Compilation of Views on the Smart Manufacturing Industry

July 2022

Produced by

Industry IoT Consortium

Sponsored By

GLOBAL INDUSTRY ORGANIZATIONS

Contents

INTRODUCTION

Manufactured goods are placed into products in multiple verticals. For example, a battery will be placed into an electric car or a magnet into an MRI machine in a hospital. Manufacturing, therefore, covers all industrial internet of things' verticals, from smart cities, to automated vehicles to healthcare and mining. Not to mention the factories themselves.

The GIO Smart Manufacturing Working Group was established to bring these threads together and examine factories, deployments and modes of manufacturing, from batch-size-one to discrete manufacturing and continuous-process manufacturing. Our focus so far has been in the factory, which will be discussed throughout this paper, specifically:

- Insights from End Users
- An Enterprise Perspective of Digital Transformation
- Technology Trends
- Korea's New Manufacturing Service and Digital Transformation
- Connected Factory for Packaging Consumer Goods
- Neural Manufacturing
- Smart Factory Case Study

Our first article discusses insights from end users—the people and companies that implement IIoT systems. You need those insights. They have been running this factory for years, perhaps decades. You need their knowledge, and even more their buy-in.

INSIGHTS FROM END USERS

Experience and research have shown that a lack of stakeholder buy-in will preclude a digital transformation project from driving both short- and long-term success. Continued alignment with stakeholders should be a focus before, during, and after any digital transformation journey. This alignment requires the team to think, plan, and work vertically.

Vertical alignment spans up from the machine operator, cell lead, plant manager and above. Tailoring the conversation based on where the stakeholders fall within that span enables the team to gather the right inputs and provide the right updates to those stakeholders. The level of granularity tends to decrease as you work up that span of stakeholders.

For example, a plant manager or possibly their manager who oversees a family of manufacturing sites, may be focused on improving on-time delivery. Their analysis may indicate that one of their levers is getting more usage out of a set of constrained manufacturing assets.

As the teams work down the span of stakeholders and meet with the cell leaders, the conversation likely shifts to the specific set of constrained assets where they believe there is an opportunity to increase usage. The discussion here gives the team visibility into where their solution would reside and scale, inputs useful to ensure any solution implemented is repeatable. This group of stakeholders is focused on usage across a set of assets.

As the team continues to work their way through the stakeholders, they inevitably meet the machine operator, one of the people who is likely most aware of the ins and outs of that machine and manufacturing process. The team will likely get inputs that help define a solution to improve the chosen metric. You may learn that the machine operator has no way of knowing when the machine has finished its cycle. A visual indicator for when it finishes provides the lead time for the team that performs cleanup and setup so the next operation can execute as soon as the machine is ready, resulting in more cycles out of that constrained asset.

Now you have a problem statement at a detailed enough level so you can start to solve them. Rather than jump directly into building a solution, first the team must validate that problem statement. They will want to meet with other machine operators to see if they also believe more lead time in knowing when a cycle will finish will enable quicker turnover time before the next cycle begins, for example. If validated and the team has the buy-in from the machine operators on this solution, the team can start to work back up the span of stakeholders.

The next stop may be meeting with the cell leaders to validate that the problem statement resonates with them and discuss what could be done at a machine level and replicated across other cells to derive value. For the visual indicator, perhaps the team agrees with the cell leaders that they could put up a digital display within each cell indicating when each machine should finish, or a light above each machine visible across the rest of the cells. Regardless, this is an opportunity to validate the problem and potential approaches and should pursue buy-in with these stakeholders. This is also an opportunity to get data to determine what this proposed cycle time improvement could mean across the cells. This allows the leadership to decide whether there is a return on investment from this idea.

As the team keeps working back up the span of stakeholders, they will get back to the plant manager. The team must be able to communicate the problem statement, proposed approach, and benefits across the plant and ensure buy-in from the senior leadership plant management team. The team would also want to explore whether the proposed solution would also be valuable across other plants or families of manufacturing plants, which will only increase the ROI of the work being done with this plant, cells, and machines.

Author

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- Industrial Brilliant Manufacturing,
- Condition Based Maintenance,
- Digital, Sourcing, & Financial Operations,
- Corporate & Industrial Data Analytics,
- Margin Enhancement,
- Corporate & Industrial Digital Commerce,
- Enterprise Architecture,
- Point of Presence Operations & Deployment Optimization,
- Regulatory Compliance (including GDPR & CMMC),
- Data Center Operations,
- ERP Migrations,
- Corporate Mergers, Acquisitions, & Divestures
- and Synergies & Integrations.

Our next article is a general piece about digital transformation: what it is, how to think about it at the enterprise level, the digital enterprise and a program for creating one.

An Enterprise Perspective on Digital Transformation

Digital Transformation

Digital transformation (DX) is a catch-all term that refers to efforts to leverage emerging and emergent digital technologies as well as organizational changes with the overall objectives of optimizing and transforming the way organizations operate and deliver value to their customers and shareholders more effectively, more competitively and with better ROI.

DX is hardly a new topic. The transition from manual paper-based financial systems to IT-based financial systems started in the 70s and was in all practical terms a digital transformation. The trend for transformation is accelerating in environments that comprise IIoT systems, which by definition, span the digital/physical and IT/OT divide. This divide has increased the challenges and complexities of digital transformation: business, technology, operation, organization, culture, governance, risk and compliance (GRC). The COVID-19 pandemic has deepened these challenges and elevated the urgency and importance of digital transformation.

Digital transformation is the journey from the “mounting challenges” to the “better outcomes” that address these challenges. The term encompasses three broad areas: *digitization*, *digitalization*, and actual *digital transformation* (see diagram below). These areas are related but they should not be confused with each other.

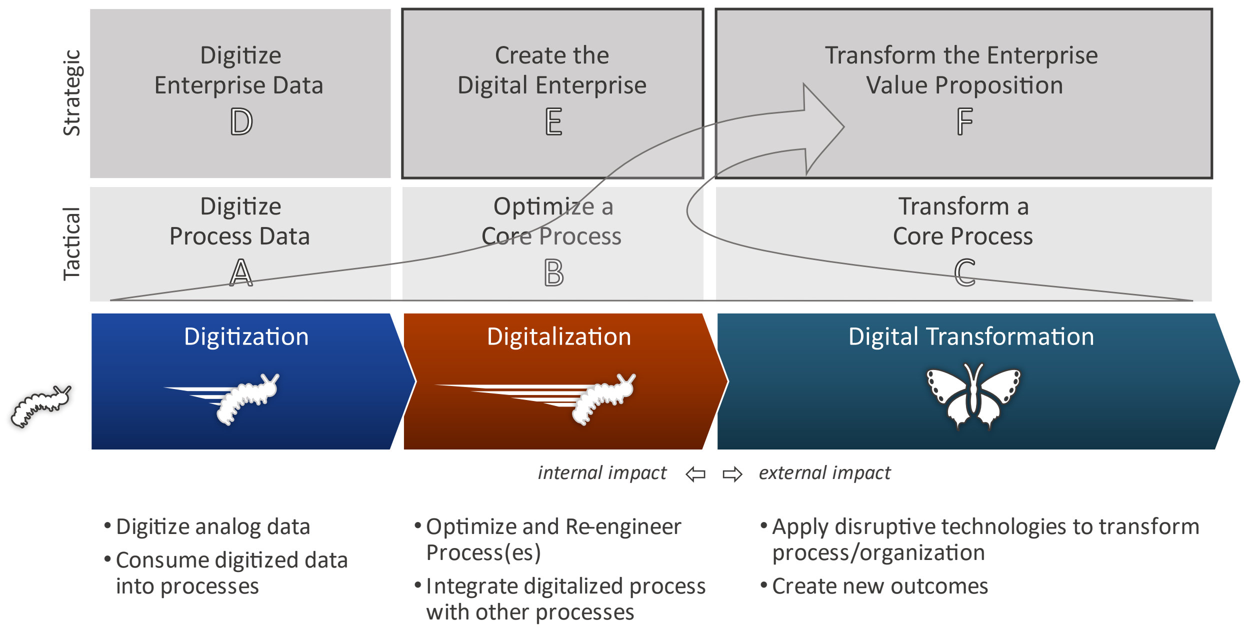
Digitization is about converting analog data into digital form (for example, operational and other types of manufacturing data) to facilitate the consumption of this data within the manufacturing processes and improving their operation. *Digitalization* is about ingesting and consuming the digitized data into the manufacturing processes for the purpose of optimizing them, integrating them and potentially re-engineering them. *Digital transformation* builds on the above, but its ultimate objective is to create new business, operational and service delivery models, uncover new revenue opportunities and compete in new markets. This is done through the implementation of organizational changes and disruptive technologies.

In manufacturing enterprises, the term “digital transformation” sometimes refers to a mix of these three related areas. Others use the term literally to mean “digital” and “transformation”.

Digital Transformation at the Enterprise Level

Digital transformation is not one-size-fits-all. The organization may target specific processes, for example to transform a factory production line to improve its effectiveness, efficiency and ROI. On the other hand, the organization’s main aim may be to transform the whole enterprise, its business, operational, service models and its core value proposition.

Conceptually, *DX at a process level* and *DX at the enterprise level* (i.e. strategic) are similar, but they differ significantly in terms of scope, scale, level of sponsorship in the organization, type of leadership, stakeholders (cross-functional), level of complexities, methodology, investment level, ROI dynamics, budgeting cycles, etc. Organizations planning to go through a DX at the enterprise level should reflect on a range of considerations:



Digital transformation conceptual model.

Think and assess before you start: Organizations must consider fundamental questions about DX: why, why not, why now, what, how, how much, risks of action, risks of inaction, etc. They must also clearly define the outcomes they seek.

Think big but start small: Organizations should start by focusing on one or more process-centric DX initiatives **A**-**B**-**C** (diagram) that exhibit beneficial proof-of-value attributes and use the learnings from these initiatives to define the enterprise-level DX strategy **D**-**E**-**F** and execute it.

How will DX affect operations and business: The impact of digitization and digitalization tends to be internal: cost reduction, improved process efficiencies, faster execution, etc. The impact of digital transformation tends to be more external and market facing, for example, creating new market opportunities, generating new revenues and leapfrogging the competition.

How to deal with the IT/OT convergence challenges: IIoT systems have unique trustworthiness challenges due to the convergence of OT concerns (safety, reliability, and resilience) and IT concerns (security and privacy) and the interdependencies between them. If these challenges are not addressed during the transformation transition (and beyond), the DX journey may be derailed. These challenges can manifest themselves at multiple levels: technological, architectural, procedural, organizational, compliance, etc.

How to deal with IIoT systems that are enterprise systems: IIoT systems have not only become a common occurrence in enterprise architectures, but some of them are starting to play prominent roles in the ability of organizations to deliver value to the market. From the C-suite perspective, these are "enterprise systems" that must comply with enterprise standards and best practices for operations, GRC, security and trustworthiness, system architecture, data architecture, etc. Compliance with such enterprise requirements is a C-level concern and must be sustained throughout the lifecycle of the IIoT systems and the whole DX journey.

What process innovations are needed to address the above issues: Implementing DX across the physical-digital and IT/OT divide is not a business-as-usual affair. This is due the unique challenges caused by the misalignment between well-established cultures and mindsets that exist in the digital world and those that are even more entrenched in the physical world. Innovative processes are needed to bridge these differences throughout the DX journey.

Digital Enterprises are more Valuable

The DX diagram above also suggests that before an organization can embark on its journey of *digital transformation at the enterprise level* (**F**), it should first transform itself into a *digital enterprise* (**E**). This is an enterprise that has achieved substantial levels of digitalization of its production and operational processes (diagram) and is able to apply disruptive technologies, streamline its structure and leverage its rich data for the purpose of transforming its business and operational models, gaining strategic competitive advantages in its internal and external operations, and disrupting the markets in which it operates.

Although the concept of the digital enterprise has been well documented, the manufacturing space is rife with manual and non-digitized processes. Consequently, creating the digital enterprise is on the critical path of digital transformation. The methodology for achieving this must account for factors such as the organization's structure, the vertical markets it serves and the state of its IT and OT infrastructures.

Enterprise Digital Transformation Program

Creating a *digital enterprise* and achieving *DX at the enterprise level* should not be considered as a project. They are a journey that is driven via a program. The enterprise DX program must have a clear and bold-yet-realistic vision, a declared mission statement, a roadmap with multiple phases and a governance structure.

The program must be sponsored by a senior executive who sets the vision and mandates and empowers a DX program team to execute it. In most cases, the program team will have to be cross-functional representing the various stakeholders in the organization: business, operations, IT, OT, security, legal and compliance, safety, etc.

The team must also be headed by an executive leader with a unique set of skills and knowhow and who leads the program throughout the DX journey to:

- understand the drivers for the transformation and the role of innovative technologies in enabling that transformation (recognizing that DX is not about technology only),
- strike a balance between the bold DX vision and the organization's capacity to execute,
- create alignment between the top-down executive perspective and the bottom-up perspectives of cross-functional stakeholders represented in the program team,
- manage the executive sponsor's engagement throughout the DX journey and
- manage the risks involved in implementing DX across the IT-OT divide, including the impact of "black sheep" DX projects.

Final Thoughts and Takeaways

Digital transformation at the enterprise level is strategic for organizations. It is the complex journey from the "mounting challenges" facing the manufacturing organization to the "better outcomes" that address these challenges. The journey becomes much more complex and challenging when the transformation affects "enterprise systems".

Before embarking on a DX journey, the organization should strive to become a digital enterprise, create a bold-yet-realistic DX vision and establish a structured program to transform that vision into a mission and a tangible roadmap. The program must also be sponsored by a senior executive in the organization and led by an experienced executive leader who can manage a cross-functional team representing the diverse concerns of the stakeholders.

Ultimately, digital transformation at the enterprise level is an agent for future-proofing the organization. It enables the organization to become nimbler, improve its ROI and become more competitive in a rapidly changing market environment.

The time to act is now.

Author

Bassam Zarkout is an Ottawa-based technology executive with 30+ years of experience in technology organizations in Canada, US and Europe, including 8 years in executive C-positions, mainly as CTO. Bassam is the founder of IGnPower, an IIoT strategy consulting practice. He is active within the IIC in areas such as *Digital Transformation*, *Industrial AI*, *Trustworthiness*, *Data Protection*, *Distributed Ledger*, and Security. He is also a veteran of the Information Assets Governance space, including RegTech, Data Privacy and Electronic Discovery.

Our next article concerns technology trends, specifically around the development of platforms for ownership and usage of data. It is less about implementation than the trend from "free" to "freemium" on platforms that owned your data to ownership by the producer of the data.

TECHNOLOGY TRENDS

VIRTUAL OWNERSHIP, THE CIRCULAR ECONOMY AND IPCT

Making predictions is a tricky business. Technology trends depend on technological innovations and factors such as people's behavior and accepted norms. Thought needs to be given to technology and its interplay with society. We have learnt from experience that technology is not adopted just because it gives value—there needs to be acceptance of the technology and its usage. GE Digital invested in technology but failed to have a corresponding impact on sales because they didn't think about the changes in its ecosystem. The lesson here is that the value for society needs to be thought through. Not doing so risks faulty predictions.

When vehicles were new in the 1900s there were no roads. Roads and infrastructure were the prerequisite for the growth of automobile ecosystem. We needed safety systems, signaling systems, road rules and licensing systems. Cars were the technological innovation, but roads were needed on which cars could be driven to bring value. Similarly, for a data economy, we need its building blocks, so we can bring benefits to all the players.

The two key attributes of physical ownership are exclusive access to the property and exclusive access to sell its ownership status in exchange for value. The virtual world of data has changed the concept of ownership: it is not exclusive.

For example, newspaper and television companies had no knowledge of which advertisements interested which consumers, but an internet company does. It is a two-way advertising medium. In the television and newspaper advertisement model, users' data was secure as there was no data they could sell. The seller has absolute control on the physical good, both physically and legally. In the internet model, who owns the data and who benefits from it?

Most platforms today like Google and Facebook use a freemium model, where they obtain a user's data for a free service they provide; the data is monetized by the platform. Privacy regulations, such as GDPR, suggest that the creator of the data should own it. Future platforms could benefit the user who creates the data, and the platform owner would get a share for enabling monetization of a user's data. If you own your data, you can grow the market. If not, there will be continuous litigation between participants, inhibiting growth. Clarity on who owns data is the primary driver for growth of IoT.

For example, who owns the data that a robot generates on a factory floor? Is it the factory owner, or the robot manufacturer? Today, a manufacturer can extract data without the data owner knowing to what use the data is put. Data ownership scales the manufacturing world, since IoT devices can be tied to data ownership and the data that comes from the IoT device will be used to execute a specified transaction. Once both the data ownership and data usage for a process is clarified, an IoT device can be seamlessly plugged in, “plug-and-play”. This enables the transition from a “platform and freemium model” to “data usage and monetization” model.

How do data ownership and data usage work together? It’s a chicken or egg situation. Data ownership will not be accepted without data usage. They are interdependent. Data usage platforms will enable the data ownership concept. How can you break this conundrum?

The key lies in a solution for all participants and a way to map their interactions. You need a mechanism that can get all participants on board and map them to their processes easily. Facebook and LinkedIn showed that we require a platform for interactions with an identity and a process that that identity can execute. For example, posts to friends on Facebook or a way to put forth your employment credentials and experience on LinkedIn. Any new platform that links data ownership and data usage has to have an identity and the ability to enact a process based on that identity. In turn, that enables communication and consummation of a transaction.

This has been true in the physical world for thousands of years. No one would execute a transaction for physical ownership of something without knowing who owned it, and in turn established that the “seller” is who he is.

In the virtual world, we need something similar: Identity, Process, Communication and Transaction (IPCT). This enables ownership of data and how the data will be used in a process. With virtual ownership and IPCT you get a way to own and transact data for the *specific purpose for which it can be used*. In IPCT, the identity gives access to the process for which the data is used and communication of the data results in a transaction.

A manufacturer can sell a machine to a buyer for which the data service is defined, and it benefits both the buyer and the seller. The data from the machine will be used for a specific process for the benefit of the buyer and the manufacturer will have access to the data only through the process and purpose for which it is used.

This results in a mechanism where you can achieve scale fast. And since the IPCT depends on processes for data usage, only those processes that are interesting to the buyer and seller rise to the top with use. Any new user can be onboarded on the platform fast and linked to their processes.

The data generated by an IoT device has a purpose defined by the process for which the data is used. Virtual ownership defines the data usage and simplifies scaling up for IoT use. Virtual ownership satisfies both users and owners of the IoT device.

Virtual ownership primes the whole ecosystem, giving a system that can scale and be beneficial for all participants. What we do not know today is how the new system will function and the factors are that we need to consider in the new system. Putting a new ecosystem in place can take decades. The car industry to replace the horse carriage industry took decades. The same was true in the airline industry. Can we have a smarter way to scale?

With the IPCT framework we can cut the transition time by a substantial amount. For example, the transition from fossil fuel to the green renewable energy ecosystem and the need to create a circular system for material usage. The issue in both these cases is we have no template for how the new ecosystems will look and what changes do we need to make, and who will be the new participants. Imagine when the car was invented in the 1900 and people were used to horse carriages. You had hay markets to feed the horses. This had to be replaced by gas pumps. It was difficult for people to imagine the new system with cars. But today we have an advantage in that we can digitally map the new system with processes and data and make the transition smoother with virtual ownership and IPCT.

Let’s see how this works. In the circular economy, a manufacturer will manufacture products to be sold also generates a digital twin with attributes that can be passed on when the physical product is sold to a retailer. Similarly, a retailer would transfer ownership to the end user of the physical and digital product. The user will use the digital product and transfer the ownership of the physical and virtual (digital) twin to the next owner and this continues over the product lifecycle. As the product progresses across its lifecycle, it interacts with different user identities, it could be the manufacturer who manufactures the product, the retailer who sells the product to the owner or company that owns the product to the recycler who recycles the product. At every stage of the product lifecycle the user follows the processes for that role, and the product flow is continued till the end of the life cycle, making material recovery possible when the product is retired. It leads the way in how products are designed for recycling and material recovery.

This becomes easy to deploy in three simple steps:

- bring all user groups with an identity on to a common platform,
- define processes for a user group and give access to those processes and
- use the platform and processes.

All data sharing functions are aligned for the specific process defined on the platform resulting in a plug and play for IoT devices.

An equivalence with smoking: When the tobacco Industry started in the 1920s or 1930s, they presented the glamour of the Marlboro man riding into the sunset with a cigarette in his mouth. It was the way to live life. But over the years evidence was mounting on the mal-effects of cigarettes on society and there was a correction that started with a warning on cigarettes followed by a ban on cigarette advertising, followed by a ban on smoking on airplanes first and later in public places. In the internet era, the mal-effects of the internet has led to laws like GDPR. Slowly, we see bans on using others’ data for gain. Data ownership is the key for the next growth phase of the internet and IoT in manufacturing, and in general.

In summary, we believe we will see the following changes in the next decades:

- The shift of digital platforms to personal ownership platforms, where the creators of data, own and monetize the data.
- Frameworks that accelerate the adoption process based on personal data.
- Transitions to a circular economy where materials used in products are recycled at the end of lifecycle using the data ownership principle and the digital twin to be transferred from one owner to the next.
- A transition to the fossil-free energy market using the data ownership and usage framework.

We at *GEOOWN* have created such a framework for data owner at data usage. It twins the physical entity with its digital twin throughout the manufacturing lifecycle and the circular economy.

Author

Abhijeet Kelkar runs a consulting company that advises companies on Building Business Models and Ecosystems. He has around 3 decades of experiences with companies and their growth strategies. He has worked in the AI market developing models for growth. He has innovated models for companies to analyze their positions in the Market , the model is called VBE model and has developed frameworks for scaling and growing new product companies in a framework called IPCT which enables different participants to participate and scale ecosystems. Another area he has contributed to which has implications for manufacturing Industry is the concept of Virtual Ownership, this enables the company to build circular business models and scale digital twins.

The following article is at once a case study of IIoT in one country and a discussion of servitization: manufacturing service.

KOREA'S NEW MANUFACTURING SERVICE AND DIGITAL TRANSFORMATION

This article focuses on Korean manufacturing services made possible by digital transformation (DX) enablers such as the internet of things (IoT) and artificial intelligence (AI). The Korea Industry 4.0 Association has emphasized business model innovation by applying digital technology inside and outside factories for domestic companies exposed to the rapidly changing market and technology environment. We describe the activities of the Korea Industry 4.0 Association (KI4.0) to promote business model innovation in the manufacturing sector.

This article addresses digital transformation of manufacturing firms with a focus on Korean manufacturing services. They can be created by firms' efforts to apply DX enabler technologies. We discuss the activities of large and small firms in offering manufacturing services and the possible role of global testbeds in facilitating their emergence.

KOREA INDUSTRY 4.0 ASSOCIATION AS AN EVANGELIST

Korea Industry 4.0 Association (KI4.0) has been an evangelist for business model innovation in the manufacturing sector since its launch in 2015, publicizing GE Aviation's service for expanded customer outcomes ("Optimized assets & operations") and other best practices over various conferences, meetings and publications. From early 2018, it launched the New Manufacturing ("신제조 [Sinjejo]") campaign encouraging Korean firms to respond to the new manufacturing challenge.

In 2018, KI4.0 defined "new manufacturing" in its *National Assembly report* (Lim, Park, and Kim 2018), as the manufacturing industry being turned into an internet business including service offering. New manufacturing is a simplified expression of manufacturing industry being digitally transformed. A firm with a new manufacturing initiative with more service and more internet-connected value-added activities would gradually arrive at a new business model that could be a big threat to competitors.

In 2021, KI 4.0 revised the definition to provide "more services" and to include more "internet-connected" value-added activities, in a *business journal paper*. KI4.0 defined the concept because Korean firms tended to neglect the digital transformation challenge, instead focusing on improving productivity in production. Some firms found the concept of digital transformation confusing and difficult to understand.

The new manufacturing campaign resulted in a Korean newspaper special series on new manufacturing in 2018 and a Korean major TV broadcasting station's *special news session* on new manufacturing in 2019.

From now on, the manufacturing service made possible by DX enabler technology such as IoT, AI and other technology shall be called the *new manufacturing service(신제조서비스 [sinjejo-seobis])*, which is now widely used terminology in Korea. In Korea, most smart factory initiatives focused on improving efficiency of the factory by application of the DX enabler technology. The message of new manufacturing campaign was "look also outside the factory", rather than "merely looking inside the factory".

KOREA NEW MANUFACTURING SERVICE

Korean firms showed progress in looking outside the factory in 2019 when the LG group, a conglomerate group called *chaebol*, declared a digital transformation initiative, which resulted in the release of ThinQ platform, opened to external developers in 2019. Apps for providing online services for consumers in 2021 were introduced to the public through *YouTube videos*.

In Korea, Industry IoT Consortium (IIC) *testbeds* and *test drives* offered good opportunities for a Korean firm and for a research institute to learn about and to develop a possible new manufacturing service. Korea Electronics Technology Institute (KETI) partnered with Fraunhofer Institute on IIC *Smart Factory Web* testbed. The Smart Factory Web testbed was approved in 2016 with the primary goals to:

- achieve a flexible adaptation of production capabilities and sharing of resources and assets in a web of Smart Factories to improve order fulfillment and
- provide the technical basis for new business models with flexible assignment and sharing of production resources.

Smart Factory Web Test bed has evolved into a testbed offering a basis for manufacturing marketplace where you can identify possible manufacturers and orders. KETI has also joined the IIC's *Negotiation Automation Platform Testbed* as a partner. The Negotiation Automation Platform Testbed enables flexible automated negotiation of detailed trading conditions and business counterpart matching across manufacturing supply chains. The Negotiation Automation Platform can be a platform offering services to firms linked with Smart Factory Web to find negotiation counterparts.

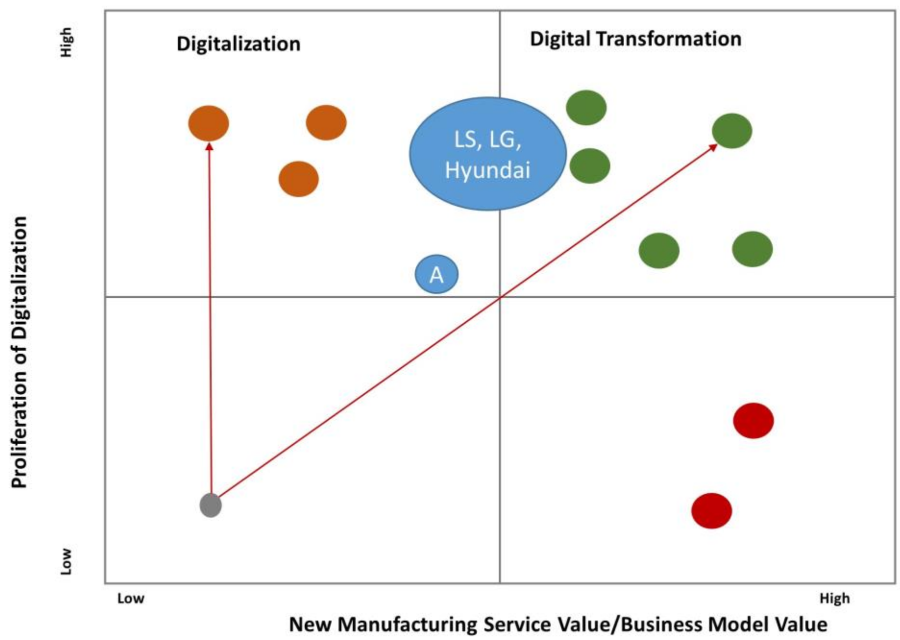
Negotiation Automation Platform and Smart Factory Web complement each other in orchestrated supply chains, thus supporting "manufacturing as a service" in the platform economy. Manufacturing as a service allows firms to manufacture their products without investing in massive infrastructure, by offering services related to manufacturing activities. The service includes offering manufactured goods to the customers who ordered online.

The IIC test drive by Inter X new manufacturing service applying AI on plastic molding process. It optimizes injection recipe operation by applying smart mold to the injection process to:

- solve on-site problems quickly as the process is run by AI solutions and
- allow users to upload their data onto the AI platform and receive optimized injection recipe operation from the service.

Smart Mold testbed for offering service based on smart mold platform is expected to emerge from the *smart mold test drive*.

Beside the IIC testbeds and test drives, Korean firms can make progress initiating new manufacturing services. Hyundai automobile showed its "Metamobility" service in CES in 2022, which is broader than mobility as a service, covering mobility of passengers through automobiles and mobility of things, relevant to logistics, using robots and other logistic devices. This Metamobility service, will be based on autonomous driving technology, mobility technology, energy technology and software for connecting devices and contents. LS Electric has its factory as World Economic Forum lighthouse in 2021. It launched its early-stage platform in 2019, *Techsquare* (LS Electric 2021), offering services to small end-user factories and inviting solution providers, not yet with cloud- or edge-connected services.



Korean firms in Digital Transformation. Source: Preparation material (originally suggested by Pieter van Schalkwyk (XMPRO) for Zarkout and Morrish (Eds.) "Digital Transformation in Industry," Industry IoT Consortium, 2020.

According to IIC's digital transformation diagram above, the shift to digital transformation can be described as a vertical upward shift (digitalization) and a horizontal shift to the right (transformational service and business model innovation).

The new manufacturing services of LS Electric, LG Electronics and Hyundai automobile are located in the upper-middle space of the digital transformation diagram. We can see a small mechanical component maker with 30 employees, who could be located in the middle-left, shown as A.

Having been successful in manufacturing process innovation with its smart factory projects, A could get requests from similar small firms for advice and support in initiating smart factory projects. It has already developed its own Manufacturing Execution System (MES) and is now developing a shipment inspection vision recognition system and a IoT real-time monitoring system supported by low-end equipment. The firm is planning to deliver shipment inspection vision recognition service to other small firms based on its successful experience of implementing smart factory projects.

It aims at earning more than the revenue in 2020 over the next five years from software business including this service. From their accumulated experience of helping other small firms, the firm decided to enter into solution business. Even though the to-be-delivered service is not transformational at the global or even Korean level, it is transformational to the firm. This shows a pattern of how new manufacturing services emerge in a small firm with accumulated experience on smart factory projects. The firms apply digital technology to serve customers outside its own factory and radically changing its own business.

KOREA NEW MANUFACTURING SERVICE AND GLOBAL TESTBED

There is increased interest on new manufacturing service in Korean firms and government. Korean firms need global partners for scaling up the market for their solution because they are likely to remain in the local market without global partnership. Korea may be one of the countries with the highest level of density of various manufacturing industries such as semiconductors, automobiles, shipbuilding, electronics, iron and steel, petrochemicals, cosmetics, clothing and biotech. It also has strong IT infrastructure and consumers with severe smart phone addiction. So Korea has a good condition for global testbeds. Any foreign firm that needs to validate its solution or service through interaction with users or suppliers in various industries within a proximity area, Korea would be the right place to find global partners.

Recently Korea Industry 4.0 Association emphasized policy for encouraging global testbed in its report to Korean government on policies for facilitating the growth of new manufacturing service.

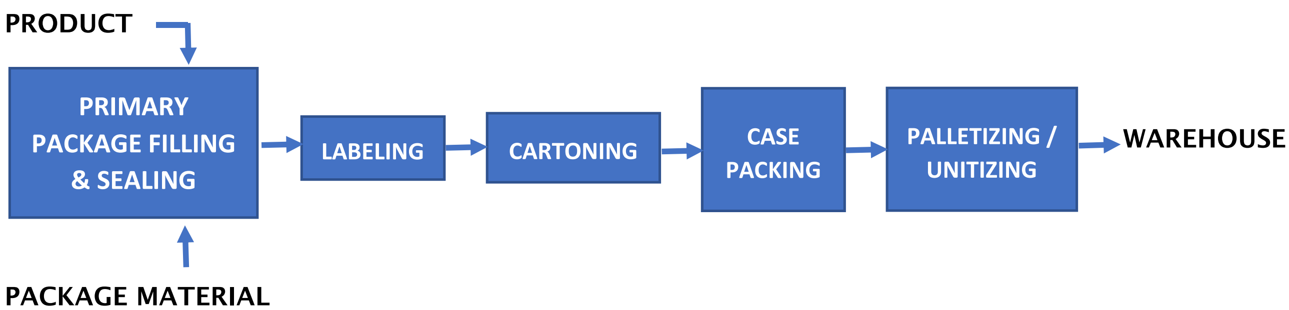
Author

Chaisung Lim is a technology innovation management professor with 22 years of teaching, after working for Korea's premier economic research institute for 10 years. His research work has been focused on technological catch-up and innovation management by emerging firms. He founded Korea Industry 4.0 Association in 2015 and became a member of the Boston-based Industry IoT Consortium, with active collaboration with peers on test beds and business-related subjects, such as digital transformation.

This next article describes how to connect machines in a packaging line to enable digital twins and the benefits they bring.

Connected Factory for Packaging Consumer Goods

In the supply chain of a consumer products goods (CPG) company, the filling and packaging line is the last area of value-added steps within the company's manufacturing system before customer-transport trucks come to take orders to the customers' points of distribution. These lines mostly comprise packaging machinery and material handling systems that can be from five to 25 years old, depending on the maturity of the product category. We discuss elements of how machines of varying ages may be connected to create digital twins of packaging lines.



For this, we must address four pillars:

- machine connectivity both between machines and the machines-to-line flow control,
- operator connectivity,
- line digital twin, and
- machine digital twin (a means for machine-condition monitoring).

Machine Connectivity

CPG companies have been connecting machines for overall equipment effectiveness (OEE) monitoring for over a decade. Equipment older than that may not be connected, though this is necessary to develop a form of a digital twin for the line that reports OEE in real time.

Machine-to-machine: Machines can be networked so that a downstream-machine state changes can be communicated quickly to the upstream machine, which may then slow its output rate.

Machines-to-line-flow controller: The line-flow controller is responsible for package flow control between the machines in the packaging line. OEE can be calculated for the entire packaging line, as each machine reports its OEE to the line controller via the machine-to-line-flow controller connection.

Operator Connectivity

The machine-unit operations illustrated above require a machine operator at each machine to replenish packaging materials (labels, cartons, cases etc.) as they are consumed. Traditionally, operator control of the machine and machine state (low material, fault cause) has been through an operator panel fixed to the machine to provide the operator a clear view to ensure operation is started or resumed safely.

As improvements progress, the operator panel needs always to be with the operator. If necessary for safety the cycle-start function can still be attached to the machine at the correct position for best line of sight.

Later, augmented reality (AR) headsets can superimpose instructions for fault recovery or machine changeover onto a live image of an area of interest in the machine.

It is not easy to deploy an AR headset onto the personal protective equipment (PPE) required within a CPG product packaging area. Leveraging an operator’s familiarity with a smart phone or tablet is easier to adopt than an AR headset that would conflict with the eye shield.

A mobile industrial tablet or protected smartphone would provide:

- instant notification of machine faults,
- a changeover procedure reference,
- a view of the machine’s instruction manual that can be rapidly downloaded from a local factory server or
- line-performance information in real time by accessing and visualizing line OEE information from the line controller.

Partnering with the machine’s original equipment manufacturer (OEM) can reduce development time of the mobile interface significantly.

Line Digital Twin

Some packaging-line integrators have provided machine-controller program add-ins and line-controller software for OEE dashboards, machine and line performance, all in real time. This is cost effective for new lines; it is challenging and costly to implement on legacy lines.

Machine Digital Twin

A digital twin for a packaging machine has two development contexts for different stakeholders.

The first is a digital twin for machine design that streamlines the design and build of a new machine from an OEM. Physics-based modules describing the different mechanical and electrical characteristics of motion axes in the machine are assembled virtually. This digital model can then determine whether the chosen components are fit for purpose. It also allows the machine-controller programmer to start writing code before a prototype is ever built. Once built, this pre-debugged program can be used, which shortens the development time significantly.

The second is a digital twin that monitors mechanical characteristics of motion axes such as torque and backlash, and electrical characteristics of axis motors such as maximum current in a machine cycle. Once a baseline pattern of these characteristics is gathered, stored and visualized within an edge-computing device, machine cycles can be compared against the baseline values. Alerts notify an operator if the gap between actual cycles and the baseline deviate beyond acceptable limits. An increase in axis-motor current might be an indicator that an axis joint requires lubrication, or if a more significant increase is measured a component may need replacement at the next available line outage. This digital twin can be developed for the machinery end user with help from the machinery-controller manufacturer (technology provider) and the machinery OEM. Another key element of the use of this twin is to restore the machine to an optimal operating condition before creating the baseline cycle pattern.

Connecting machines and lines together enable digital twins of machine and lines. This enables debugging before deployment, increasing uptime and improving OEE as greater visibility of operations is provided. The operators must also be portably connected to contextualized data streams to be more effective in their tasks that keep the line running.

Author

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Professional history: Over 30 years in the Food & Beverage Industry in packaging machinery and systems development and deployment for the two largest F&B companies globally. Co-chaired the Pack*Spec* committee of the OMAC Packaging Workgroup. Prior to forming AdvME he participated in developing a digital transformation strategy for end of line in packaging for the largest global F&B company.

This article talks about neural manufacturing. Going one step further than digital twins, we can connect machines into a neural network that can learn as it operates.

NEURAL MANUFACTURING

Smart factories are leveraging data analytics and connected everything to enable unprecedented levels of automation and optimization. Technologies such as IIoT, digital twins, artificial intelligence (AI), 5G and Li-Fi, augmented and virtual reality (AR/VR), robots and cobots, blockchain, cloud and edge computing create a manufacturing-plant environment where fast-correction, streamlining and the elimination of expensive prototype development are both possible and happening already in many factories around the world.

Due to the Covid–19 pandemic and the need for self-correction and automatic streamlining across the value chain of manufacturing, can we make smart factories even smarter? How can we reinvent the factories to refine their business operations and enterprises needed to focus on building resilient digital value chains to maintain operational efficiency? Resiliency is required to handle challenges from outside an enterprise, such as the Covid 19 pandemic, and to address the challenge of any events that can affect operations.

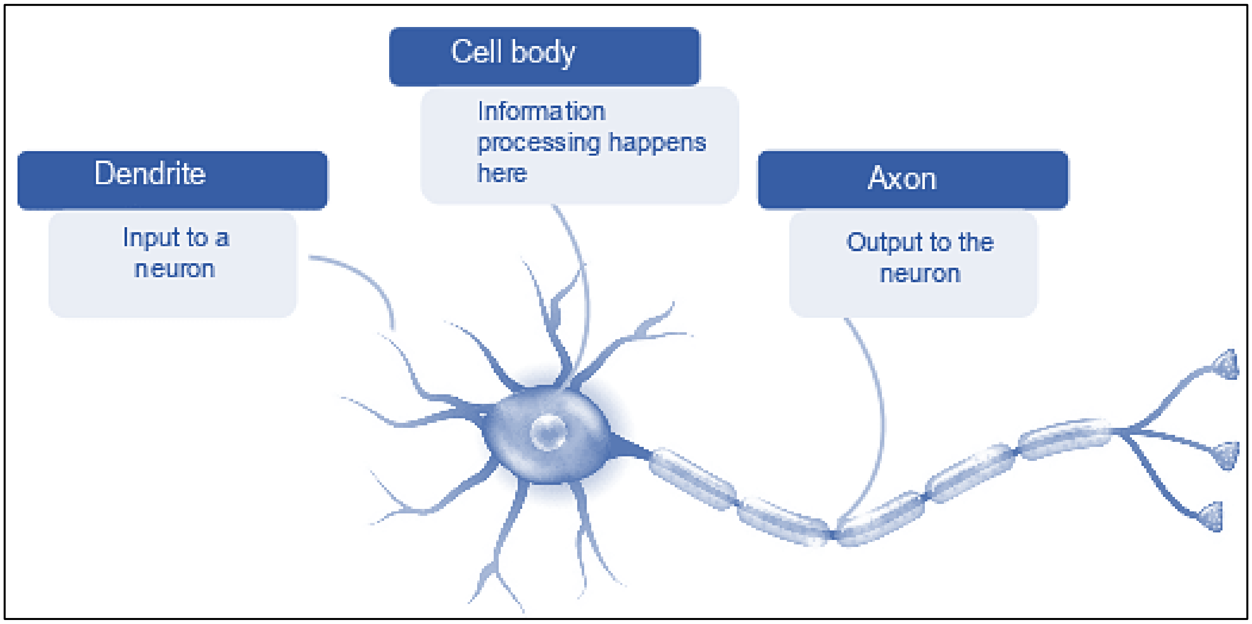
Manufacturers are leveraging trend data across the value chain to identify consumer behavior so as to shape products around them, to achieve zero defects, optimize risk management and to adapt to internal or external events. However, analyzing data to pinpoint trends is not easy to achieve without the availability of data in near real time and near-real-time data analytics and decision making, especially given the large volume of data produced by a smart factory.

What is the solution? How do we get smarter? What model or platform can help us to achieve this?

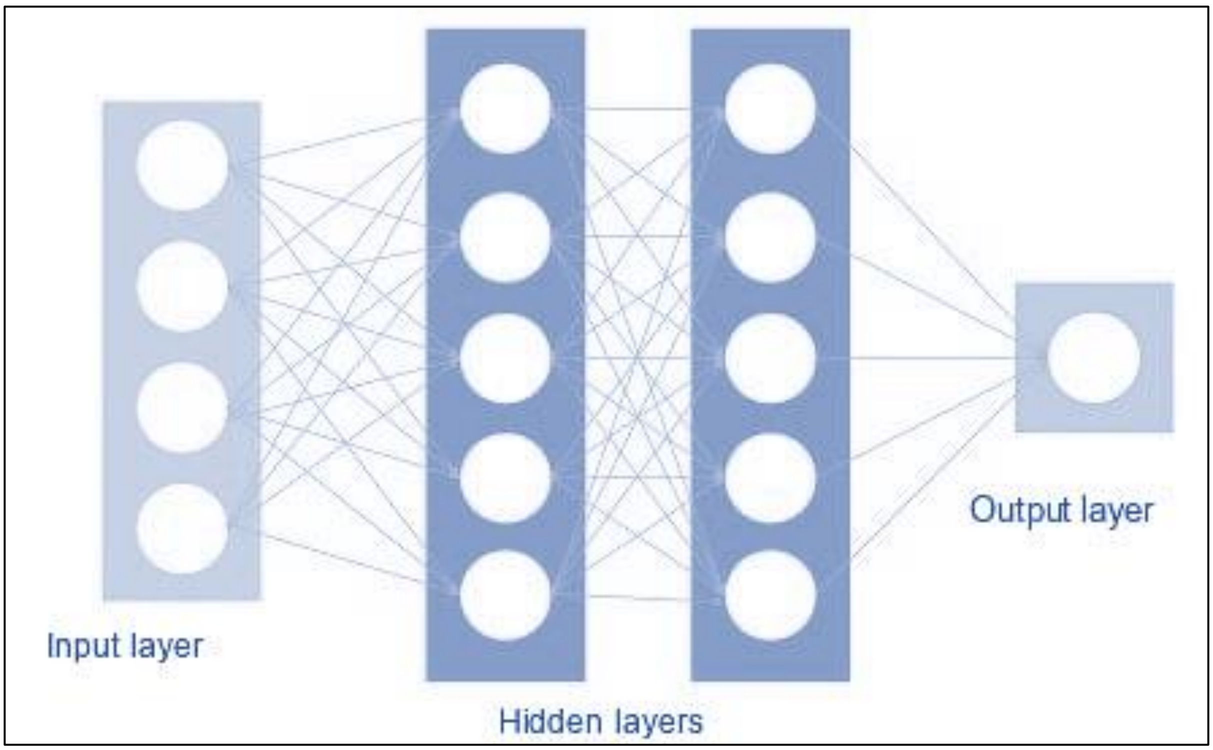
There is a successful model for this in nature and, in fact, in our body, the *neural network* (NN). A neural network is a network of biological *neurons*. In a biological neuron, there are:

- "Dendrites", which receive signals from other neurons that are connected to it.
- "Cell Body", where the information processing happens and take in all the information coming from the different dendrite.
- "Axon", which sends the output signal to another neuron for the flow of information.

Next, let's model this to an AI neural network (ANN). The network starts with an input layer that receives input data. The lines connected to the hidden layers are called *weights*, and they add up on the hidden layers. Each dot in the hidden layer processes the inputs, and it puts an output into the next hidden layer and, lastly, into the output layer.



Neural network. Source: Simplilearn.



AI neural network. Source: Simplilearn.

Comparing NN and ANN you can observe how an ANN replicates a biological neuron:

- Input to a neuron → input layer
- Neuron → hidden layer
- Output to the next neuron → output layer

So, an AI neural network is a system of hardware and software patterned after the operation of neurons in the human brain where each neuron is referred to as a node. ANNs are a means to achieve deep learning. Let's apply this concept to manufacturing and see how even smarter factories of future can be achieved.

Self-learning AI nodes in the smart factory are playing a large role in the reinvention of smart factories. Each node monitors a certain part of the value chain of the enterprise, gathering data from various sources such as sensors, devices and machines to teach itself what the of normal operation parameters are. Over time, each node learns every detail of the manufacturing value chain and uses it for analysis, modeling the data and decision making. It shares this data with other nodes so they can advise on where to optimize and even accomplish this without human intervention.

Each node can identify where and when, what action is required. For example, where and when to do maintenance and to how to know precisely what components need maintenance to reduce the risk of equipment failure. If needed, each node can interact with other nodes or to the machine and automatically halt a production line to prevent failure. It issues a ticket for repair, creates an inventory list for components and assigns technicians for the repair in a matter of seconds.

At the same time, the node can notify another node in the value chain to notify customers or logistics partners of the delay in production and what products are affected to ensure expectations are set along the value chain. This fast, reactive and adoptive process saves time and product loss, and quickly becomes proactive as each node learns patterns and identifies triggers in advance. It can model predictive response and best practices for future events and their effects. Each node also has the ability to identify all processes, objects and elements and understand their operating parameters, making recommendations for safer operations or pinpointing where the greatest risks are for operation.

Introducing the neural network concept into smart factories creates a way of understanding how manufacturing, throughout its value chain, can be fully resilient, adaptive and purpose driven. This provides a way of thinking to executives to understand what their path to the future of their manufacturing value chain would be and to understand what they need and what steps to take toward their goals. Neural manufacturing can define a platform, based on the value and KPIs that are desired, for maturity assessment of manufacturing and the path to the next level of maturity.

The entire world is set to change, events that you can predict and the ones that you cannot, all of which will have an impact on how we do things, including in manufacturing. Shifts will occur in user interaction, shift allocation, warehouse management, route management, risk management, supply chain changes and challenges, and the entire manufacturing value chain.

To survive and keep up the pace of the manufacturing enterprise and business operations you need to employ smart factories. But to be able to be on top of the game and transform a threat to your advantage while everyone else suffers, you need to have even smarter factories and equip yourself with the neural manufacturing concept and platform. Team of experts and scientist at *TCS* can help you throughout this journey to plan such a concept and deploy such a platform. Are you ready to be even smarter?

Author

Farid Bichareh is an executive, technology expert and entrepreneur with over 22 years' experience defining solutions/strategy for smart manufacturing and digital transformation, IoT/IIoT, and innovative Optical Wireless Communication/Li-Fi and AI. He has co-founded several businesses and served as a board member and top executive for several organizations. At the Industrial IoT Consortium, he chairs the Smart Factory Task Group and is a member of the Steering Committee. He is a frequent speaker and author.

And finally, we have a case study from an association in Turkey on the work they have done to build a technology center.

SMART FACTORY CASE STUDY

Turkish Employers' Association of Metal Industries (MESS) is the first and one of the biggest employers' unions with 260 global conglomerates and key, industry-driver local members including automotive, molding, machinery, durable goods, iron & steel and cabling with 210,000 employees providing for a family of more than 1,000,000 people in Turkey. MESS aims to develop well-balanced, reliable, and stable industrial relations, while increasing the competitiveness and the productivity of Turkish industry. 30% of MESS members are among the largest 1,000 exporters in Turkey. MESS members account for 25% of total manufacturing of Turkey.

MESS is a part of both national and international platforms and contribute to key decision-making such as *International Labour Organization* (ILO), *Business Europe* and *European Tech & Industry Employers* (Ceemet).

As the leading employers' association, representing the most important manufacturing companies in Turkey, MESS has established a distinctive technology center, *MEXT*, in the heart of Istanbul that provides direct support and guidance to Turkish industry with regards to digital maturity assessment, capability development and workforce up-skilling. MEXT, builds on and enhances the technology and innovation capacity of manufacturing companies, encourages them to define their digital transformation roadmaps and start the execution as quickly as possible, as well as foster their engagement with world-class institutions and technology companies on their transformation journey.

MEXT sits on a 10,000m^2 area in which there is a 1,200m^2 state-of-the-art digital factory, training classrooms, conference halls and a showcase area. MEXT training programs are tailored to the needs of manufacturing sector with a comprehensive digital transformation curriculum that addresses the four different levels of employment in manufacturing: CXOs, mid-level managers, engineers, experts and operators. 50,000 employees will benefit from these programs each year.

MEXT Digital Factory is a 5G enabled real production environment comprising two production lines and integrating more than 100 complex Industry 4.0 use cases to demonstrate their added value in manufacturing. At the physically set-up discrete line, a shaft-mounted speed reducer (gearbox) is being produced in the style of an automotive fabrication cell and showcased on assembly line inspired by the processes of the relevant stakeholders. The virtual continuous line, being the first application in the world, demonstrates a continuous production line of a steel galvanization plant integrated with the control systems used in real-life production. The objectives are to convey the benefits of Industry 4.0 applications to industry and to use the real production environment for hands-on training sessions with employees and as a testbed for new Industry 4.0 technologies.

End-to-end integrated industrial IoT stack covers Enterprise Resource Planning (ERP) systems, Warehouse Management Systems (WMS), Manufacturing Execution Systems (MES), Product Lifecycle Managements (PLM) system and three different IoT platforms that run in parallel.

MEXT digital factory.

Providing real practical examples of what a factory of the future is, how it works, what it generates as values and how state-of-the-art technologies are deployed helps to make the digital transformation more tangible for companies. During initial investigation, digital transformation can be perceived complicated or abstract; demonstrating how it is deployed on a real manufacturing environment is convincing to decision makers.

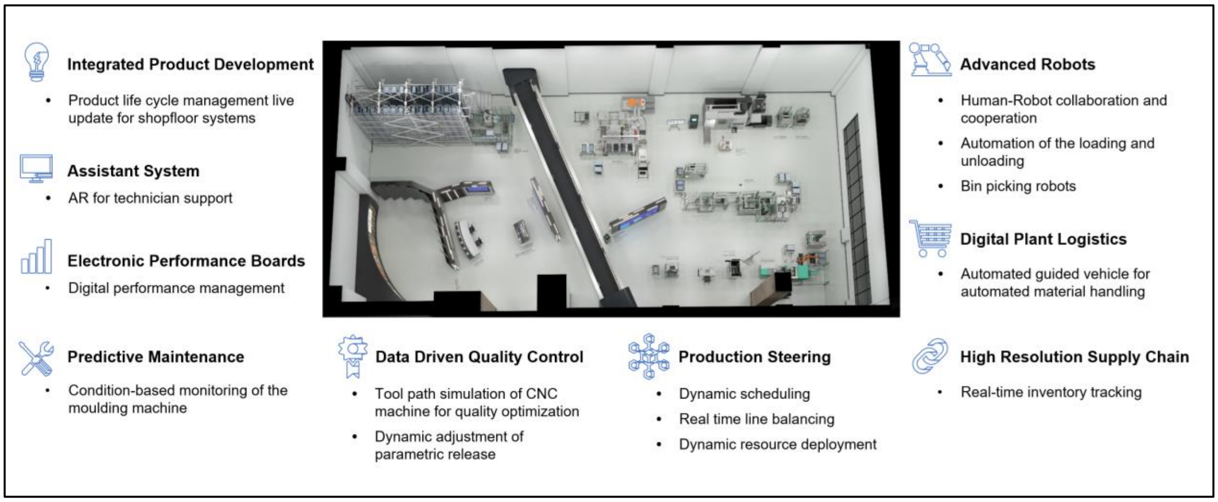
Policies to increase the number of model factories through *public-private partnership model* and incentivize the services that companies get from model factories are crucial. It is also needed to make sure that model factories have strong links to each other and have a common strategy.

Model factories can support companies through online platforms by sharing best practices, success stories and a comprehensive picture of available public policy programs. This will reduce friction and provide a single point of reference for robust strategy development.

Another duty of a model factory is to provide tried-and-tested use cases as reference points. These use cases in a catalog should include an overview of the *business case*, description of the *technical solution*, quantification of the *key performance indicator* (KPI) improvements, including *return on investment* (ROI) estimates, and the *benefits* and *challenges* of deploying the solution.

It’s a fact that SMEs often have lower visibility, negotiating power and a smaller business development workforce to establish partnerships compared to larger companies. Model factories should also address this challenge by consolidation of clusters for SMEs and technology providers, access to technology testing and demonstration, specialized information and partner matchmaking.

MEXT is also offering consultancy services focusing on digital lean manufacturing, machine retrofitting, digital performance management, automation, robotics, IoT architecture, data management and long-term coaching for scaling pilot projects.



Exemplary use cases.

Since its launch on August 2020, MEXT is recognized as the nation-wide pioneer technology center focusing on digital transformation for the whole industries in Turkey—beyond automotive, durable goods, steel and machinery, scaling to non-metal sectors like textile, cement, fast moving consumer goods (FMCG), pharmaceuticals etc.

In addition to being a state-of-the-art model factory, MEXT also provides the industry with ecosystem partnerships to strengthen relationships across the industry. MEXT has joined the *WEF Center for Fourth Industrial Revolution Network* and is actively contributing to policy making that is shaping the world. A partnership with *Plug and Play*, the world's largest innovation and entrepreneurship platform has been launched to bring the newest start-ups to the use of the manufacturers. Strong collaboration with *Fraunhofer IPT* has been formed and close cooperation with Singapore's *Economic Development Board* (EDB) for *Smart Industry Readiness Index* (SIRI), which is recognized as the global standard for digital maturity assessment methodology by the WEF.

MEXT is determined to lead the way as the enabler and facilitator of the digital transformation via the digital factory and global ecosystem partnerships.

Author

Semih Ozkan is Advanced Manufacturing Technologies Director at MESS Technology Center, MEXT in Turkey. MEXT is a distinctive technology center established by MESS to support its 250+ member companies along their digital transformation journey towards Industry 4.0 and to develop capabilities, adapt new technologies, business models and stay competitive.

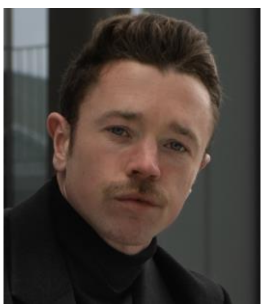
Since Feb 2019, he has been leading and coordinating design, build and implementation phases of *MEXT Digital Factory* and production processes with lean and digital transformation perspectives to advance operational performance by combining manufacturing expertise with state-of-the-art digital tools. He is defining technical roadmap of MEXT to pioneer in digital transformation and stay up to date.

Appendix

Appendix 1 Editors and sponsorship

Chief Editors

Farid Bichareh is an executive, technology expert and entrepreneur with over 22 years' experience defining solutions/strategy for smart manufacturing and digital transformation, IoT/IIoT, and innovative Optical Wireless Communication/Li-Fi and AI. He has co-founded several businesses and served as a board member and top executive for several organizations. At the Industrial IoT Consortium, he chairs the Smart Factory Task Group and is a member of the Steering Committee. He is a frequent speaker and author.



Michael Linehan is the Director of Program Operations at the Industry IoT Consortium, charged with developing both the processes and the people behind staff operations.

Stephen Mellor is Executive Vice President at Object Management Group and the Chief Technical Officer for the Industry IoT Consortium, where he aligns groups for business, technology, security and industry. Stephen was the Chairman of the Advisory Board to IEEE Software for ten years and a two-time Guest Editor of the magazine. He is also a signatory to the Agile Manifesto.

Global Industry Organizations

GIO provides an environment for discussion and open exchange among global industry organizations involved in digital transformation and ICT. The motivation was to share experience to accelerate the common response from peer industry organizations using an open discussion platform working effectively.

The GIO seeks to promote the digital transformation of multiple industries, including the ICT industry, by facilitating cooperation between relevant affected global industry organizations. It seeks to provide multiple “enablers” that smooth the way for increased global productivity and services through the deployment of scalable and interoperable digital technologies.

GIO is open to all industrial organizations willing to promote digital transformation. It is also:

- equal: all participating organizations have equal rights,
- global: multiple industries and different regions can share ideas and
- lightweight: a simple, agile approach to meetings and deliverables.

Any kind of industry organization can attend, including standards-development organizations (SDOs), industry-shaping fora, open-source communities, alliances and policymaking bodies.

Industry IoT Consortium

The Industry IoT Consortium (IIC), on the other hand, was initiated by five global companies to accelerate the development of the industrial internet by building an ecosystem for open collaboration. Typical industrial internet of things (IIoT) systems are too large and complex for a single company to tackle. Collaboration is needed on common services so that competing products can be built upon them.

Initially, IIC focused on developing common vocabulary and frameworks so that companies and individuals could communicate easily. That mission has largely been achieved. Now, IIC is more focused on digital transformation for users, by offering business deployment accelerator teams and documented digital transformation enablers to smooth the way to successful deployments.

IIC membership requires an annual subscription, based on company revenue. It is open to all organizations willing to work together to build the market. It is also:

- equal: all participating organizations have one vote,
- global: with 150-member companies from 30 countries

Any kind of industry organization can join IIC. IIC also has formal liaisons with many entities that want to work on shared interests, such as Plattform Industrie 4.0 to work on manufacturing and the Digital Twin Consortium to promote the use of digital twins. IIC also works closely with GIO to advance smart manufacturing activities, such as the publication of this white paper.

Associations

Why join an association? Associations constitute environments where industry organizations can meet, share views, discuss challenges and consider means of cooperation on topics of common interest. They pursue their work in a complementary manner to that of their participants.

The modes may vary. IIC, for instance, meets quarterly face-to-face around the globe (or at least it did, before the pandemic) and holds regular weekly or bi-weekly meetings of over 20 groups of different sorts and some ad hoc or “tiger team” meetings to get things done. GIO holds monthly meetings, occasional face-to-face roundtables to address specific topics, meetings at shows where likely participants congregate and publishes reports such as this.

The reasons for doing so are many. First, such meetings and publications advance and *grow the market* for all participants.

This is especially important for small companies, who can *connect with larger companies*. This helps large companies fill in certain niches in which they have not innovated, and it helps the smaller company sell its products and services. It may even lead to an acquisition and a life on the beach for the small-company shareholders.

The ecosystem also enables various *initiatives*. This can be as simple as writing a paper, such as this one. In the IIC, we can bring companies together to create testbeds, scaled-down, real-world systems to test out new technologies, technologies being used in different ways and new business models. It could also include test drives—generalized solutions that are specialized for specific verticals. These initiatives can even be directed towards specific business deployments.

There is a good deal of *information transfer* across companies. Sharing best practices, insights and experience relating to digital transformation across multiple industries and regions. This may include cross-education between different industry organizations. IIC has clear non-disclosure policies (if you disclose it, its public, but we’ll only publish contributions after a vote). This includes pre-competitive information and individual learning from the best in the field.

Associations are a way to *align vocabulary and components*. If we can see that something needs to be built, but there’s little competitive advantage in it, we can define requirements for a standards-development organization such as Object Management Group (which is also a type of association) and compete only on value-added products. This is a form of resource sharing to accelerate the industry and avoid unnecessary overlap.

Finally, *consensus development*. Associations act as a vehicle to gain consensus between participating industry organizations and reach win-win solutions.

Although participation in an association can cost money and certainly costs time, the more engaged a participant is in an association, the greater the return. Full-on participants shape the market both for their own intellectual satisfaction and for commercial benefits. This advances the technology and the market more than a single individual or company could ever do.

We invite you to join us to push this further ahead.

APPENDIX 2 DISCLAIMER

This document is compiled by the Industry IoT Consortium (IIC), sponsored by the Global Industry Organizations Initiative (GIO). The information within is the result of a collaborative effort between organizations, enterprises, and experts that have engaged with the IIC, reflecting current views on industry developments regarding smart manufacturing. The IIC and the organizations, enterprises, and experts involved in the compilation of this document agree to it being referenced and forwarded by GIO's participating organizations.

For more information on GIO and IIC, please go to *http://www.gio.zone/#/Index* and *https://www.iiconsortium.org/about-us.htm*.