White paper

Creating and implementing an industry 4.0 strategy

A manufacturing practitioner’s point of view

Many manufacturers are grappling with how to create an Industry 4.0 (I4.0) strategy that aligns with their business needs and ensures the smooth adoption of their chosen technologies and systems. This document provides recommendations for manufacturing companies to realize the benefits of digital advancements while avoiding the pitfalls that naturally come with disruptive technologies.

Introduction

As a manufacturing industry professional with decades of experience working with engineering, technology and operations management on the shop floor, it is interesting to see how the I4.0 ‘revolution’ is playing out across manufacturing industry verticals and sectors.

Having seen and assessed facilities in aerospace, automotive, process and general discrete manufacturing businesses to determine their need and readiness for adoption of the tenets of I4.0, it’s clear that there is no ‘one-size-fits-all’ solution. Every company, and in some cases individual divisions, has unique needs and requirements. However, if applied correctly, every one of them stands to benefit and see significant value.

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How does a company accomplish I4.0 migration?

By taking these three steps:

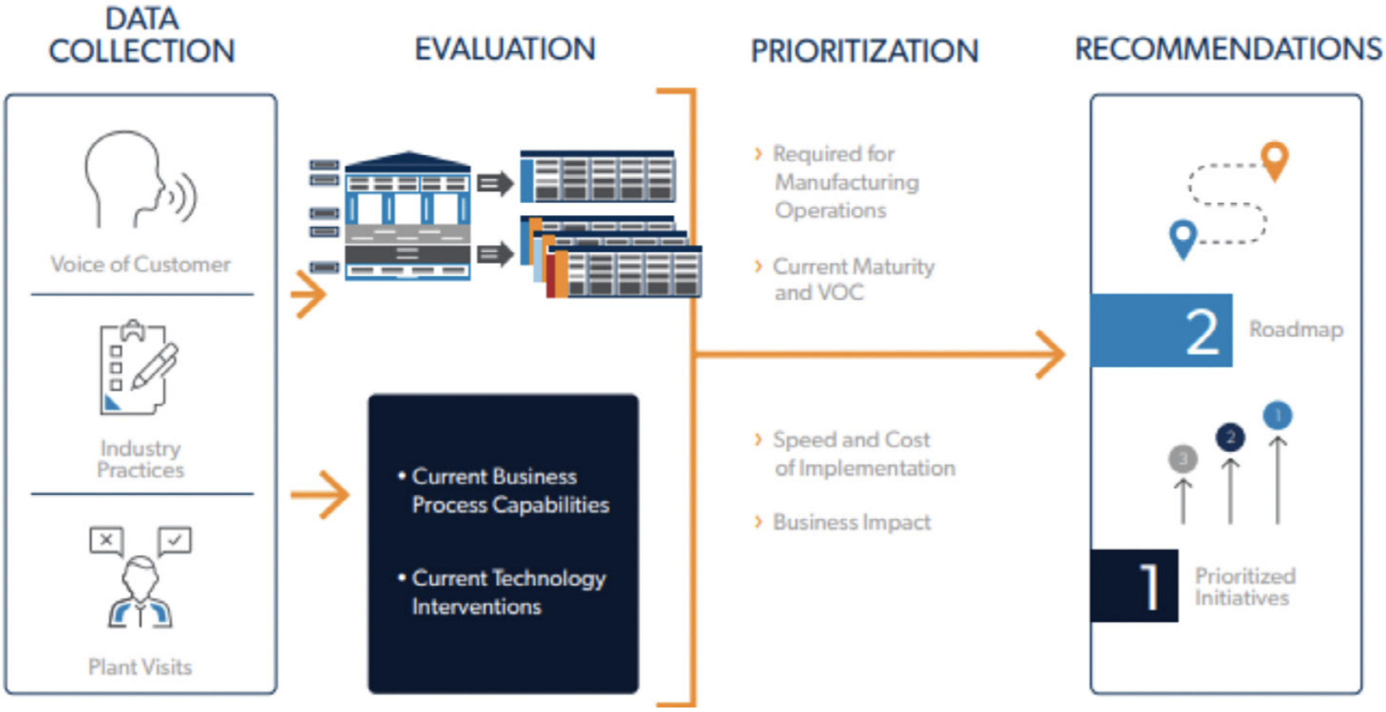
1. Create a strategy
2. Implement a roadmap and timeline
3. Navigate the challenges and opportunities

Create a strategy

The first step is to understand and define the approach.

I firmly believe that achieving smart manufacturing is a journey, not a destination. For any company, the journey begins with developing a strategy and creating a roadmap, with milestones of increasing levels of maturity.

Every company needs to start with a comprehensive understanding of their current manufacturing maturity levels as measured by their own internal metrics, in comparison to their industry peers. These metrics are almost always on the parameters of Safety, Productivity, Quality, Cost, Delivery and Morale (SPQCDM). This information, in the context of the company's future business strategy regarding product mix, customer segments and markets served, provides leadership a solid basis upon which to formulate an implementation roadmap and timeline.



These two outputs serve as the guides for leadership to define and create the roadmap for I4.0.

Methodology

It is important that a smart manufacturing strategy is built from the ground up, not top down — originating on the shop floor. Companies must assess the current maturity of their representative plants to cover the variety of manufacturing processes, levels of automation and operational differences as driven by the local/national requirements. Often initiatives stall, or even get abandoned, from failed efforts to understand and define how the I4.0 solution must enable and will impact day-to-day operations.

In these assessments, make sure you also capture the Voice of the Customer (VOC) as it relates to all functions of manufacturing, both direct and indirect. This should include production, quality, maintenance, logistics and supply chain, production planning and scheduling and plant leadership, as well as support functions like human resources, internal relations, utilities and all departments of plant engineering and information technology.

The VOC captures the pain points and identifies what is needed for the function or department to improve on their performance metrics. It should surface up best practices that can be horizontally deployed. The VOC results also generate quantitative data that can be used to build a business case for investments in technology solutions.

For example, a quality inspector doing an audit / inspection in a large factory setting states that his productivity will improve by 10% if he can have a digital tablet instead of a paper-based checklist. With a tablet, he could record his findings with pictures and text, pull up a history of defects and the root cause analyses instantly, create the report and send it right away to the relevant stakeholders for corrective action.

The additional benefit of quicker rectification and resolution is also an improvement in the product quality metrics of the line and plant. In this example, the key insight gained is the need and benefit of a digital technology and solution for the quality function. This takeaway, when collated and if supported by the VOCs from all the other plants in the assessment, should then formulate one small piece of the digital strategy for the quality function and find a place in the overall manufacturing digital roadmap and timeline when it gets defined.

Create a roadmap and timeline

A good comprehensive maturity assessment exercise should result in a quantitative report with two outputs:

1. Current level of maturity

The current level of maturity in a set of capabilities varies from customer to customer but is defined for each of the four core functions of manufacturing:

- Production
- Quality
- Materials
- Maintenance

The level of maturity for each capability in the function is typically rated on a scale of 1 to 5, with the lowest level defined as "reactive." Maturity progresses in definition, integration and orchestration until the highest level of maturity, 'proactive', is reached. In addition, the desired maturity level should be captured. The desired maturity level is determined by what it will take for that core function to achieve its own defined Key Performance Indicators (KPIs) for world-class manufacturing.

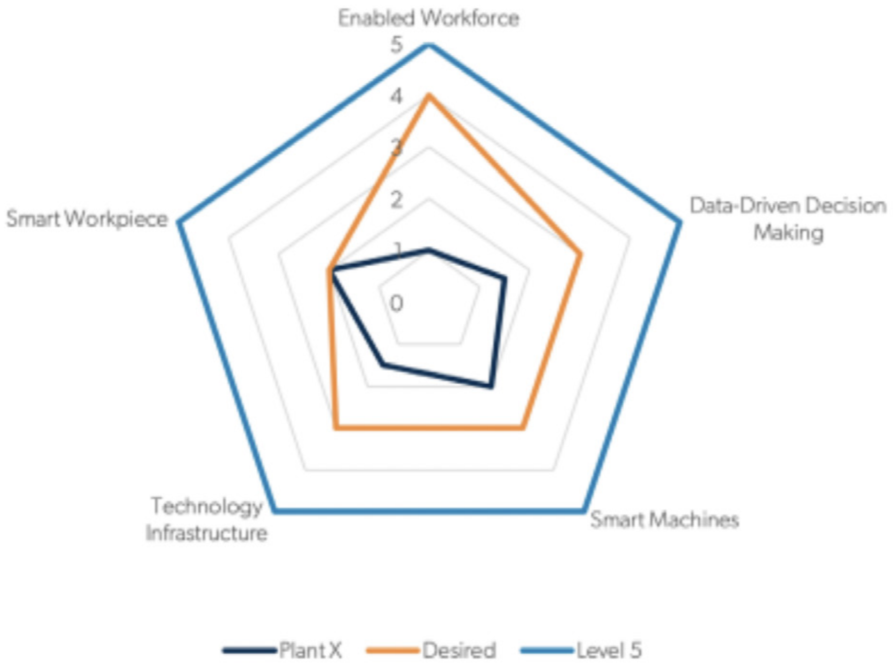
The gap between current and desired maturity level is then used to identify the initiatives needed in each of the core functions. Then, the digital and technology enablers for implementing these initiatives are defined. These identified initiatives are entered into consideration for the roadmap.

2. Smart manufacturing maturity matrix

The assessment report should also give a Smart Manufacturing Maturity Matrix (SMMM). This is derived by assessing all functions on the five dimensions that define a smart factory:

- Enabled workforce
- Data-driven decision making
- Smart machines
- Technology infrastructure
- Smart workplace

The SMMM gives a summary overview to leadership on the current state and maturity of the manufacturing footprint to help determine the feasibility of smart manufacturing capability.



Challenges and pitfalls to avoid

Once the roadmap of initiatives is defined, implementation timelines are developed to specifically address the customer priorities, needs and situation.

Then, each of the Initiatives is executed as an individual project, complete with a project owner and cross-functional team tasked with timebound deliverables.

In the execution phase - and this is applicable to technologies and systems of all kinds - it is very important to conduct thorough due diligence of the technology / system selection. This is even more critical in cases where there are multiple technologies that need to interface or integrate. The example I give below is a case where the manufacturer learned this the hard way - trying to implement multiple technologies in a greenfield I4.0 plant on a new line, launch a new product and go to production, all on an aggressive timeline.

Case study

The JIT-JIS Tier 1 supplier had built a new plant to supply sequenced part assemblies to the original equipment manufacturer (OEM) plant for a new program. With an ambitious goal to achieve world-class performance metrics on productivity, quality and delivery, multiple new technologies for material handling system (MHS), manufacturing execution system (MES), part track & trace (TT), quality error proofing (EP), performance metrics reporting and dashboarding (PMR) were evaluated and selected for implementation.

Automated Guided Vehicles (AGVs)

The MHS selected for the main assembly line was an Automated Guided Vehicle (AGV). This was a new undertaking for the company, which up until that point had used more traditional conveyor systems for assembly lines, so there was a natural learning curve that the engineers had to go through in designing, engineering, and implementing an AGV mode of conveyance for the assembly line.

In getting the standalone AGV system to work, issues related to the control system for controlling the speeds through different zones on the line, start and stop at stations, mechanical issues for vehicle movement and part handling, were resolved fairly expediently.

Automated storage systems and tracking technologies

The number of variants of the part assemblies to be manufactured and supplied to the OEM was very high, necessitating a large work in process (WIP) part inventory to be maintained to feed the assembly line. The company decided to go for a fully automated multi-level carrier-based system with highly complex controls to carry this WIP inventory and buffer stock. The carriers would carry multiple part variants and use RFID technology used for real-time tracking of the parts in this system. This automated stock system again was a big departure from the more manual storage and retrieval systems that the company had used in the past.

In getting this automated WIP stock system to work in standalone mode, there were complex concerns that took well beyond the planned time to resolve, including issues and failure modes related to the control system for carrier routing and tracking and the RFID system for part tracking.

Automated VSMS and pick to light technologies

The large number of variants of part assemblies naturally resulted in large number of components to be assembled to the part assembly on the line. Fully automated vertical storage machines (VSM) with real-time inventory tracking and extensive pick-to-light systems were deployed on the assembly line for the sequenced supply and assembly of these components to the part assembly online.

With VSM systems, issues and failure modes were related to getting accurate real-time inventory, and the uptime required to supply sequenced supply of components to the assembly line. The dependency on manual scanning of materials going into the VSM and accurate picking of components out of the VSM resulted in inaccurate inventory reporting and tracking. Additionally, downtime on the VSM due to mechanical / electrical / controls failures resulted in assembly line stoppages. It was realized that the application of VSMs for sequenced component supply tied to the line takt time was infeasible and the VSMs were later redeployed to the warehouse for offline storage of components. The entire sequenced components supply was then moved to manual sequenced kit racks with pick-to-light systems.

Manufacturing execution system

MES software was selected and developed specifically for the plant, to handle many functions — of sequenced part supply from the WIP stock system to:

- Pre-assembly operations
- The AGV assembly line
- Label print management, sequenced kits and other component supplies to the assembly line
- Error proofing on the assembly line
- Work instructions display at stations

This was the most extensive application of MES functionalities undertaken by the company to date. A very high level of issues and failure modes were experienced during and after the implementation through launch and even beyond production ramp up, with a lot of workarounds and temporary fixes having to be put in place.

Performance metrics reporting and analytics

It was envisaged that with MES in place, an automated reporting system would be developed for reporting and dashboarding plant metrics, along with analytics capabilities for quality and maintenance.

Further downstream, mobility (tablet-based) solutions for production supervisors, maintenance technicians, quality inspectors and materials delivery personnel were also planned.

Major issues faced

RFID application for part assembly tracking, all through the stock system, pre-assembly operations and assembly line, was a big challenge, particularly so in this case because of the sequence adherence requirement. RFID 'zoning' errors resulted in missed / wrong part tracking and inventory, causing downtime, line stops, wrong part assembly builds and ultimately shipping of part assemblies to the customer with inaccurate configurations or sequence. As a workaround, the tracking of part assemblies on the main assembly line had to fall back to barcode label scans.

System integration

The MES interfaced with multiple automated systems, including the stock system, AGV line, VSMs, error proofing and performance metrics reporting, among others. With a lot of complex functionality developed into MES, the system got bogged down very quickly, resulting in a significant lag in communication times. Critical real-time actions processing like part assembly scan confirmations, sequenced label printing, error proofing confirmations, sequenced orders communication to VSMs, presentation of work instructions onscreen to operators at station, experienced high processing times and missed transaction events. The result was a direct impact to online speed, quality and uptime. Issues including errors in sequencing, component supply, instructions and proofing caused operator cycle time overruns, incorrect part assembly configuration builds and line stops.

As a workaround, the MES functionality had to be de-contented — work instructions, non-critical error proofing, cycle time and downtime data, data collection for performance metrics reporting — were taken out and scheduled to be put back in at a later date after stabilizing the system to support core operations.

The more advanced digital solutions like mobility (tablet-based) solutions envisioned for different functions (quality, maintenance, production and logistics) were put on hold until the other must-have functionalities were fully realized.

Lessons learned

Clearly, in the above case study, the plant was trying to do too much too quickly with I4.0 technologies.

While the technologies themselves are sound and fairly mature, applying them correctly and in a phased manner is key to a smooth successful implementation. A better approach in this case would have been, once a technology (e.g., RFID) or system (e.g., MES) had been thoroughly evaluated and selected, to do a proof of concept (PoC) in a selected area first. A PoC implementation provides learnings, insights and pitfalls to avoid. Based on that information, the implementation can be scaled successfully, avoiding a lot of issues, work arounds and rework.

As evidenced in this case study, the underlying root cause for a significant number of issues was deficiencies in the network planning and design to support real time communication requirements for decision making in the manufacturing processes. Low latency, high availability and secure communications is a must for mission critical applications. Further, with rapidly increasing need to support mobility, wireless communications has come center stage. The evaluation and selection of these technologies (e.g., 5G, WiFi), as well as incorporating them upfront in the network strategy and design assumes paramount importance. This combined with capabilities to compute or process data for real time decision making and analytics (Edge computing) is the backbone for successful Industry 4.0 solutions implementation.

Another major learning was the approach to systems integration. There were several new systems (in which the company had no prior experience) that were introduced all at the same time — AGV, VSM, fully automated stock system with sequenced delivery — that had to be integrated and interfaced with MES and RFID tracking technologies. It was very quickly realized this integration effort presents multiple challenges on the technical front, and adequate time and technical resources were not budgeted in the project timeline to rectify these integration issues.

Additionally, no matter how well functional requirements specification (FRS) is done for a system (e.g., MES), there will be a number of new use cases / alternate process flow scenarios / failure modes that will come up while going into implementation in production operations. A good example in this case was the part assembly sequence handling. While MES was developed to handle this functional requirement as per the process flow designed by the engineering team, the process flow as implemented had several "exceptions" to accommodate requirements of operations — points in the flow that cause a break in the sequence, including new quality checkpoints where the part can be set out (and set back in later) and set outs at select locations due to material unavailability.

These kind of exception scenarios are inevitable and very often cannot be foreseen in the project planning phase. Also, while these can prima facie appear simple to accommodate, in reality these can get very complex quickly, due to the dependencies and interfaces with other functionalities and systems. A thorough Failure Mode and Effects Analysis (FMEA) would be required to be done before making changes in MES to avoid serious unintended consequences. For example, in this case, there was an instance where-in the process of making changes to MES to accommodate a new process flow, a failure mode was missed, causing a sequence mismatch on the assembly line, leading to wrong part assembly configuration builds. This resulted in both serious downtime to rectify the issue and significant rework effort to correct the wrongly built product. The takeaway here is to plan and budget adequate time and resources for these eventualities during the commissioning and implementation of critical systems (such as MES), especially when implementing complex functionalities with new technologies and interfaces to multiple systems.

Conclusion and recommendations

Smart manufacturing is not a destination. It is a journey leading to increasingly higher levels of maturity and benefits. This journey starts with a well-defined strategy that is built ground-up and not top-down.

Start with maturity assessments and capture the VOC results to gain a deep understanding of the current state, then identify opportunities for improvement that I4.0 technologies have to offer. With this understanding, develop the set of Initiatives that will deliver the most value in improving performance, as measured by the manufacturing organization's SPQCDM metrics.

Once the initiatives are defined, create a roadmap for implementation. Each of these initiatives can result in one singular project or a set of multiple projects that would need to be executed. The execution would be done by a project owner / owners or internal cross-functional team and external partner / supplier for the selected technologies, tasked with a project charter for delivery.

The cadence of these projects must be laid out with consideration of the criteria of complexity and timelines, resources availability, benefits with regard to budget, company's divisional and geographical business needs, and other considerations that impact business performance.

Once the roadmap is defined, it is very important to secure leadership's long-term commitment for execution. This is crucial because, as evidenced in the case study in this document, there will be some pitfalls, bottlenecks / issues that will come up during the execution of these projects resulting in delays in delivery, which will need unwavering support from management to resolve and take to successful completion.

There will always be lessons learned with each project and in manufacturing, "traditional" or "smart," it is always about continuous improvement (CI). As long as the spirit of CI is alive and well, companies undertaking the smart manufacturing journey on their very own defined path will definitely succeed.

About the author

Sairam Vedapudi is a manufacturing engineering and technology professional with 27 years of global industry and consulting experience. His expertise and career experiences are in industrial and manufacturing engineering projects, plant operations management, greenfield plants setup and launch, Industry 4.0 solutions consulting and advisory.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