs,[15] a theory of motivation that is depicted as a pyramid, with the most basic, most important needs at the bottom, and the most complex needs at the top.

Similarly, Monica Rogati's Data Science Hierarchy of Needs[16] is a pyramid showing what's necessary to add intelligence to the production system. At the bottom is the need to gather the right data, in the right formats and systems, and in the right quantity. Any application of AI and ML will only be as good as the quality of data collected.

When beginning to adopt AI, many manufacturers discover that their data is in many different formats stored throughout several MES, ERP, and SCADA[17] systems. If the production process has been manual, very little data has been gathered and analyzed at all, and it has a lot of variance in it. This is what's known as 'dirty data', which means that anyone who

The Data Science Hierarchy of Needs



SOURCE: "THE AI HIERARCHY OF NEEDS" MONICA ROGATI.

tries to make sense of it—even a data scientist—will have to spend a tremendous amount of time and effort. They'll need to convert the data into a common format and import it to a common system, where it can be used to build models.

Once good, clean data is being gathered, manufacturers must ensure they have *enough* of the right data about the process they're trying to improve or the problem they're trying to solve. They need to make sure they have enough use cases and that they are capturing all the data variables that are impacting that use case.

For example, gathering only one variable about revolutions per minute of your machine is not going to be enough to tell you why a failure happened. However, if you add vibration, temperatures, and data about many conditions that contribute to machine failure, you can begin to build models and algorithms to predict failure. In addition, as more data is collected, you can create accuracy requirements, such as *This algorithm will be able to predict this failure within one day's time, with 90% accuracy.*

If this all sounds complicated, solutions are available to automatically collect the data from a variety of devices and systems, then automatically clean the data or format. This allows engineers to focus on building models and algorithms, rather than spend time cleaning the data.

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Start by solving a simpler problem

Starting an AI journey with a data first approach allows manufacturers to start understanding and controlling their processes from the beginning. This not only helps manufacturers get to a controlled process and begin reaping some relatively quick benefits like eliminating process variations, it will improve the types of analytics they can do in the future, with more advanced AI and ML models.

Remember: If your process is out of control, adding AI to it won't magically fix it.

Another crucial reason to start with gathering data and solving immediate production problems is to gain first mover advantage in your industry. Companies like Google, Amazon and Facebook dominated their industries because they were the first to begin building data sets. Their data sets have become so large, and their data collection and analysis so sophisticated that they are able to grow their competitive advantage.

For manufacturers, the equation is similar. The sooner a manufacturer starts the journey toward AI, the sooner they

will build large data sets that will enable them to execute advanced AI and ML models. With each iteration, they'll put more distance between themselves and the competition.

Adopting AI and ML is a journey, not a silver bullet that will solve problems in an instant. It begins with gathering data into simple visualizations and statistical processes that allow you to better understand your data and get your processes under control. From there, you'll progress through increasingly advanced analytical capabilities, until you achieve that utopian goal of perfect production, where you have AI helping you make products as efficiently and safely as possible.

The Four Levels of a Smart Factory Evolution

For many manufacturers, the path to building a Smart Factory is still confusing because of information overload. In order to overcome this challenge, manufacturers should view this transformation as a journey with four stages that reap ongoing benefits to their operations . As with any extensive company-wide transformation, trying to achieve the end goal too quickly can leave you back where you started, having wasted time and money.

It's critical that manufacturers understand that the Smart Factory is primarily about data.

Prior to the Fourth Industrial Revolution, commonly known as Industry 4.0, manufacturers relied on clipboards and manual methods to collect machine data, perform root-cause analysis, or gain insight into their operations. But as the competitive landscape of manufacturing changed, and consumer demand increased, the industry reached a point where these manual processes were no longer efficient. In fact, they cost manufacturers time and money in the form of lost productivity, suboptimal machine output and product quality.

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The Smart Factory evolution is about building upon the advancements of the Third Industrial Revolution by automating the collection of data from machines and applications, and transforming that data into immediate insights. This new technology turns the tedious, but critical, process of extracting insights from data into one that is instantaneous, streamlined, and achievable for every manufacturer.

Level One: Available Data

A level one system is pretty much the status quo. At this stage, data is available but difficult to use to make decisions or implement improvements. The data is in siloed systems, requiring manual work to integrate and translate into useful information. Problem solving at this level is possible but extremely time-consuming. When a product quality or machinery issue arises, operators and engineers must scramble to manually gather data from various systems before they can ascertain what happened and how to fix it. This manual approach is not only frustrating, but costly; it drains time, resources, and money from the factory. Manufacturers at level one should move to level two as soon as possible or risk wasting millions of dollars in lost production output from unplanned downtime each day.

Level Two: Accessible Data

A level two system integrates all the disparate data sources into one single source of truth[18] and continuously gathers and tracks production data. With the data in one location and always available, problem solving becomes almost frictionless. When an issue occurs, operators and engineers can access the data in the system using data visualizations and dashboards—essentially leveraging the system as a query engine. With easy access to all the data, they are able to answer questions quickly, increasing plant productivity.

In addition, a level two system allows engineers to focus on addressing high-value issues such as improving the product itself, changing materials, or adopting a mass customization strategy. However, at level two, proactive analysis, which enables factories to make improvements before issues occur, still requires time, effort and engagement from engineers.

To move from level one to level two, manufacturers must implement a new data architecture, which takes only a matter of months. To do this, you need to evaluate whether to build your own system or select the right solution providers and partners[19]. Also, when selecting a new architecture, make sure it allows you to scale the amount of data you can collect without paying higher marginal costs or sacrificing system performance.

Level Three: Active Data

A level three system shifts manufacturing operations from reactive problem solving to proactive analysis and improvements. The system enables operators and engineers to be truly preventative and proactive in solving problems, which would not be possible in a level two system.

To move from level two to level three, you must build on the previous level's data architecture by adding new system capabilities such as machine learning and artificial intelligence[20]. These new tools allow you to start generating insights in as little as two or three months, depending on your product mix. These new features, combined with the level two system that aggregates all your production data, create an intelligent system that on its own will find valuable insights and predict failures more accurately, while delivering information to the appropriate person at the right time. Users do not have not have to query the system or perform manual process analysis in order to find the answers to solving production issues.

An example of level three system attributes include machine learning models that predict product defects or machine failures and identify ways to produce products more efficiently. In a level three system, a person is still needed to make the changes that the intelligent system recommends.

Level Four: Action-oriented Data

At level four, the data system actually deploys the recommendations that it finds from analyzing manufacturing

data. For example, a machine learning model will identify an optimization, then generate and send the recommended new settings to the machine, where it is automatically executed. In such a closed-loop artificial-intelligence-controlled production line, the time it takes to execute on an insight discovered by the system becomes minimal.

Achieving level four requires datasets that are large enough and have enough validated cases to provide the information needed for the system to "know" the impacts of a production change. The time needed to move from level three to level four varies based on the amount of time it takes to gather the necessary datasets.

Building a Smart Factory

Approaching the move to a Smart Factory as a journey with four stages is critical for one simple reason: there are no shortcuts that can move a manufacturer from level one to level four. Those that have tried find their systems have so much process and data variability that they quickly become mired in complexity. Level three and level four systems require a huge amount of data, which can only be generated and made useful in level two. A step-by-step

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approach allows manufacturers to progress through a natural evolution. In the earlier levels, they learn more about data systems in general and the data they need for their specific processes. As they learn, they begin to amass the datasets they need to enable the system to identify and execute production-process improvements based on data. With this methodical approach, manufacturers will build a Smart Factory more quickly and with less frustration.

Sources

1. https://www.forbes.com/sites/sarahlandrum/2017/03/17/millennials-driving-brands-to-practice-socially-responsible-marketing/#b2e033a4990b
2. https://www.economist.com/briefing/2017/05/06/data-is-giving-rise-to-a-new-economy
3. https://www.engineering.com/AdvancedManufacturing/ArticleID/12918/How-Will-Industry-40-Impact-Quality-Assurance.aspx
4. https://www.qualitydigest.com/inside/quality-insider-article/what-your-companyrsquos-cost-poor-quality.html
5. https://arimo.com/machine-learning/2016/manufacturing-downtime-cost-reduction-predictive-maintenance/
6. https://www.manufacturing.net/article/2006/03/22000-minute-manufacturing-problem
7. https://fredblog.stlouisfed.org/2016/05/manufacturing-up-down/?utm_source=series_page&utm_medium=related_content&utm_term=related_resources&utm_campaign=fredblog
8. https://www.nytimes.com/2018/06/25/business/economy/unemployment-productivity-robots-training.html?emc=edit_nn_20180626&nl=morning-briefing&nlid=78431560201806 26&te=1
9. https://www.information-age.com/digital-transformation-manufacturing-123462474/
10. http://archive.is/WxpC

11. https://www.nybooks.com/articles/2010/02/11/the-chess-master-and-the-computer/

12. https://www.prnewswire.com/news-releases/many-companies-lagging-in-industrial-iot-readiness-300440596.html

13. https://www.smartindustry.com/articles/2016/faurecia-integration-yields-real-time-transparency/

14. https://www.supplychain247.com/article/3_ways_the_iot_will_transform_manufacturing_processes/GT_Nexus

15. https://www.simplypsychology.org/maslow.html

16. https://hackernoon.com/the-ai-hierarchy-of-needs-18f111fcc007

17. https://www.forbes.com/sites/willemsundbladeurope/2018/10/03/beyond-digital-transformation-how-industry-4-0-benefits-your-customers-employees-and-culture/#55ceb0e529fc

18. https://www.smartindustry.com/blog/smart-industry-connect/your-factory-must-speak-the-same-data-language/

19. https://iiot-world.com/analytics/the-clearest-fastest-way-manufacturers-can-capitalize-on-data-analytics/

20. https://www.forbes.com/sites/willemsundbladeurope/2018/10/18/data-is-the-foundation-for-artificial-intelligence-and-machine-learning/#629156f251b4

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