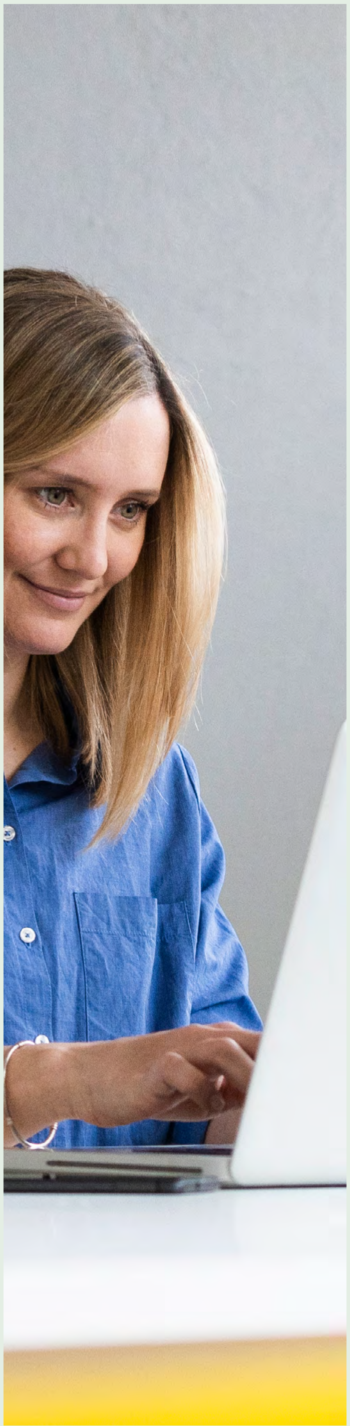
WHITE PAPER



NAVIGATING TO SMARTER, LEANER & AGILE MANUFACTURING WITH SUSTAINABILITY

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PREFACE

The manufacturing industry is under pressure to increase its top line and bottom line to stay competitive. As a result, manufacturers are exploring different avenues to help them.

Businesses are optimistic about their prospects and aim to deliver the best with the rapid adoption of Industry 4.0 and cutting-edge technologies across engineering, design, sales, production and operations. There has been a shift towards a deeper analysis of manufacturing data to drive d data-driven decisions on the production floor more precisely. In addition, there has been an urgent call for green and sustainable manufacturing practices as manufacturers aspire to be a carbon-neutral society.

This industry must deliver more from less. It must extract the maximum from existing assets and make its brownfield plants more productive and efficient. Sharing information between the production floor and business systems can help industries build a connected enterprise and realize operational efficiencies through seamless data interfaces between systems vertically and horizontally. Furthermore, it helps identify process bottlenecks, production inefficiencies, quality issues and organizational resource skill and talent issues. Addressing this enables delivery more from less and is a step closer to reducing carbon footprint.

Manufacturing process data correlates with machine data to generate critical information, models and statistics by Data Scientists—the processed data in real-time helps address the inefficiencies before causing production losses. In addition, the information provides a holistic view of all the process flow on the manufacturing floor; be it labor, machine, process, material or otherwise.

As we aim to shape and simplify the manufacturing process and operations with a human centric approach, this paper series touches upon the critical aspects of the Manufacturing Execution System (MES) and lays out a detailed view on the evolution of MES and its impact in Smart Manufacturing.

The current paper (the first of the series) focuses on the evolution and regeneration of MES driven by customer needs and challenges that have shaped the adoption across industries. In this journey, while we unravel the challenges faced in navigating to a Digital Manufacturing Execution, we also discuss democratizing the use of MES-MOM applications– irrespective of size, category, business line and geography.

Intended Audience

The paper series aims to provide a view of the usage and ratification of MES-MOM for roles in the services industry that are focused on clients across manufacturing segments and anyone new to the Industrial IoT space and eager to quickly understand the scope, benefits and challenges specific to MES. It also helps enterprises calibrate their expectations when considering MES as a critical part of their IT ecosystem.

Head of Manufacturing, Enterprise

Provides an overview of utilizing MES and associated tools and products that offer deep insights into the process and help to improve major KPIs set at various hierarchical levels. Overall, the paper will help them to understand the criticality of an MES platform and how it can drive actionable insights to improve the manufacturing processes

Site Manager / Site IT

Deprived of the right tools that can help smartly capture the manufacturing processes and operations to trace the entire lifecycle of an end-product, site managers struggle to understand the process effectiveness without data in a synchronized and seamless manner. The paper shall guide and enable them to leverage MES effectively for paperless and automated manufacturing setups.

Leadership, System Integrators

This paper guides on the impact that MES driven Digital Manufacturing can deliver. The generation shift from being just an MES data collection application to a more comprehensive and holistic product covering QMS, MPS, and MOM alongside MES shall enable leaders to make an informed decision on their investments and choose the suitable MES packages and products.

Consultants, System Integrators

This paper is a perfect guide and learning artifact to understand the concepts and offerings of an MES application, its usability and its integration with peripherals and OT systems. It can provide a jump start for all who wish to learn and grow in the MES application development domain.

HOW HAS MES EVOLUTION COMPLEMENTED INDUSTRIAL TRANSFORMATION?

Evolution of MES

MES aka 'Manufacturing Execution System' has become the backbone of any manufacturing ecosystem. Execution processes at the manufacturing plant are of highest importance and require close control to ensure quality, cost efficiency, right delivery and hence business growth. While the enterprise planning and logistics processes are typically managed through an 'ERP' system, the execution control and reporting processes are managed through MES.

An MES is modeled on the ISA-95 standard and is designed to bridge the communication between the plant floor and management at executive levels. The MES Wheel reflects the key modules and goals of a MES application. It gives a glimpse of functionalities that are integral to the production execution process and are recorded at various stages of the process. Irrespective of the make and nature of the industry (such as discrete, processing and batch process), the core concepts and coverage of a MES application remain the same whereas there are different ways and mechanism to perform the execution, differing at the product level itself. The constituents of this wheel are set to expand as we innovate call the pillars of the floor – man, material, machine, methods …

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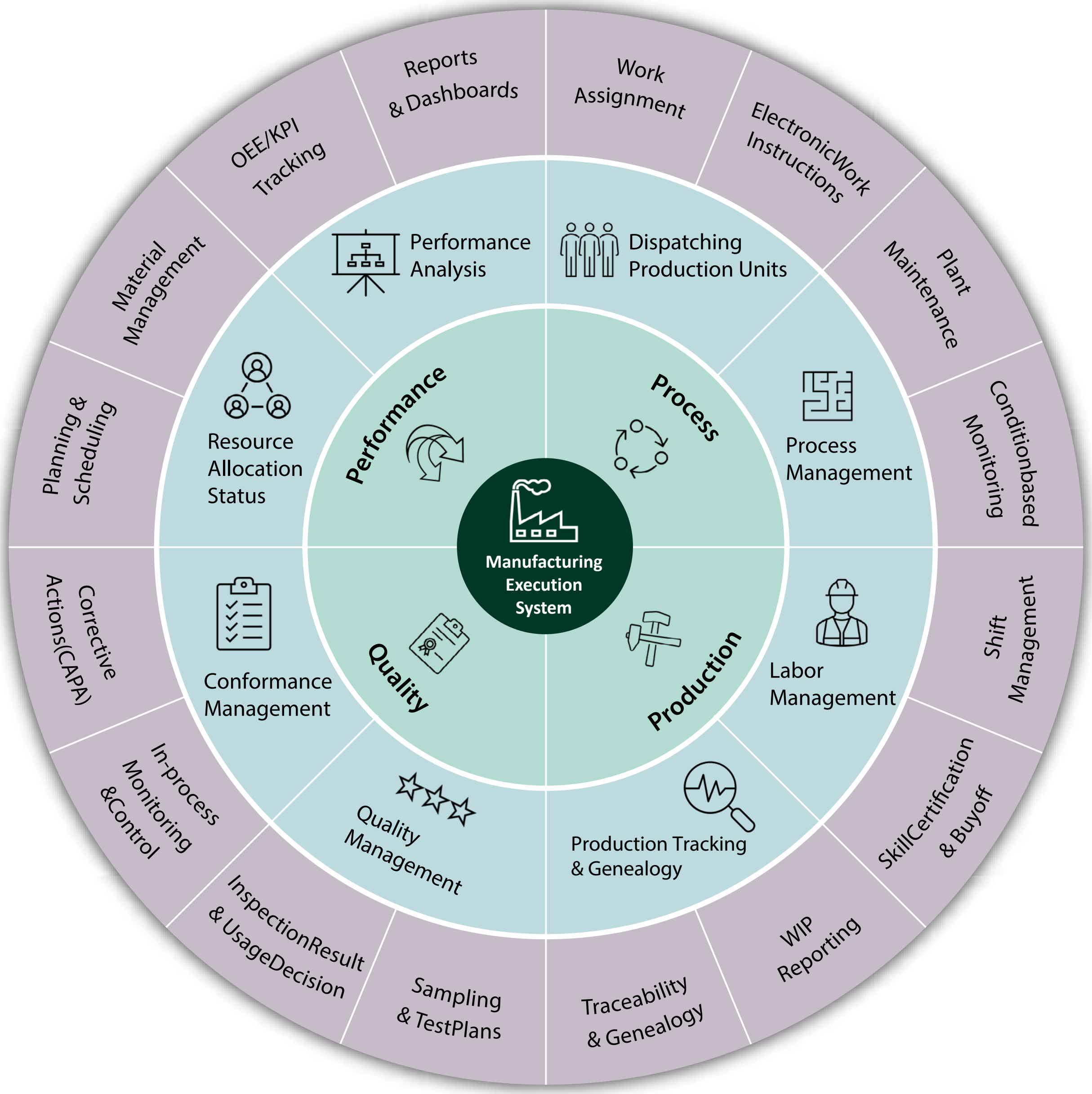

Figure 1: The MES Wheel

With Industry 4.0 (I4.0) modeled around cyber-physical systems, IoT, networks and data exchanges between humans and machines, the MES 4.0 complements the I4.0 journey. MES helps plant personnel with flexible production planning, factory-wide real-time information on actual vs. target production, cell/assembly/plant level information and material tracking. It also provides insights and tools for continuous performance optimization. With IT-OT integration, MES 4.0 utilizes machine learning, artificial intelligence and big data to track all operations in real-time along the entire process chain and facilitate dynamic production. Advanced analytics provides actionable insights to help improve productivity and performance while making manufacturing more digital, smart, clean and sustainable.

While ISA has defined standards for manufacturing, the technology stack is not standardized. While standards and data models are defined, these are not widely adopted by the industry or product vendors. Instead, enterprises are adopting standards customized to their process and technology maturity. Standardization combines processes, procedures and visual work instructions that allow operators to perform tasks with more precision and quick turnaround time. While it brings better clarity and predictability, it also gives rise to consistent quality, better flexibility, reduced wastage, easier compliance and knowledge retention. Studies and analysis have suggested that best-in-class and large-scale manufacturing enterprises continuously invest in bringing in standardization and drive continuous improvement in a closed loop process. The table below captures the impact of standardization.

Standardization	Best-in-Class	Average	Laggards
Standardize processes across the enterprise for **optimizing operations**	67%	42%	35%
Standardize **measurement of KPIs** across enterprise	72%	58%	51%
Standardize processes for response to **adverse events**	64%	51%	19%

Figure 2: Standardization of Manufacturing Processes and Operations across the Ecosystem

While process, workflow, and KPIs have been standardized, standardizing the technology stack, including MES, continues to be challenging. Additionally, as brownfield plants have a mix of legacy and new technologies and disparate machine vendors across the plants, it isn't easy to define a template.

Based on various market studies, the following key business drivers determine the adoption of MES - MOM applications across multiple industries, including manufacturing.

Industry 4.0 transformation towards digital manufacturing should fix manufacturing agility, manage site differences and complexities, and digitize production operations while simultaneously standardizing MES deployment and implementation. The following graph provides a preview of the key business drivers for implementing MES -

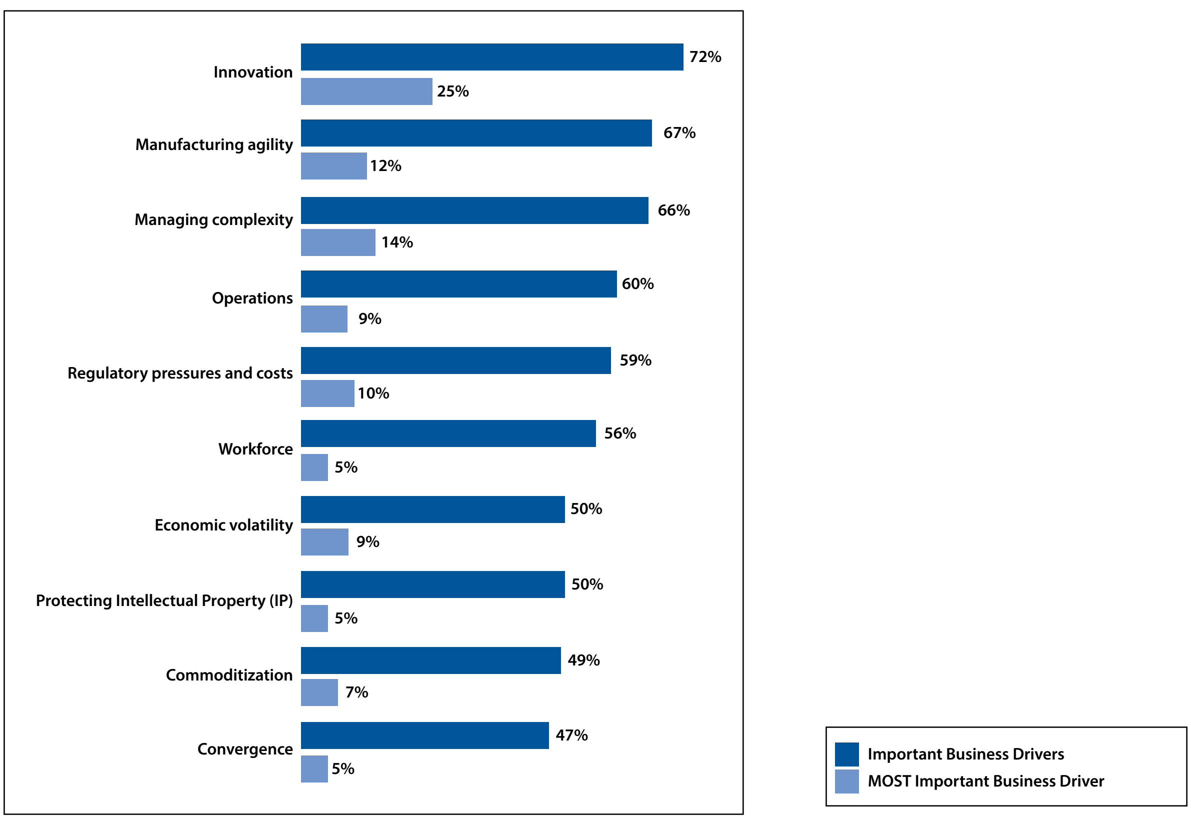

Figure 3: Key Business Drivers for Adoption of MES Application in Manufacturing [4]

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Industry 4.0 transformation cannot be delivered without digitizing the entire manufacturing process. MES helps digitize production scheduling, execution, tracking and performance analysis. The tangible outcomes from MES deployments motivate manufacturers to roll out MES across their operations and plants. However, this has not happened because of multiple shortcomings on both the demand and supply side. On the demand side, this is owing to the nature of manufacturing setups, the wide diversity in production processes and the technology maturity.

Research, analysis and discussions with manufacturers point out that various factors and challenges influence the adoption of MES into the production ecosystem. The key challenges that hamper coherent usage of MES applications include the following: -

- **Integration**
- **Lack of a holistic integration framework for OT systems** – While ISA-95 existed for a long time, there were no prescriptive standards for the application stack. E.g., MES interfacing with OT systems and real-time data gathering has been a challenge.
- **Integration challenges with ERP and PLM systems** – Integration with ERP and PLM systems is the core requirement for any MES solution, as ERP becomes the single system of truth. The integration with ERP, PLM, Quality, EAM, and many others means customization for each manufacturing enterprise due to the lack of interface, data model and use case standardization.
- **Adoption**
- **Lack of alignment between Process, People and Product (3Ps)** –Typically, most MES platforms have fared well on these aspects individually but have failed to promote and drive an alignment between them.
- **Cultural influences and factory adoption** – Since MES is set to impact the factory floor and the size of the impact depends on the maturity of systems and processes, process and cultural difference have been a global obstacle in site adoption.
- **Customizations & change management** – Though several well-established and industry-standard/specific MES products exist in the IT world, we need significant (>50%) customization to set up an MES application. Customization is a function of materials, machines, production lines and sites; hence, there is a huge challenge in managing and maintaining the application and effective change management.
- **Return on Investments**
- **Return on Investments** – As it requires significant upfront investments, most small to mid-segment enterprises don't derive any value in such an investment. So, they prefer to rely on paper-based processes.
- **Time to Market** – A MES deployment usually takes six to nine months at a site depending upon factors like customization, site coverage and process mapping. This long realization cycle deters investments. Due to high customization, the time to go live with MES is almost 6 to 9 months. Standalone MES does not provide the ROI. MES must be integrated with machines, ERP and other planning systems to make an impact.
- **Cost of Ownership** – The price of product licenses, annual support, product upgrades, infrastructure, CAPEX for application setup and OPEX cost for application maintenance around an MES package is still high. Businesses are, therefore, reluctant to set up and operate an MES system. There is also an effort to support MES continuously to address the process, infrastructure, application and product KPI/metrics changes.

An important aspect where MES adoption has lagged is the strategy and evaluation of the application potential. A primary reason in most cases has been the failure to identify the proper business case and relevant KPIs. Being a user-engaged application, early benchmarking allows users to validate the real benefits and RoIs. Fragmented rollouts without much visibility result in a misguided rollout.

Proper pre-implementation assessments to enable the larger landscape to work seamlessly and the associated change management have now been recognized as critical factors to make implementations successful, and end users invest in new MES solutions. The need for repeated custom developments also drives decision makers to continuously look at new technology as a replacement to existing systems instead of an add-on to the existing setups. With the advent of Covid and the recognition of some key challenges, we expect to see rapid adoption of MES applications in a unified manner across industries.

Across industries, MES has been the cornerstone for the industrial floor and its core concepts are harnessed across processes. However, the methodology, extent of usage and coverage may differ based on various dependent factors. Figure 4 shows the overall adoption of MES applications across different industrial sectors. While food and beverage and discrete industries rely on MES for production excellence, others have embraced it too. Due to obvious reasons, the auto and aerospace industry, which constitutes a large chunk of discrete manufacturing, has implemented MES focusing on traceability and quality improvement. The pharma and life sciences industry also has a strong rationale for improving MES adoption as regulatory compliance mandates detailed audit capabilities against all 4M components.

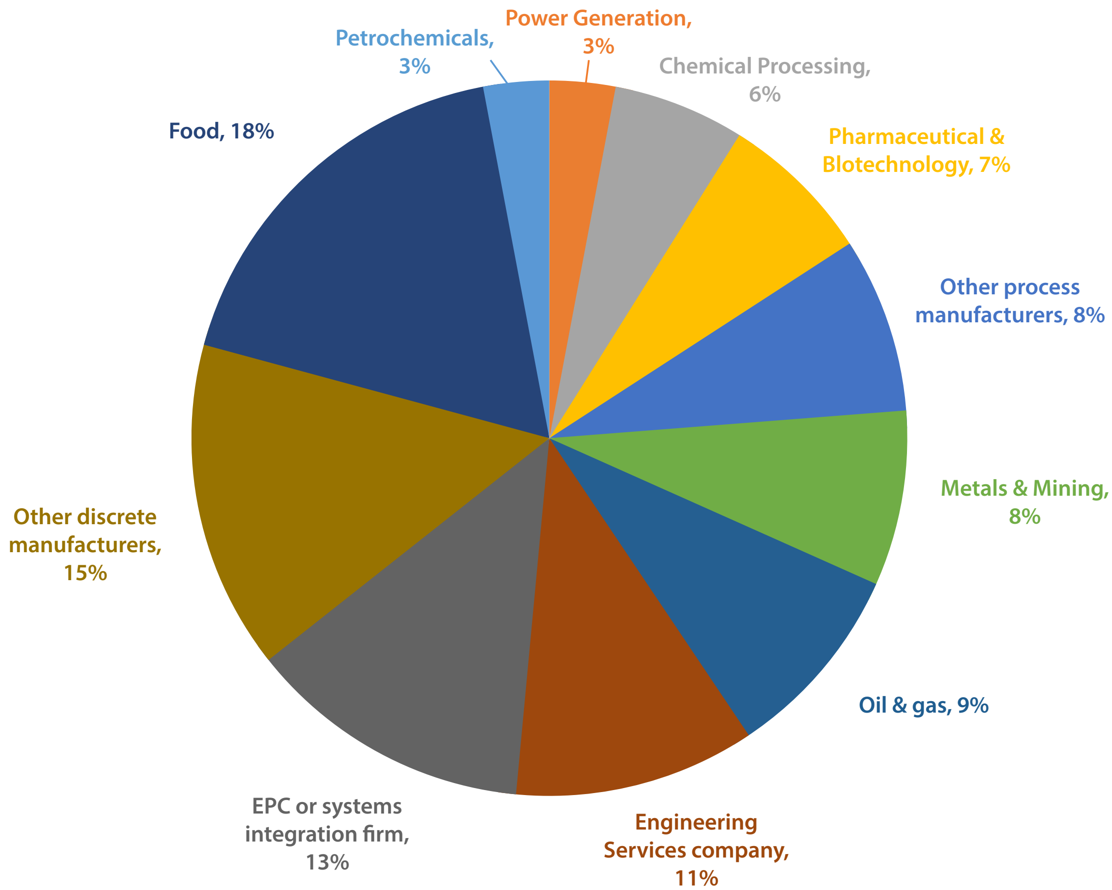

Figure 4: Adoption of MES by Industries[2]

Key drivers for MES adoption

Reporting, production management, and quality system ranked as the most used applications/solutions across industrial sectors (Figure 5). These existed even before MES and Industry 4.0. However, they were not digitized and not in real-time. This caused delayed information and intervention. With MES and digital manufacturing, production scheduling, execution, tracking, performance analysis, OEE and other KPI/Metrics are real-time, enabling production managers to intervene or even preempt events that can cause production stoppage.

Reporting in digital dashboards, KPIs, or other management or compliance reports is the most important function for most enterprises. Real-time, overall productivity, cycle times and yield improvements are key KPIs that can be generated from MES.

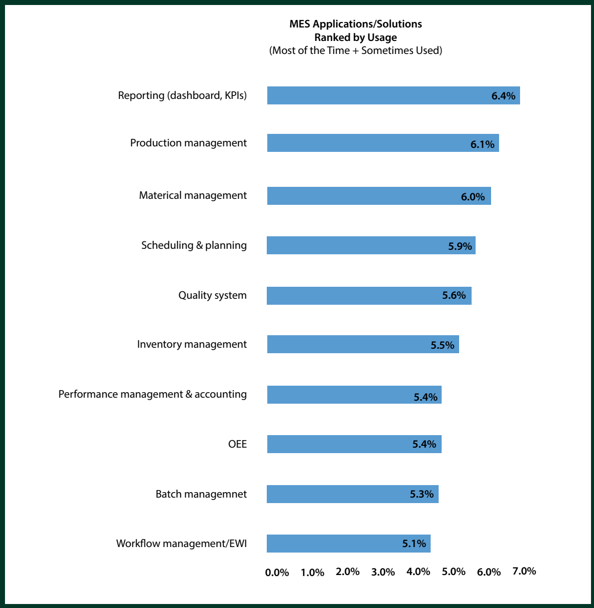

Figure 5: Usage of MES Solutions[2]

Integration of quality results is vital for any MES application. Integration with LIMS, automated batch and product quality, prioritization of inspection characteristics, and flexible inspection planning are essential aspects of digital quality assurance delivered through MES.

The MES Planning & Scheduling application assists the site manager in visualizing and optimizing production cycles. It shows scheduled downtime events, such as when maintenance or training occurs or when there is changeover time between products. Effective planning is an essential function of overall productivity and is vital for floor operations.

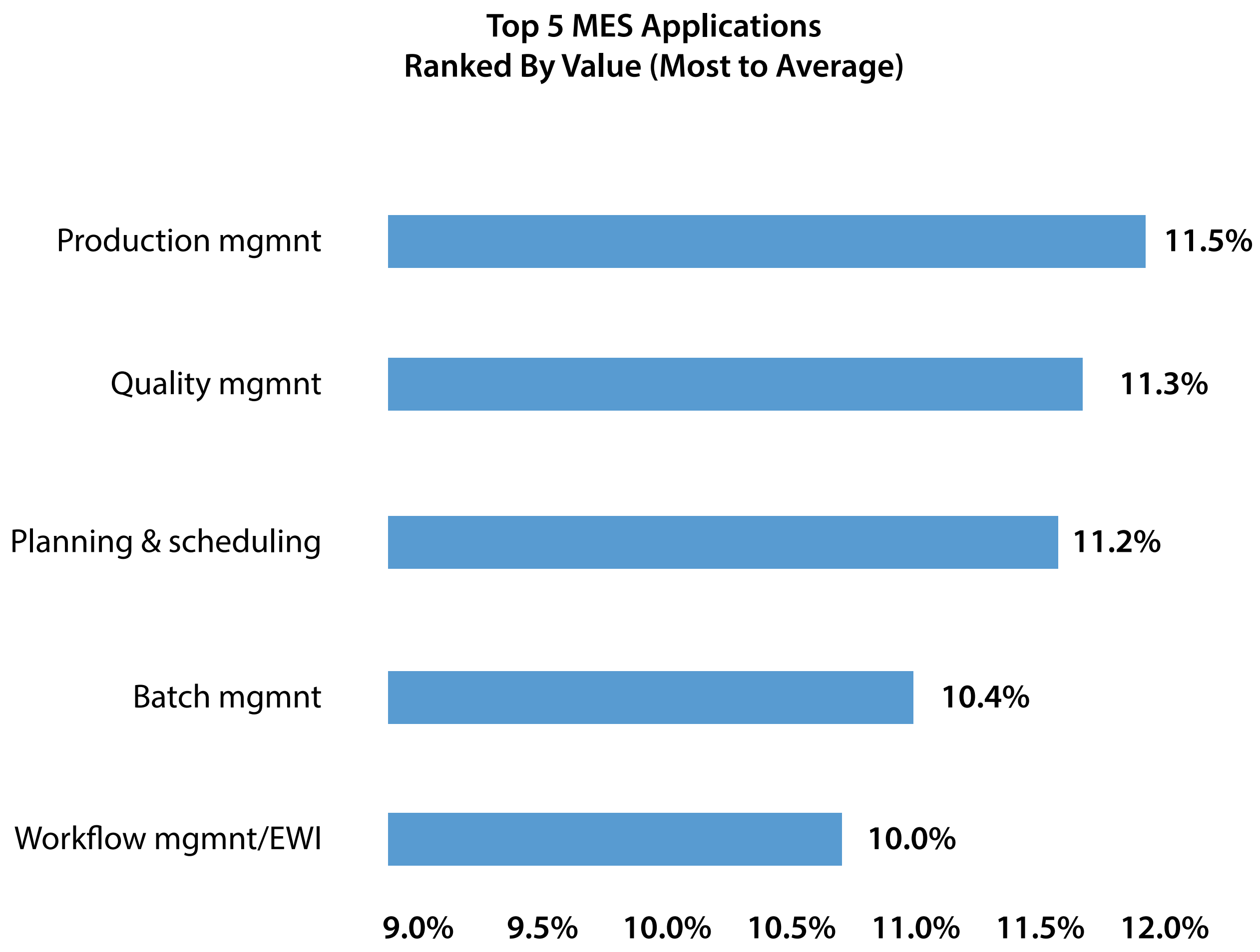

Figure 6: Top 5 MES Modules[2]

Thus far, only PLM and ERP were mature applications deployed in manufacturing enterprises. Most processes were manual or semi-automated within the factory shop floor. MES, LIMS, QMS, and other such applications were not deployed, and even if deployed, the ingested data was manually fed. We have analyzed the top reasons for the poor adoption of MES: -

1. Traditionally, the focus has been on the PLM and ERP system. MES is a data collection framework/bus to gather only information about ERP requirements (e.g., yield qty, scrap, and order confirmation details). Most small to mid-sized entities choose to build a Lite-MES version with basic functionalities rather than invest in a full-cycle MES implementation
2. With consumer demands for customizations (ETO manufacturing) driving new requirements for speed and agility, many manufacturers are struggling to keep up with the traditional setup of an MES system. As a result, the MES must be easily configurable and require less customization across the industry process types.
3. Typically, a lack of support from supervisors and plant leadership leads to a superficial MES deployment; the primary reason being losing manual control, technology skill, and trust in systems beyond control systems. Plant management must lead the adoption process. The system KPIs must be understood and appropriately acted on whenever a variance is identified.
4. Paralyzed Data Storeroom – With most of the production data being held in traditional historian applications and ERP holding the production execution entities (order confirmation and inventories), MES has become a duplicate data storage room. Though MES caters to the complete traceability of site processes and activities, the significance is barely understood by the plant-IT team
5. Lack of futuristic outlook – IT budgets have always been a constraint for small to mid-segment manufacturers. They have looked to manage their production processes through manual paperwork driven by instincts and experiential learning. Our analysis has established that over 60% of business entities lack a futuristic outlook and are primarily driven by workarounds.

MES on ISA-95 Framework

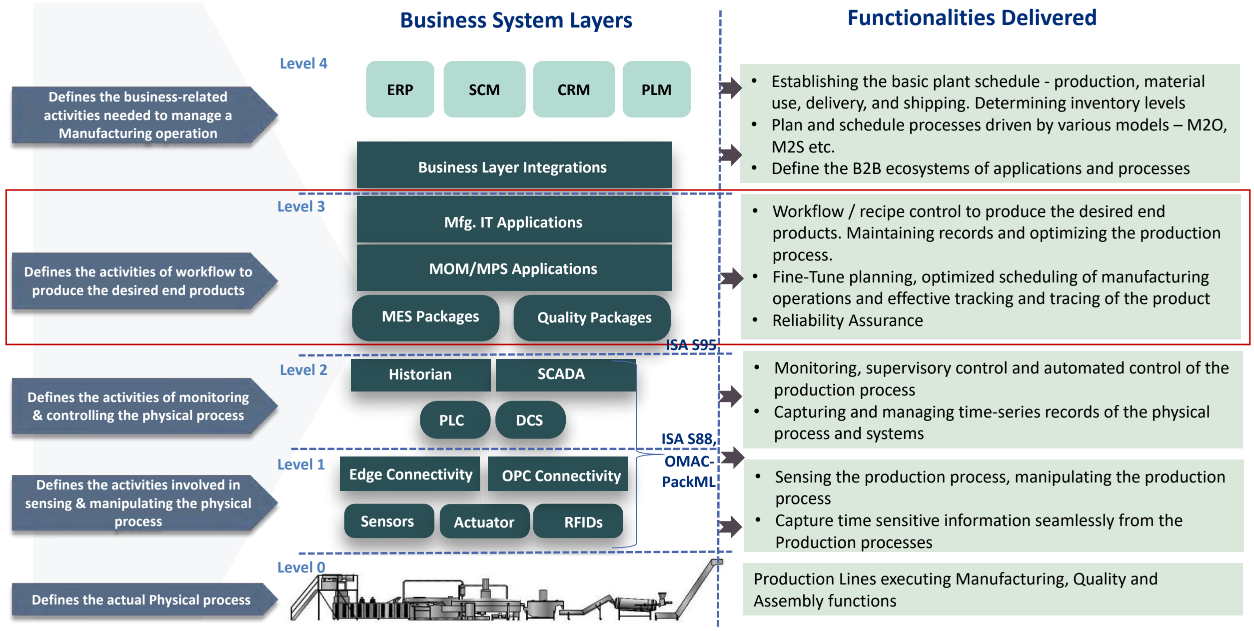

Figure 7: MES on ISA-95 Architecture

The ISA-95 framework depicts the position and role of various applications across the manufacturing technology stack and the business functions they deliver. Each layer provides specific functions related to the manufacturing process within the framework. For example, MES is one of the elements critical to IT-OT integration between business logistics to manufacturing systems. So, it facilitates a closed collaboration model between plant and business processes, effectively supervised and controlled through best practices and data.

ISA-95 Part 3 defines MOM as "activities, functions, and exchanges within level 3 of a manufacturing facility that coordinates the personnel, equipment, and material in manufacturing." It includes the critical components of production operations management, maintenance operations management, quality operations management and inventory operations management. MES-MOM, on Level 3, allows manufacturers to standardize and optimize processes across production execution, monitoring, change management, real-time reporting, optimizing schedules, and other such critical actual production process parameters, resulting in optimized asset utilization, minimized lead times, expedited time-to-market, agility in manufacturing processes, and increased production visibility and collaborative abilities.

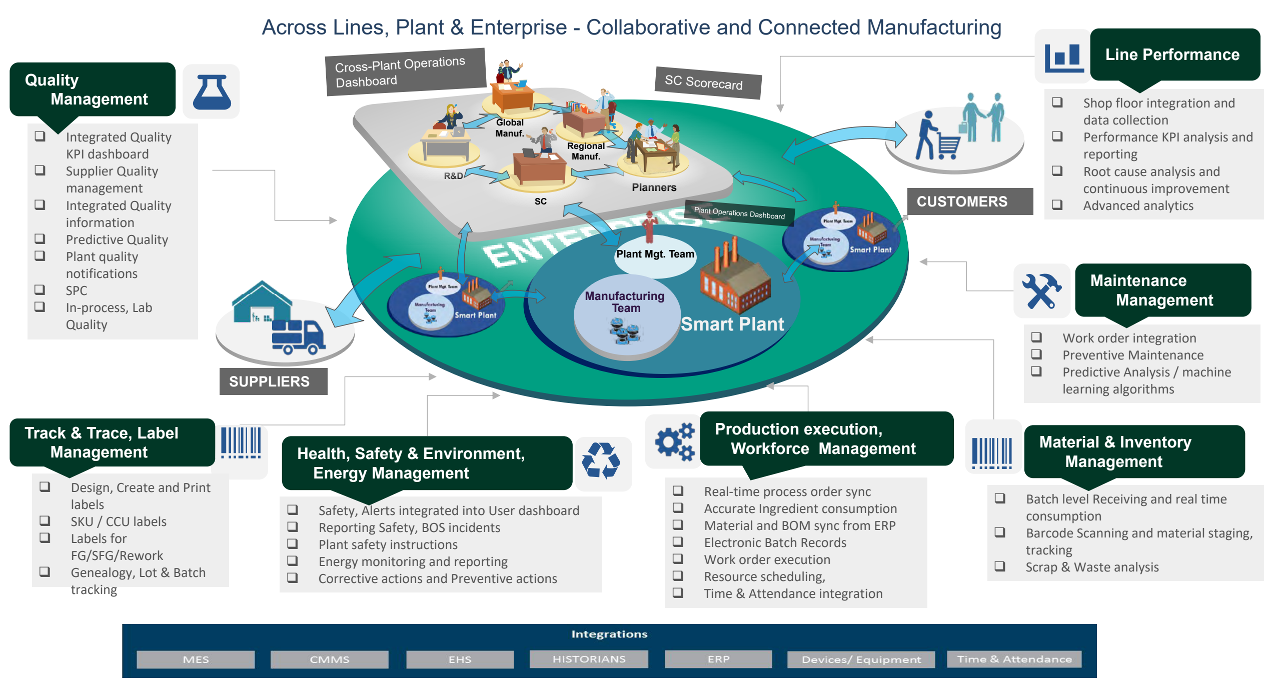

Figure 8: Leveraging MES / MOM for Collaborative & Connected Manufacturing

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As we look forward to the industrial transformation, the vertical and traditional ISA-95 model may stand the ground but not be sufficient. An essential milestone for the massive manufacturing transformation is a forward-looking view beyond IT-OT convergence (though it builds the platform), providing wider access to data and applications than a typical ISA-95 architecture with an ambition to embrace production excellence through intelligent operations management.

The industrial revolution and rise of MES…

Industry 3.0 focuses on bringing IT and electronics closer to the manufacturing floor and enabling vertical integration between various layers of ISA-95 architecture. Typically, using PLCs, SCADA, Historians and HMIs, revolutionized production automation and eliminated many manual and paper-based jobs. Eventually, it brought machines closer to the enterprise, enabling a better and more efficient decision-making process and improved planning accuracy at the enterprise level, thus serving the suppliers and customers more predictably and efficiently.

MES 3.0 complemented the rise of Industry 3.0 and effectively utilized the integration protocols and linear connectivity between systems and platforms. As a result, productions are better traced, and outcomes are tracked until customer delivery. Automation and computerization at the production level enabled interoperability between modules like quality, production, labor and asset, and near–real-time data exchanges between systems. ERP is being brought closer to production with the reinvention of MES. Work instructions, recipes, BOMs, processes, orders and inspections are now available on systems and printed handouts for faster operations and efficient production.

In addition, IT enabled and empowered roles across the manufacturing network. For example, plant Managers, Line Supervisors, Quality Controls, Quality Inspectors, Production Superintendents and Production Operators can now track and trace the overall progress daily and seek necessary interventions and adjustments for materials, machines, operators and processes.

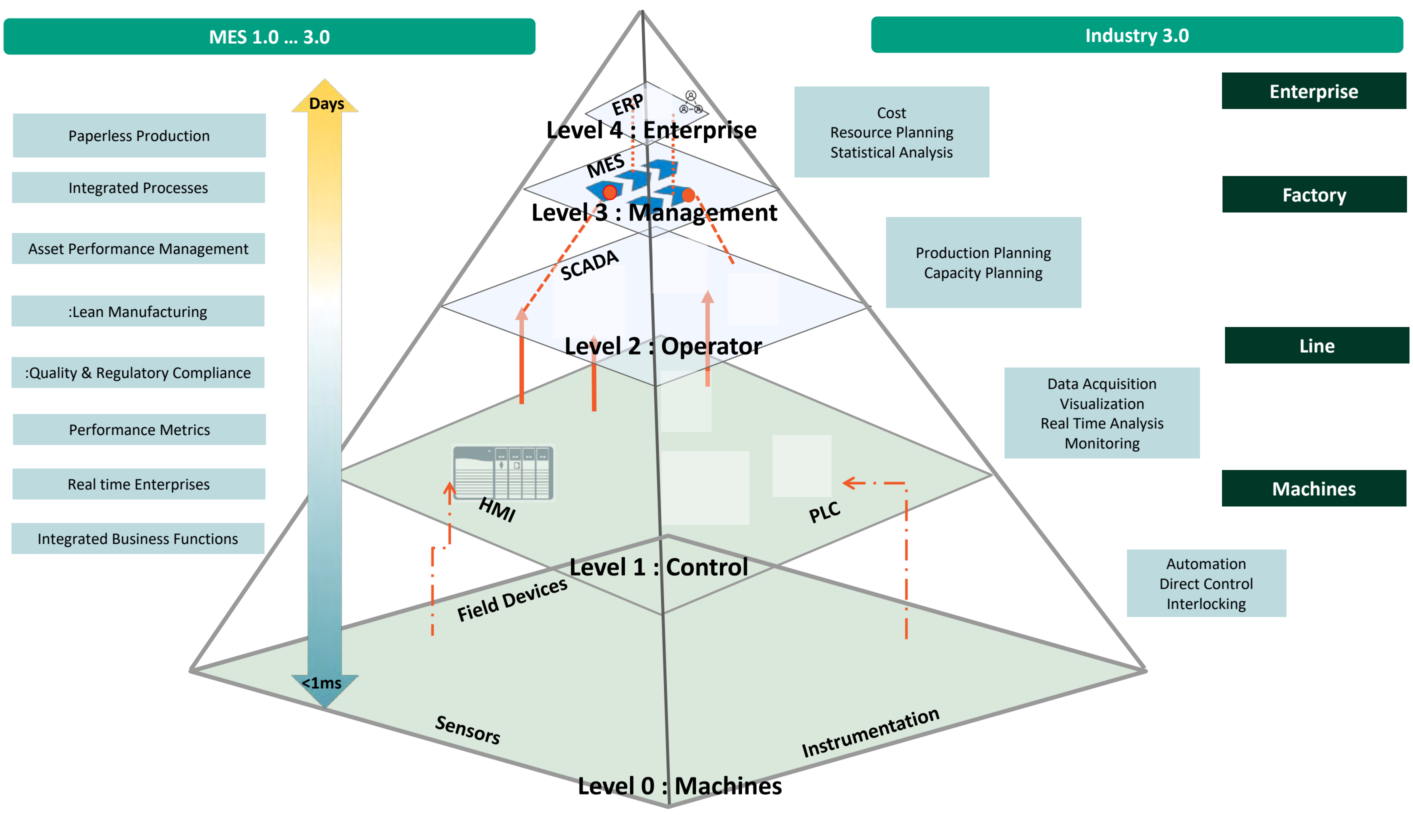

Figure 11: MES during Industry 3.0

The IoT driven industrial revolution brings in a paradigm shift in industrial production. It brought together a rapid change in technology, industries, and processes. It primarily optimizes the computerization of Industry 3.0 – bringing disparate tools and processes together, efficient decision making through pre-built algorithms without any human interventions and shaping the industry to be smarter and self-resilient.

The evolution caused a rebirth of MES and laid a foundation for MES 4.0. With the advent of technology, MES 4.0 enables finite capacity scheduling, dynamic resource allocations and status tracking, lifecycle tracking of an individual production entity, managing labor assignment more effectively, efficiently utilizing resources and reducing wastages, improving quality management, and streamlined and integrated engineering to manufacturing. It creates a dynamic platform to respond quickly and agilely. In addition, it enables analysis of manufacturing data in real-time that includes materials, labor, machines and processes through dashboards and reports. A series of such information inputs helps to identify points of failure, aids Root-Cause Analysis (CAPA) and assists in optimized planning and utilization of resources, hence improving productivity, quality, and overall performance at the site. Furthermore, it helps to eliminate data silos with real-time dashboards and analytics. Cloud based processing of information has further reduced operational costs and brought in security by design while building on the culture of continuous improvement across business operations and functions.

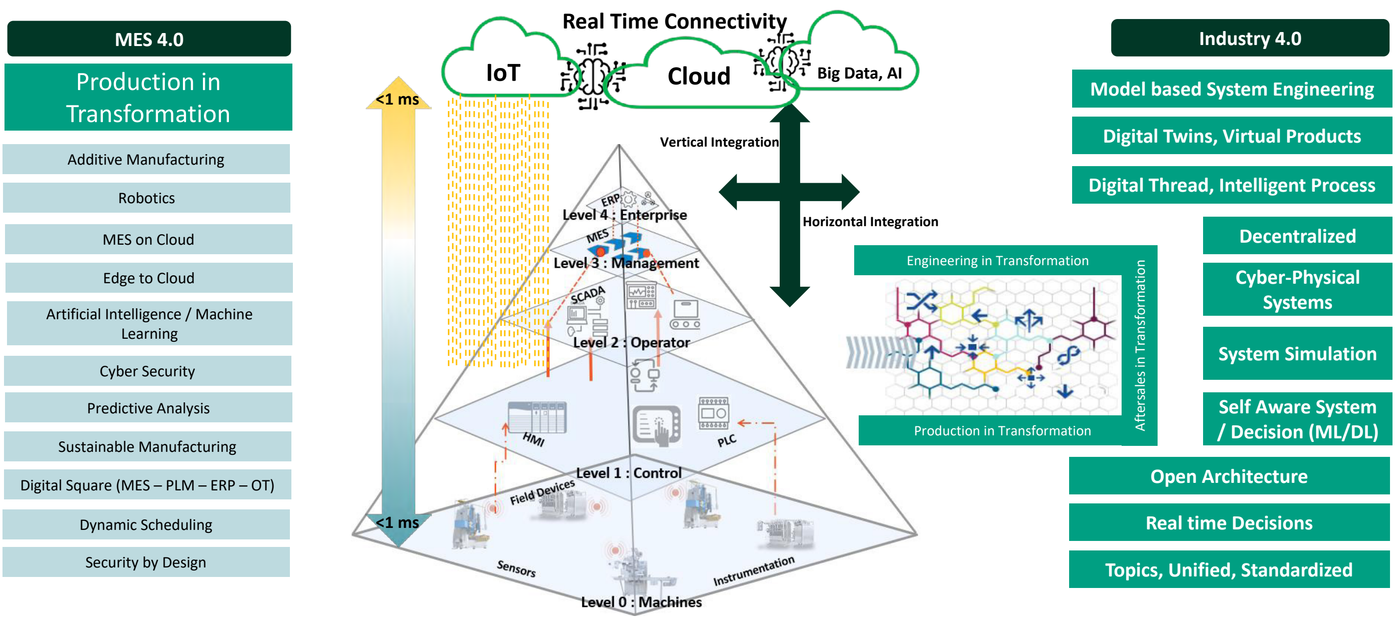

Figure 12: Smart MES (MES 4.0) complementing Industry 4.0 goals

Democratization of manufacturing data is crucial to the success of this transformational journey. The key manufacturing data (events and critical information around equipment, machine, and production lines) is analyzed to bring meaningful and action-oriented messages. Each part of a digital enterprise will churn out different values from the data, but the concept of free and secured access is a prerequisite of Smart Manufacturing. As the enterprise shifts focus to Smart Manufacturing and Industrial IoT, it must expand the architecture to support broader objectives and join the larger industrial revolution. The development cycle supported by PLM goes from ideation through CAD, simulation, process design, manufacturing, and service. It involves the overlaying of transformational operational architecture with PLM architecture to support the integrated enterprise and is the core of a Digital Thread.

Evolution of MES in alignment with Industry 4.0

MES evolved from a shop floor system to one connecting the information flow in a loop from design and orders to manufacturing and streamlined material supply. In addition, it incorporates feedback to design systems to enable better and faster NPI while feeding back to the ERP for efficient planning and ensuring tighter cash flows.

MES 1.0 primarily focuses on the execution of core MES functions (such as Operations, Quality, and Genealogy) in conjunction with peripheral enterprise systems and functional areas. It forms the base and layout of various functions to be used on the production floor during the manufacturing process to collect key manufacturing records (mostly manually then).

The next stage in evolution, **MES 2.0**, calls for a collaborative MES that anchors the interfacing between MES functions and business operations to optimize the supply chain, assets, and outsourcing and foster a healthy competitive environment. Eventually, it combines the earlier gen-MES functionality to operate and improve plant operations with an enhanced ability to integrate with systems, people, and value chains.

MES 3.0 brings many opportunities to integrate strategic initiatives, business operations, plant operations and manufacturing and derive improved values from existing assets, with an increased focus on operational improvement and corporate compliance. Unlike before, it provides an integrated model of events from plant operations that can influence and assist in better planning and engineering. Also, the aggregated views from the enterprises roll down through operations to real-time production views.

MES 4.0 presents a mature model of manufacturing that complements and makes the proper use of Industry 4.0 offerings by incorporating advanced technologies on the execution floor, thereby making manufacturing greener, smarter, agile, and leaner. MES 4.0 is a concept of developing a smart factory by integrating PQIM pillars through smart objects for navigating intelligent processes. MES 4.0 is a critical component of Industry 4.0, acting as an enabler for boundless digitization. It is possible because it performs the role of an agent between shop floor entities. It provides a connected ecosystem for real-time information exchange with better and faster decision making and autonomous feedback.

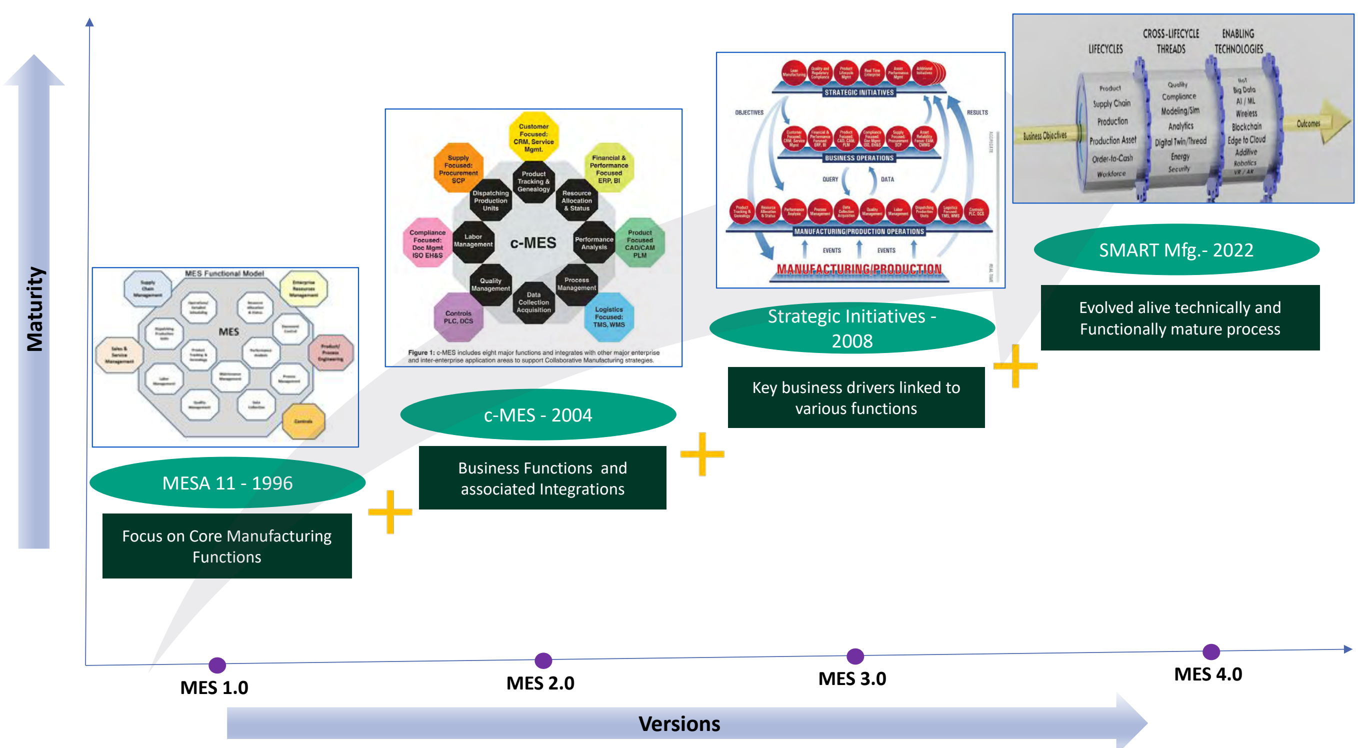

Figure 9: Evolution of MES over the years[1]

Realizing Digital Manufacturing and Smart Factories is a crucial component of MES 4.0. Manufacturing process variations that need to be addressed by MES include the following -

- Engineered To Order (ETO) – Most products involve significant customization. MES needs to have the ability to reflect these easily, e.g., digital work instruction, digital production assistance, production tracking, and machine data interpretation in MES should be seamless
- Configured To Order (CTO) – Where the manufacturing process is templatized, the cell, production process and machine integration are standardized. MES should be used to optimize the process and identify inefficiencies

The emerging trend will be towards more custom designed items or like Engineered to Order but closer to the speed of Make to Stock.

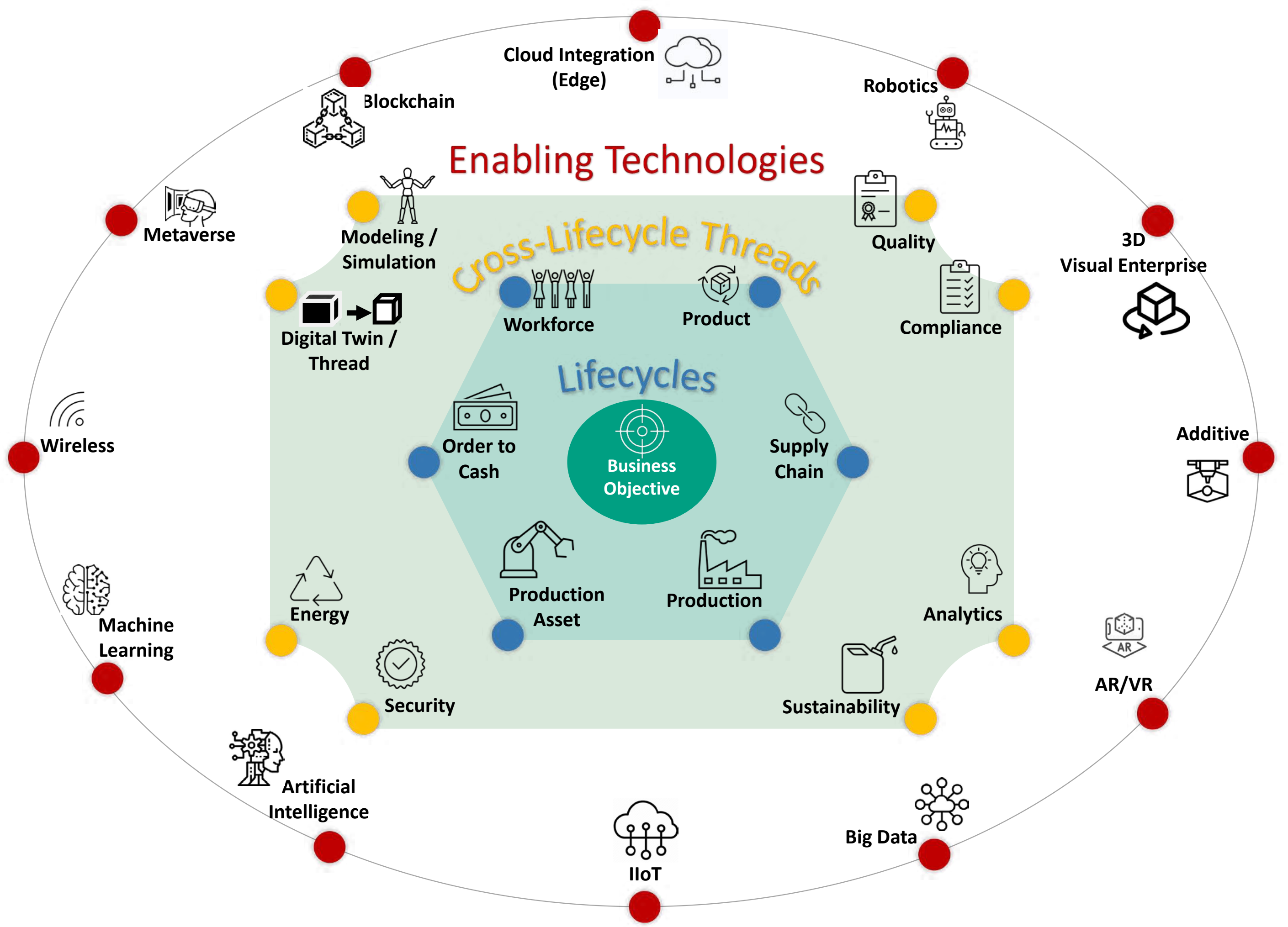

Figure 10: Components of Smart Manufacturing[1]

Benefits of the usage of an MES

Traditionally MES was used to guide operators and later machines to do the right thing. The objective was expanded to proceed with the proper steps and instructions to prevent known errors. This helped in improving quality and reducing repair effort and cost. With the advances in Industry N.0, new areas emerged where MES could contribute to improvements. For instance, it resulted in better WIP visibility, leading to higher efficiency by planning better, reacting more pointedly, and reducing costs stuck without turning revenue into profit faster. A structured and strategic MES implementation, seamlessly integrated with various manufacturing as well as business operations, can reap significant benefits, including: -

- **Paperless operations (lowers the cost of operations)** - Paperless manufacturing offers industries a feasible option to help streamline production and facilitate internal communication to boost output, increase revenue, and eliminate manual error overhead. Hence, reducing the recurring costs of paper, ink and spares is a benefit. But more than that, the chance of mutilation, destruction and error prone data entry from paper is an immediate gain ensuring cost savings, error proofing and a digital genealogy. This is where users reap the highest benefit, with a typical reduction in manual data collection of around 80%.

- **Reduced waste (Lower cost of ownership) -** The ability to see into the planned production combined with a similar view of the warehouse enables timely material consumption to prevent wastage. This aspect could be governed by the material's shelf life or even by regulations leading to changes in product definition, making some components obsolete. Another major area is the reduction of inventory, where average improvements are over 20%, reducing inventory costs.
- **Improved uptimes -** The increased OT integration ensures that machines are monitored and data collected for MTTR and MTBF, leading to preventive maintenance schedules, thus reducing unplanned downtimes. The digital twin has enabled the modeling of the equipment as a digital entity. The closer we emulate it, the better we can move towards predicting failure in run time than a passive preventive protocol. Even with the preventive ability, customers have reported an average improvement of 20% in throughput/uptime.
- **Better traceability (Better compliance and customer service)** - The genealogy created during the manufacturing cycle can be further updated in the operations and service cycle enabling effective tracking and tracing, leading to better warranty support and customer service.
- **Improved connectivity between the shop floor and business systems (and associated stakeholders)** – Enable better real-time feedback and control. It bridges disconnected systems and associated delays in information routing.
- **Improved sustainability -** Increased focus on health and safety as well as per unit consumption of electricity and generated waste is the rising pillar of MES beyond production, quality, inventory and maintenance. The recent disruptions in energy security globally are likely to bring more focus on energy and waste management, especially where energy costs make up a significant component of the overall operations cost, e.g., chemicals, cement, metals, and mining allied industries

The following statistics are based on analysis and research across various industries and manufacturing segments. It shows a significant improvement across multiple KPIs with a digital MES platform being implemented within the plant ecosystem compared to a legacy paper-based manufacturing data capture and recording. In return, it assists in improved productivity and greater customer outreach than ever before.

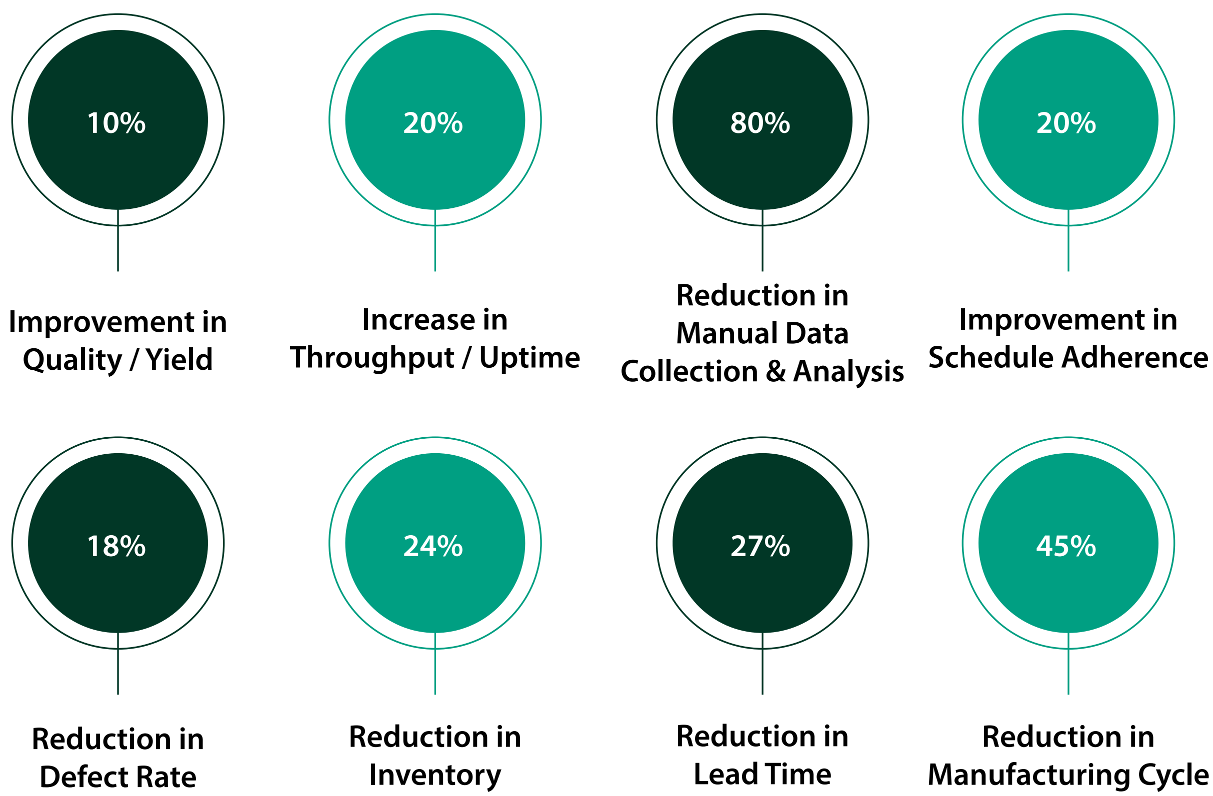

Figure 14: Positive Impacts on KPIs with the implementation of MES – MOM Applications[3]

Implementing MES ensures a structured approach to tracking materials, machines, labor and processes during the entire manufacturing cycle, from the kitting process to warehouse delivery. The data collected through the lifecycle of the execution can further be utilized for deeper analysis and to set up a robust feedback mechanism, resulting in a Live factory away from the 'Dark Factory.' In addition, it galvanizes the exploration of use cases, as depicted in Figure 15.

The data garnered using core MES systems can be further analyzed to draw patterns and inferences. With a blend of Core MES and IIoT services, the golden template can be modeled as shown below. The fundamental use cases focus on presenting the current state of the industry – productivity, asset performance (through OEE use case), quality (through OEE and Digital Quality use case), asset state and condition (CBM use case) and energy utilization and sustainability (energy monitoring). Once the manufacturers analyze the current state of the production, they can further explore building a healthier and smarter practice using strategic use cases for effective labor productivity (knowledge and learning use case) and superior asset usage and maintenance (through predictive maintenance, asset management and maintenance visualization).

This represents a significant advancement in the thought process that emerged initially in foundational MES deployment using MES-MOM modules, as shown in Figure 8.

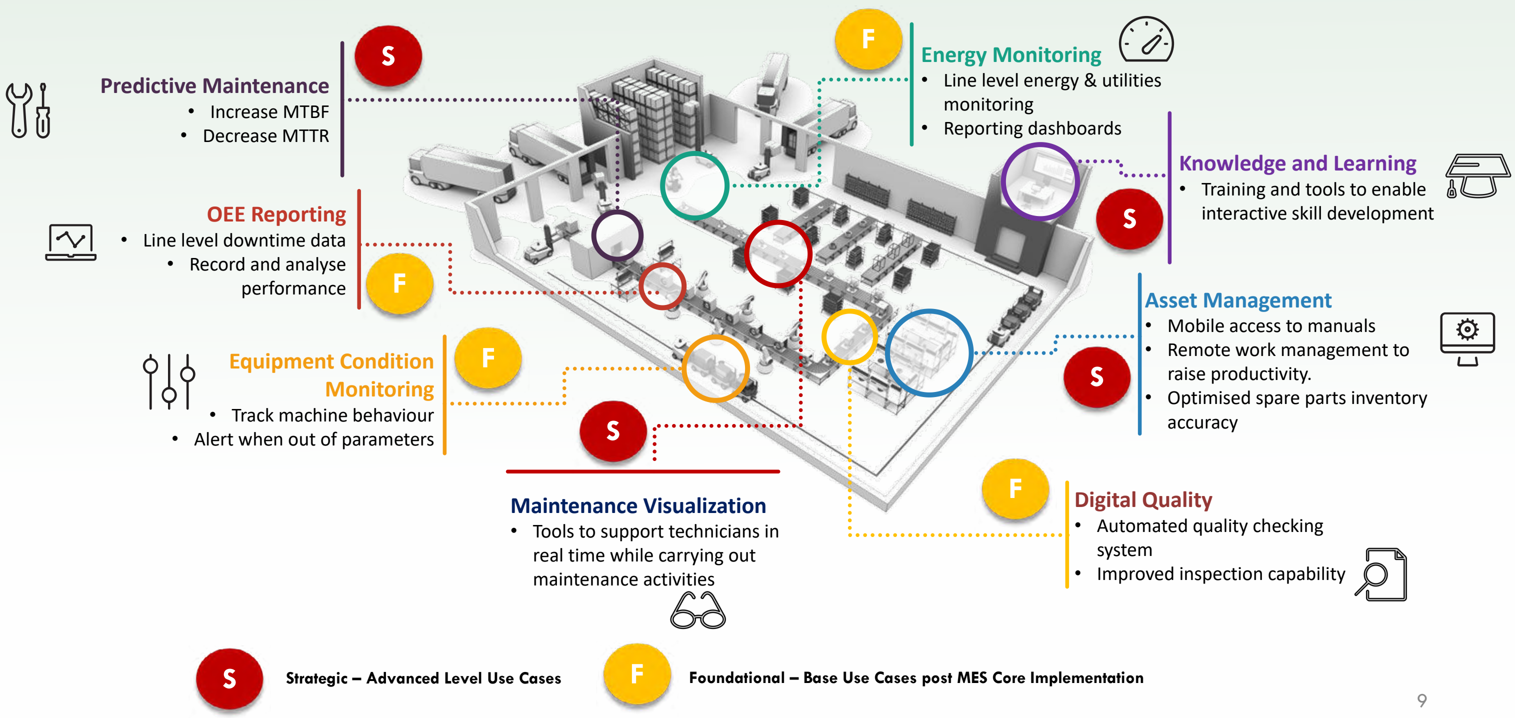

Figure 15: Touring of use cases to develop a Smart Factory

There have been significant benefits for manufacturers with the implementation of MES systems. While MES allows for precisely analyzing production lines and finished products, it can detect any inconsistencies on the shop floor, halting them to limit the number of bad parts and reduce wastage. The following caselets depict the advantages of the setup of an MES system in factories: -

American Aerospace Manufacturer with global service operations

At a SE Asia MRO facility, demand was outstripping supply. An analysis showed that visibility first isolates their problem and then devises the corresponding solution. The integrated solution from shop floor to dashboards to intelligent planning improved OEE by over 15% in a few months. The condition-based and energy monitoring capabilities embedded in the solution help them to keep their uptime and sustainability goals on track with a 10-15% reduction in idle times and a 20% drop in unplanned downtime. With installing sensors and power meters and wireless integration with MES systems, labor productivity increased by 20% and elapsed turnaround time by 78%. This alone was sufficient justification for implementing it across 15 facilities globally. The solution was implemented in a lighthouse site within six months and is being rolled out to other sites with three to four months of rollout duration per site.

Producer of Soft drinks based out of the UK

A volume intensive soft drinks company faced many challenges with unplanned downtimes, machine breakdowns and high production costs. To overcome these challenges, they embraced a phased Digital Manufacturing strategy across all sites in the UK. The program focused on five critical aspects - OEE, CBM, Asset Management, Energy Monitoring and Predictive Analytics that helped increase the production capacity by 8%, bringing OEE from 43.5% to 49%, resulting in business benefits of ~1.2 million GBP annually. Additionally, it helped cut down the energy cost by 7%, which was essential to meet their sustainability targets. The overall program was completed within 18 months across the sites. Notably, the solution integrated the sensors' data into the AWS cloud leveraging Siemens Edge and performing analytics over cloud.

Figure 16: Magic Quadrant for MES 2023[5]

Based on the analysis of prominent research papers such as Gartner, the following are some inferences –

- The maturity of this domain has led to the emergence of multiple players over the years. Various product innovations have shaped the MES market space. Their sole intent was to develop and scale a package that can serve manufacturers for a specific domain(s) covering all aspects, including MES, MOM, and MPS and enriched with an Industrial Integration bus for Sensors and Control systems along with inherent support for IoT Technologies (AIs, ML, Cloud Native etc.). E.g., Tulip MES focuses on life sciences and brings compliances for a highly regulated setting through a Low code & No Code platform and out-of-the-box connectivity for sensors and IIoT Devices. Similarly, Critical Manufacturing has led this segment and gained significant traction in semiconductors and electronics. It is strongly committed to data management, analytics and extended MES capability, supported by a sophisticated platform that manages IoT and transactional MES data in the same data model
- The market giants with full stack offerings across the supply chain, including design and make capabilities (PLM, SCM, ERP, MES etc.), with companies like SAP, Siemens, Oracle and Dassault Systems continuing to dominate the MES markets driven by a monolithic ecosystem setup. In a typical software ecosystem, it is often established that manufacturers have enrolled for the entire bucket of applications from the same product. For e.g., in an SAP ecosystem, the industry opts for SAP S/4 HANA, SAP Teamcenter PLM, SAP CRM, and SAP DMC (MES offering).

This paper covers the evolution of MES, its key drivers, challenges and trends. We also explored emerging patterns and the great reinvention of MES systems, collaborating and complementing industrial revolutions.

In the upcoming papers, we shall delve deeper into the emerging landscapes and discuss how the industry is staying ahead of the challenges. We will critically analyze the adoption of MES-MOM across various geographies and draw parallels with industrial growth. In addition, we will bring forward the daily relevance of MES-MOM for all roles across the factory. As enterprises embrace Smart Factory setups, we will present the importance of MES-MOM in accelerating that journey. Finally, we look forward to assisting manufacturers in building strategies on their MES goals, forming the heart of their industrial revolutions. Stay tuned as we bring in the following interesting paper in this series.

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Abbreviations

MES - Manufacturing Execution System

OEE – Overall Equipment Effectiveness

SoS – Save our Ship

MOM - Manufacturing Operations Management

IT – Information Technology

KPI – Key Process Indicators

IoT – Internet of Things

IIOT – Industrial Internet of Things

MPS – Manufacturing Planning & Scheduling

QMS – Quality Management Systems

OT – Operational Technology

ERP – Enterprise Resource Planning

GBP – Great Britain Pound

PLC – Programmable Logic Controller

HMI – Human Machine Interface

SCADA - Supervisory Control and Data Acquisition

AWS – Amazon Web Services

ISA – Industry Standards Architecture

CBM – Condition Based Monitoring

AR/VR – Augmented Reality / Virtual Reality

PLM – Product Lifecycle Management

CAPEX – Capital Expenses

OPEX – Operational Expenses

ROI – Return on Investment

LIMS – Laboratory Information Management System

AI – Artificial Intelligence

F&B – Food and Beverages

PQIM – Production Quality Inventory Maintenance

NPI – New Product Introduction

MTTR – Mean Time to Repair

MTBF – Mean Time Between Failures

BOM – Bill of Materials

CAPA – Corrective and Preventive Actions

CAD – Computer Aided Design

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