TATA CONSULTANCY SERVICES

Building on belief

Embracing digital industrial - Realizing the worth through progressive adoption

Abstract

As organizations around the globe wake up to the need and rewards of operational transformation, digital industrial platforms have come into their own by harnessing the rules of physics and being governed by the principles of data analytics. In essence, these platforms allow organizations to build resilient, interoperable, and efficient working models that re-orient core functions to enhance visibility and mitigate outages. In turn, this reduces cost pressures and allows enterprises to remain in the reckoning in an increasingly competitive world.

In manufacturing functions and processes, resilient operational technologies (OT) can empower people to strive for excellence and propel them to improvise to achieve connected efficiencies in the 'PHYGITAL' ecosystem. This is enabled by feeding real-time and periodical information generated by the machines into information technology (IT) applications, which can then synchronize, visualize, derive, and predict the next course of optimized actions to be followed in human-machine interactions.

For technology to be truly transformative, it needs to be prudently aligned with the enterprise's business objectives. Only then can on-site workers visualize the machines in production plants, assess their running conditions, and interpret with the machines over the digital representation of machines.

In such instances, technology gathers production variables, and pressure and temperature conditions, and mixes them with diverse static data residing in the cloud or data centers. It also empowers the artificial intelligence-based programmable algorithms to be applied to these datasets to generate multiple advisories, alerts, and analytics for the operators.

That said, it is equally crucial for engineers, factory workers, and the operations and maintenance team to understand, adopt, and use these digital levers data-intensive applications. Said simply, the remedy to inefficiencies does not lie in embedding additional sensors. Rather, it rests on the enterprise's ability to harmonize the set of heterogeneous data.

Introduction

Inefficiencies in human-machine collaboration could be one of the greatest operational hurdles at manufacturing plants. Eliminating them is a multidimensional function of high data- and asset-intensive production steps. In most cases, the key hurdles primarily appear in three folds:

1. Incomplete set of production data emerging from the plant: This could be attributed to the lack of planned assessment, or the unavailability of digital sensors in a critical equipment resulting in accumulated production data being unused.
2. Operational constraints imposed by traditional boundaries and disjointed applications: Not only does this result in disparities in the use of data from different sources and systems but it also prevents the syndication of data for analytics models to work comprehensively.
3. Gap in using the technology as per SOP: Lack of human-machine collaboration and only minor interpretation with available data is a proof for the under-utilization of digital industrial technologies.

Overcoming these limitations and eliminating inept work culture demands thoughtful, progressive adoption of digital industrial principles aimed at achieving defined objectives. The overall rationale behind this business investment can be realized as in the manner defined below:

- Economization of manpower, resources, supplies, and distribution.
- Sustainability to remove constraints and ensure progressive scale-up.
- Limiting outages and wastage through accuracy and programmatic visualization to prevent loss.
- Distant production monitoring and utilization of equipment and installed assets at an optimal level, and leverage predictive algorithm to simplify maintenance overhead and improve productivity.
- Decisions driven by data for a comprehensive dataset and analytics view.

Following due process in practice is of paramount importance to retain excellence while accelerating productivity and controlling costs. This means adhering to certain proven adoption steps designed specifically for this purpose, and defining next-level objectives in relation to the anticipated hurdles along the way. It is, therefore, imperative to assess the possibilities of data extraction from different sources, and review how they can be coupled with technology to achieve the intended results.

For instance, digital sensors embedded in the factory can stream the time-series data continuously, as can the other historian and supervisory control and data acquisition (SCADA) systems. These bulk sets can be lodged in the cloud space for processing. For results to show, however, they must be blended with multiple other data – demand forecast, supply of ingredients, research and laboratory information, inventory level and influencing factors such as weather, manpower, utility supplies, and so on. Only such comprehensive data structures can provide a holistic landscape and suggest the optimal way forward.

The philosophy to set up the connected industrial ecosystem works best when digital industrial-driven boosts are deployed with careful consideration – such as the internet of things, cloud, and other core applications working in harmony. Experiments and innovation have been running at pace to unify the different corners of the process in efficient and resilient ways.

Roping the 'THINGS' with technology to realize the results

While embracing the digital industrial into the organizational ecosystem, there are certain proven adoption steps that can propel productivity with the philosophy of the connected industrial landscape, based on the successful convergence between digital and physical systems. Creating a representation of every machine and process involved in the production cycle can offer visibility across all levels of the plant. But it is more important to mine the sourced data from the critical path of the production line, and derive insights and patterns using analytics and machine learning algorithms to predict the behavior of machines running and their outcomes. The core of such a system design revolves around embedding digital sensors and actuators on the equipment running in the production line, and exchanging the data with these devices over a standard industrial protocol such as Open Platform Communications United Architecture (OPC-UA). It is essential for this to be bidirectional, which enables re-calibration of the operating parameters from the generated setpoints using a digital twin simulation at the IT application system.

The tabular representation below (Table 1) assists in understanding the interconnected layers and their sub-components:

Data Source Layer	
Specialized SystemS	HVAC, Escalators, Elevators, Security Surveillance, Security Alarms, Access Control
Bolt-On Sensors	Energy/Water Management Sensors, Smoke Sensors, Lighting, Flood Detection , Power On/Off, temperature Sensor, Motion/Intruder/ Occupation Detection, Fuel/Ground Water Level Detectors
Installed Asset Base	Generators, Condensers, Transformers, AHU, Bulk Fuel Tanks,Power/Water Reticulation, Transmitters
Site / Field Equipment	Chillers, Fuel/Water Line Monitors, Fans, Water Tanks/ Hydrants, Fuel Pumps, Distribution Boards, Charging systems, AQ Monitors, UPS/Battery Systems

Edge Layer
Supervisory Control Station – SCADA , HMI
Gateway Devices(like Smart Edge Industrial IoT Gateway, powered by Raspberry Pi, Dell Edge Gateway, Cisco 900 series, HPE Edgeline etc.)
OPC-UA OPC Publisher
Protocol Translator
Data Validator Data Processor Data Formatter Data Exporter Stream Analytics Service – Edge Level

IoT Platform Layer
Foundational IoT Services – Device Registration, Authentication & Data security
Data Management Services, Time-Series Data Storage
Data Ingestion, Command & Control, Data Processing Services
Data Analytics Services – Stream Processing & Predictive Analytics
Gateway Services

Application Service Layer
Data Repositories inside platform (Data Lake Service, Sensor Data Management Service, Asset Service, Rule based Action Service)
Dashboard & Visualization
Digital Twin of the Asset, Processes
Workflow Automation and Integration with Enterprise Application (ERP, CRM)
AI/ML based Cognitive Functions

Table 1: Interconnected layers in OT- IT convergence

Connected operations

The founding principle behind connected operations resides in the completeness of the data coming from the operational technology systems and different IT applications. Until organizations reach data uniformity, harmony between the shop floor and top floor cannot be established. The idea of working under the umbrella of a smart factory is meaningful only when industrial assets are connected, their health parameters and production rates are monitored from the command center, and equilibrium is maintained on demand and supply operations. Only then can the overall factory operations be orchestrated in a guided manner.

The operational framework of a connected factory envisages an outcome synchronized through the adoption of connected industrial assets (plant site and remote installed base), development of a predictive model for generating actionable insights (set-points), an integrated command center dashboard for condition monitoring, and a connected workforce and facility management. The diagram below (Figure 1) is a dissection of connected operations running across the multiple units of the digital factory:

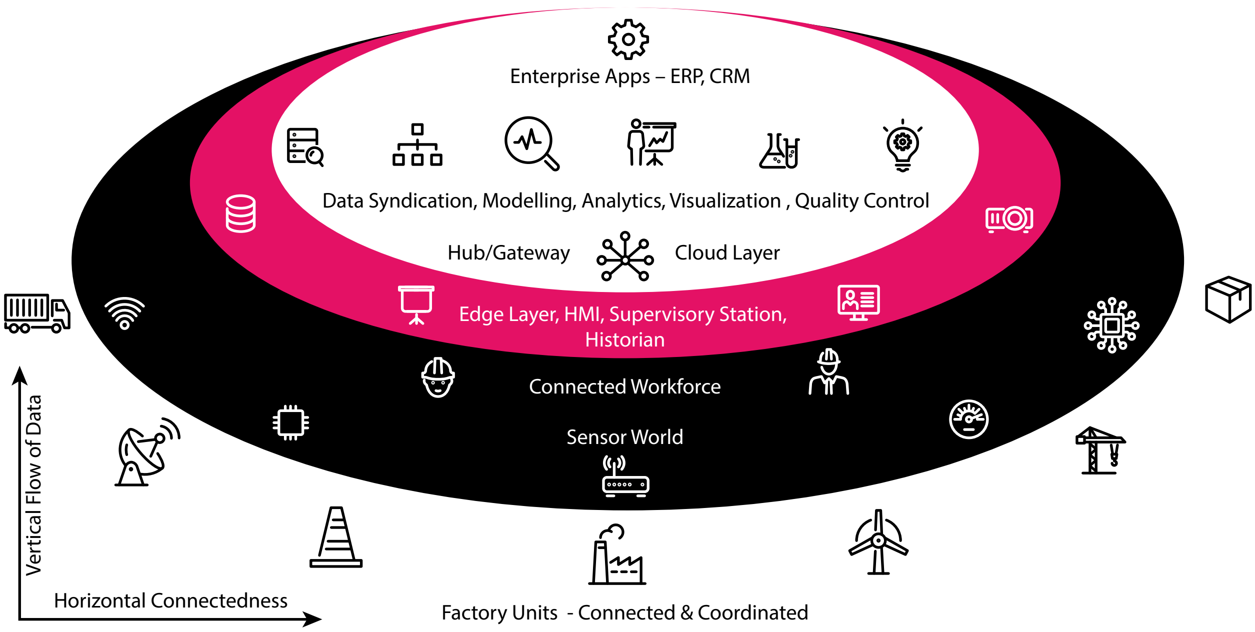

Figure 1: Connected factory landscape

Connected industrial assets

Over time, organizations made significant investments to digitally connect industrial assets and machines via embedded sensors and actuators. The aim was to enhance performance and improve production. Work has been done to make machines OPC-compliant to secure the exchange of the factory core data. Simultaneously, aligning purpose with the data being captured gained significance. The common form of the challenges across the industry segment are:

- Prone to breakdown, reoccurrence of irregularities and errors – unplanned outage.
- Reduction in efficiency as cycle counts rise.
- Practicing time-based maintenance while overlooking health alerts.
- Maintenance cost, uncertainty of availability of spare parts.

The challenges make it clear that while connecting the assets is important, identifying critical assets and data patterns generated by them is even more so. These contribute greatly in the simulation steps through the digital-twin-based arrangement. In a data-intensive factory landscape, it is crucial to apply advanced data science techniques for creating prediction models and clustering. Different prediction models must be used to map the process data to the appropriate band of golden efficiency, to be targeted on a real-time basis. Actionable insights are a fusion of contextual knowledge and the algorithm’s output. The critical success factors depend on the extent of usage and exploration of these techniques by plant operators with adequate knowledge and prudence. Here are the sets of prime consideration to realize the return from investment:

- Stay contextual by design to stay sustainable and aligned to the business aspiration.
- Tune process and model periodically to maintain the accuracy of prediction.
- Leverage programmatic business rules to generate alerts, health check indicators, and advisories to be acted upon.
- Revisit SOPs to align adoption and standardize factory processes.
- Oversee utilization level of manufacturing intelligence, data analytics, and visualization of different operations.
- Check the influence of physical–digital convergence in business KPIs such as TEEP, MTTR, MTBF, etc.

Command center for remote surveillance

Most organizations visualize industrial IoT systems as resilient, purpose-driven, and result-oriented. However, the fundamental concept of 'shop floor to top floor' must be reinforced with a thorough assessment of THINGS in place. Only after that can enterprises bring intelligence into the technologies to make them self-adaptive, scalable, and flexible with the capability to create exponential value.

One such example is the unified command center to monitor the condition of the machines and critical health parameters of machines running in production and remote installed base. The command center sends signals to optimize operational attributes and keep the production curve in an ideal trajectory. Poor visibility of asset-health and attenuated performance will have a negative impact on customer satisfaction while increasing costs. There are quite a few examples where manufacturing organizations adopted the centralized monitoring system to track the installed base performance and factory production performance across geographies.

The benefits of such a solution can only be realized through the meticulous implementation of a remote surveillance system. Below are some example cases for the manufacturing industry:

- Factory live feed: Site details, active machines, running batch jobs statistics, operations in active state, cycles run count, uptime, and downtime.
- Equipment view: Asset details (device ID, device type/subtype, make/model, operating status, pressure and temperature, vibration, job axes movement, alerts and hazardous spikes, maintenance schedule, and spare parts involved (Part #, SKU).
- Detect anomalies from the time series data and generate programmable advisory alerts to avoid critical issues, calling for tuning the analytical model.
- Controlling and monitoring the workflow-driven digitalized steps to facilitate operators for guided operation and troubleshooting.

Integrated workforce and facility management

The overarching objective of the digital industrial is to improve workforce productivity through digitalized means and deploy adequate measures on health and safety through technology levers. The areas truly enhanced by this technology deployment are listed below:

- Coordinated way of working through collaborative effort over the centralized connected system and digitally implemented interpretation with factory assets.
- Guided operations through the application of AR/VR/MR/XR- (Augmented Reality, Virtual Reality, Mixed Reality and Extended Reality) based techniques for quick execution and error-free manipulation of production lines.

- Wearable devices such as bands, helmets, and jackets equipped with sensors (proximity detection, elevation measurement, temperature, pressure, rotating speed of the machines, fire, etc.) to alert workers and turn off digital circuit to prevent possible accidents.
- Gamified training through realistic simulation, virtual assistance, and workshops.
- Live status tracking of different hardware through PLCs, HMIs, I/O controllers, routers, and servers running in the facility, and remote sites.

Predictive algorithm to schedule maintenance

Organizations, in several ways, are now poised to realize the investments they made to establish a digital version of factory operations, and monetize data collected from sensors embedded in the assets.

The global market size for predictive maintenance is expected to grow from $4 billion in 2020 to $12.3 billion by 2025. This is fueled by the adoption of emerging technology that will substantially lower the overhead of maintenance costs and unplanned outages. Bolstering this trend is a dynamic business environment that demands skilled operators on the floor, which has made technology-driven decisions the highest priority for enterprises.

A host of research and assessments have been carried out to identify anomalies in data and generate early prediction models to avoid downtime. The good news is that they have not been limited only to predictions of mechanical or electrical faults, but diagnostic and prescriptive ones as well. This allows for advisory services with remedial details – be it cable or bearings or piping or other parts responsible for the fault. Depending on the pattern of the collected data, the AI/ML-based logic derives preconfigured rules that trigger the next set of action points. This is made possible because most, if not all, equipment run in a harmonic fashion, and the inputs from multiple sensors are critically examined by the predictive logic in place.

In this regard, there are primarily three kinds of data – (1) Those generated by sensors, (2) Machine log data, and (3) Process parameters. Intelligent data processing logics digest these streaming data, map them with the help of predefined conditions according to the pattern, and generate analytical results and alert notifications.

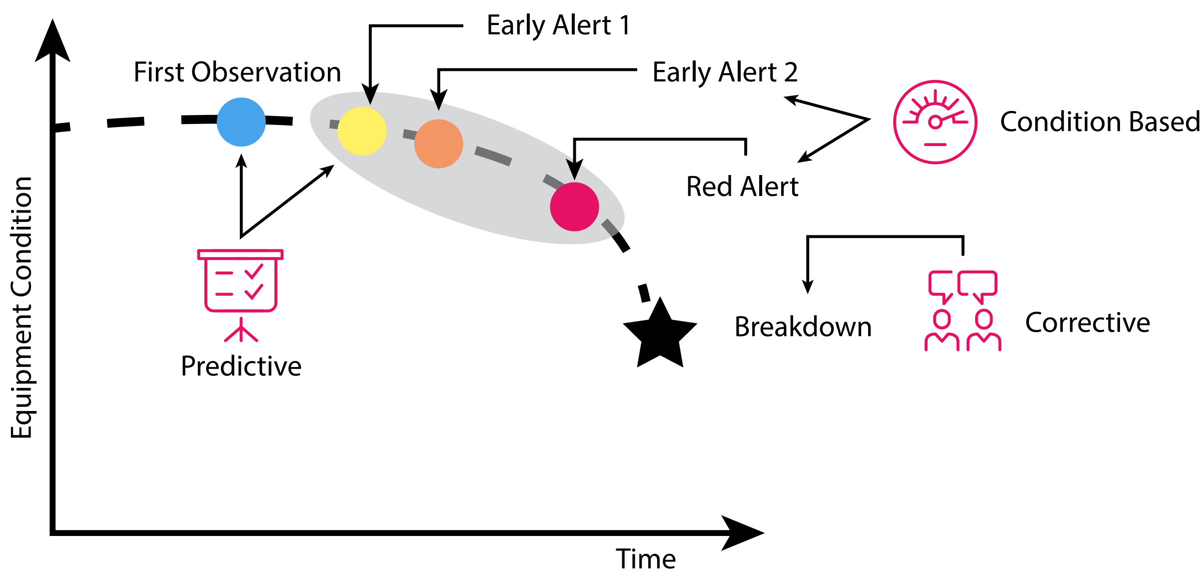

Figure 2: Predictive Vs. Condition-based Vs. Corrective maintenance alert

For asset-intensive organizations, it is crucial to plan use cases on select assets that are critical to the production cycle. An initial assessment helps define the vital attributes and process parameters to be fed into the predictive algorithm (Figure 2). It is worth noting that the range of the input parameters can vary from 50 to 500 or even more, depending on the complexity of the job a piece of equipment performs. Results from the pilot deployment must be analyzed in-depth, measuring the financial benefits from the machine's insights so that accurate suggestions can be made to scale up and accommodate additional assets in a phased manner.

Smart manufacturing

Being cost-intensive increases the criticality of deciding to invest in smart factory automation. Most organizations, unsurprisingly, prefer leveraging existing hardware. This is where progressive adoption kicks in, assisting enterprises in attaining automation and digitalization in a phased manner, thereby enabling smart manufacturing.

This means choosing one production plant to deploy, upgrade, and realize the expectation initially, and then following the same methodology for other plants across geographies. This entails making a digital replica of machines and processes running in the live production line and using it to maneuver, control, automate, and scale up the physical production strength. The minimal initiative is to ingest the AI/ML-based cognitive service into industrial robots to humanize automation by the principle of run as per sense and experience.

The digital twins of production must be envisaged to empower users (controllers, operators, designers, and plant engineers) to interact with production machines in an informed and intelligent manner (Figure 3). The role of wireless network connectivity is critical here to support the integrated plant operations and enhance the effectiveness of the human-machine interface.

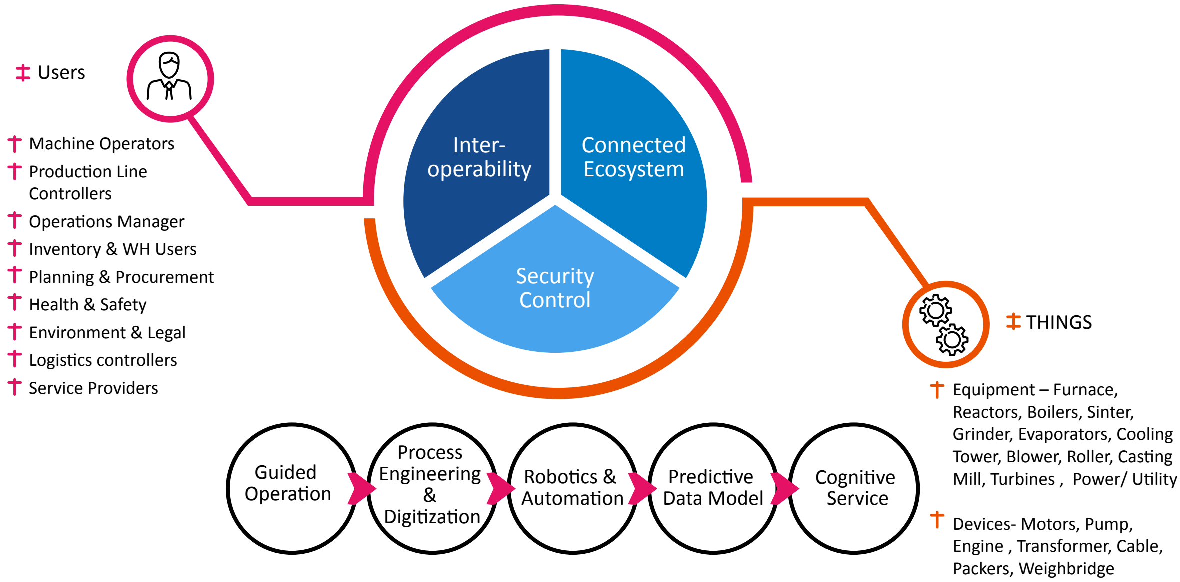

Figure 3: Smart factory - The harmonization in a production plant

Smart product

Being and staying connected is the bedrock of today's world. In fact, white goods or medical device manufacturers have already incorporated sensors and microcontrollers in their devices to communicate with them even at customers' premises. Building a domestic ecosystem with all devices, transactions, health care, and security measures that can be controlled with a single application running on a mobile device is no longer in the realm of fiction. Appliances such as washing machines, refrigerators, air conditioners, and TVs are already connected and linked.

Medical devices such as sphygmomanometers (BP measurement), glucometer, home gym apparatus, etc, are similarly connected. One can even plan to link their vehicle to an application, and even link banking, insurance, and other shopping channels. However, this is just one side of the story. The other side is enabling the OEM to see the performance of these devices and using the generated data to run models to predict maintenance needs or identify other troubleshooting measures. Sensors and other controllers embedded in these smart devices will gradually be cheaper, more advanced, and more widely available. With high-speed computing capabilities, internet, and 4G mobile (5G in the near future) connectivity, the age of smart, connected assets will go truly mainstream. 'Care-as-a-Service' is beginning to emerge as a business for many manufacturers in the consumer products segment, engineering, agro-mechanical, or health care product business.

The day is not far when chemical-sensor-based research will illustrate how our internal body transmits signals to communicate health anomalies – taking us one step further than the connected wearable devices.

Conclusion

While embracing the digital industrial philosophy in the factory ecosystem, it is equally critical to retrofit conventional machinery for the digital landscape. The is where progressive adoption over a period allows enterprises to realize benefits even from a brownfield landscape. The co-existence of legacy/outdated systems and new sets of IoT/digital technologies is common to most of the organizations in the manufacturing, pharma, metals, or oil & gas sectors.

It is true that operational and technological makeovers cannot happen overnight. So, it is more important to work out the right sustainability framework that enforces an equilibrium between the old and new technologies. This journey might start with just one unit within a plant where experiments are undertaken with sensor-fed data to derive insights and analytics, tuning process parameters and realizing the yield. Thereafter, the next set of connected assets can be encompassed to initiate progressive adoption and onboarding additional machine data into algorithms and tuning capabilities.

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Koushik Chakrabarti is a Solution Architect – Presales and Solution at TCS for manufacturing clientele in India. He has around 20 years of experience in IT Industry and has worked across various areas such as customer relationship management, digital experience, manufacturing operations management, industrial IoT platform, and smart factory solution. He has worked with multiple international and domestic clients across domains such as life sciences and health care, banking, manufacturing (discrete and process), retail and telecom. With domain contextual knowledge, Koushik worked intensively with customers to address the ground level business problems that resulted in customer delight.

Koushik is a B. Tech (Computer Science & Engineering) from Kalyani University, West Bengal, with first- class distinction. He also has multiple certifications from IBM, Adobe, Oracle-Siebel, and AWS. He is also an active article writer and keeps publishing articles on LinkedIn and blogs on the latest technologies such as automation and cognitive robotics.

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