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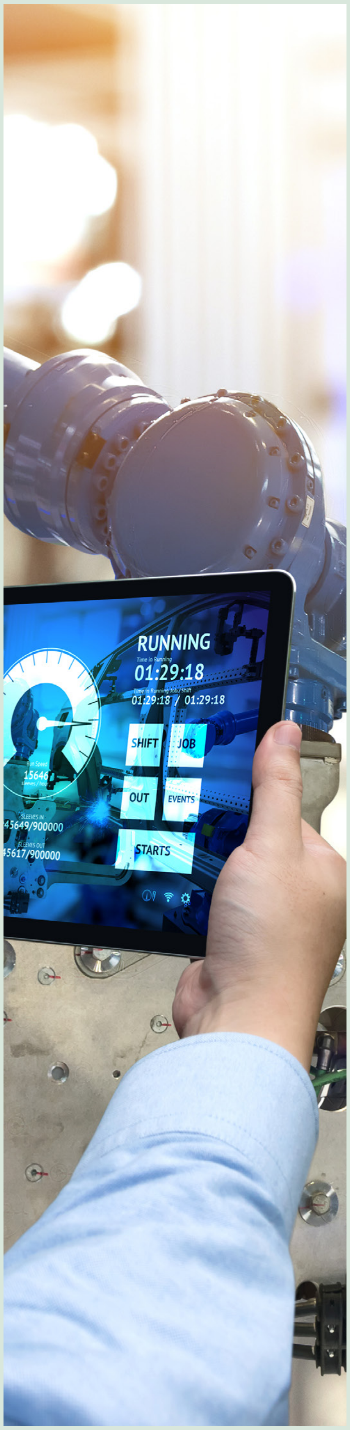

THE INTEGRATED PRODUCTION OPERATIONS IMPERATIVE

Abstract

Developing strategies to manage production operations efficiently is a continuing concern for manufacturing enterprises. Transforming raw materials into a final product involves a complex set of activities arranged in a sequence of processes depending on the nature of the transformation. The production process is complete when all the necessary features of given a product have been achieved. These process steps are bound by tight quality standards, resource awareness, demand for higher plant throughput, rapid changes in operating conditions and the increased complexity of the plants themselves. Hence a great demand to consistently manage data related to multiple processes, as well as the relationships between them. Therefore, enterprises have faced persistent issues while maintaining and managing integrity in the overall production operations.

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Integration – an important requirement but often undervalued and not prioritized. Without integration, there would be no integrity in overall production operations, nor would it run efficiently.

Despite implementing complex business and advanced technologies, most of them are managed as individual systems rather than as a totally integrated entity. Moreover, different functions adopt technologies differently, creating a connectivity gap in their overall operations. Consequently, most manufacturing companies have been unable to achieve a holistic integration of information flow. And as volatile demand patterns and uncertainty become the new normal, these conventional and disconnected production structures are no longer able to keep up.

However, those enterprises that have started to utilize digital tools for an end-to-end integration are better positioned to adjust within their ecosystem dynamically. There are strong drivers for integrated operations, despite the organization-wide transformation it would require. These drivers go beyond normal production and operational efficiency improvements and fall into three categories:

1. The increasing complexity of production operations and the desire to maintain the integrity
2. The possibility to define a unified architecture for securely and reliably moving data between diverse infrastructure
3. The ability to integrate vertically and horizontally across the value chain

These drivers give a strong push towards orchestrating production operations into a fully integrated closed-loop flexible and continuously optimized process.

Integrated Production Operations

The idea of integrated production operations has been around since the 1970s. It aims to integrate the entire business, from product design, process engineering, supply chain management, production and maintenance and outbound logistics . This means integrating the manufacturing enterprise using integrated systems, data communication and new processes to improve overall production efficiency.

However, most attempts were cumbersome, expensive and unreliable. More recently, a progressive line of thinking has developed which applies technology, ably supported by Industry 4.0 (I 4.0), to integrate all aspects of production across boundaries.

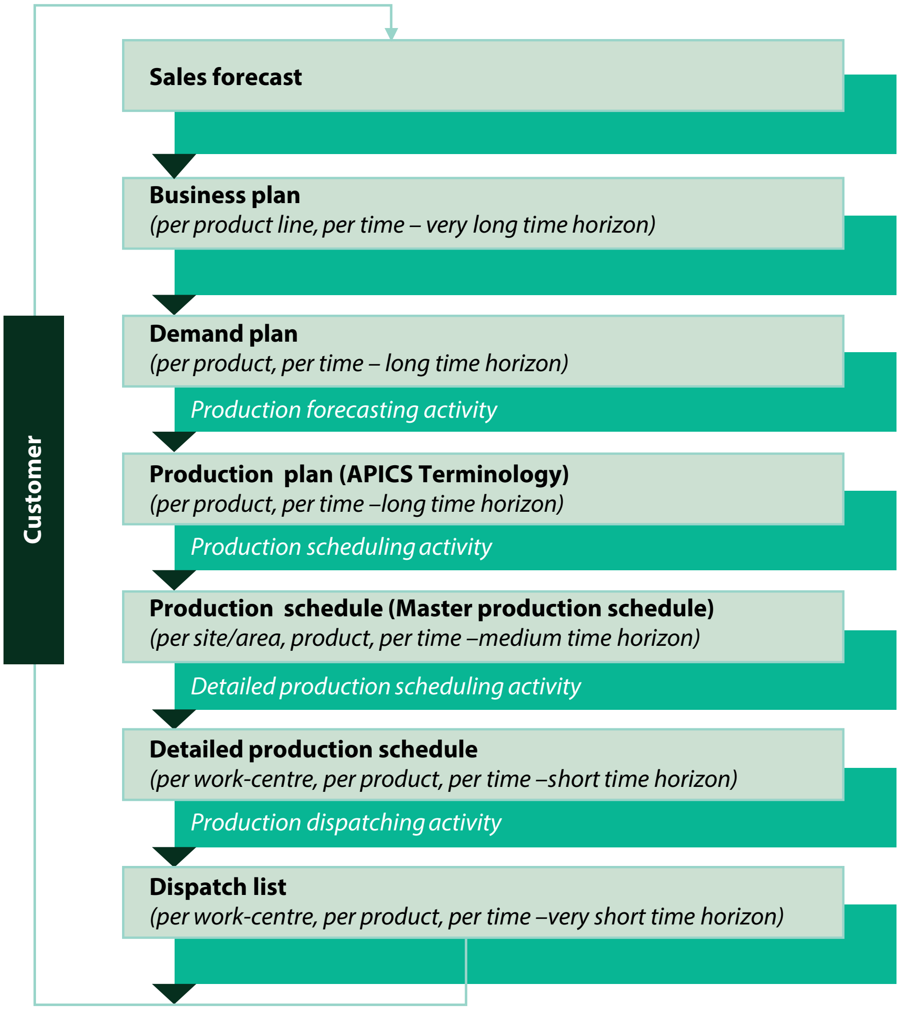
Integrated Planning and Scheduling

Production planning and control can be considered as the nervous system of production operations. Therefore, integrated production planning in a networked manufacturing system plays a crucial role. It holistically manages the efficient use of resources, people and systems through planning, coordinating, sequencing, scheduling, monitoring and controlling production activities to transform raw materials into finished products or components in an optimal manner. This seamless integration is also known as the smart factory and signifies the opportunity to drive greater value.

The overall process flow helps to understand the need for such an integrated approach.

1. The **business plan** is defined and used by business processes.
2. **A business activity** uses information in the business plan to generate a demand plan.
3. The **demand plan** is used to forecast demand and results in a production plan.
4. **A production plan** is the overall level of manufacturing output (also stated as a monthly rate for each product type).
5. An **approved production plan** is management's authorization for the generation of production schedules (ERP system).
6. **Detailed production schedules** define the production of products and intermediates, as defined by physical segments of production.
7. The lowest level of the sample schedule is the **dispatch list,** with the list of activities to perform.

In return, for reporting functionality, manufacturing execution systems (MES) provide information to ERP systems about the activities that took place within a work center.



This means cross-functional harmonization between planning and production structures which conventional shopfloor control system based centralized and hierarchical architecture can't manage. The traditional monolithic approach is not optimal anymore in a highly dynamic environment further influenced by I4.0. In response, the automation architecture is evolving with advances in computing technology that have given new impetus to redesigning of manufacturing systems. There is a growing demand for complex distributed systems that can manage large-scale factory automation.

In this new paradigm, networked manufacturing systems can adapt to make-to-order, in which customers are actively involved in the design, production and distribution process to ensure the best service outcomes. When implemented well, this can be a pivotal approach to boost production optimization.

Lack of integration impedes operations

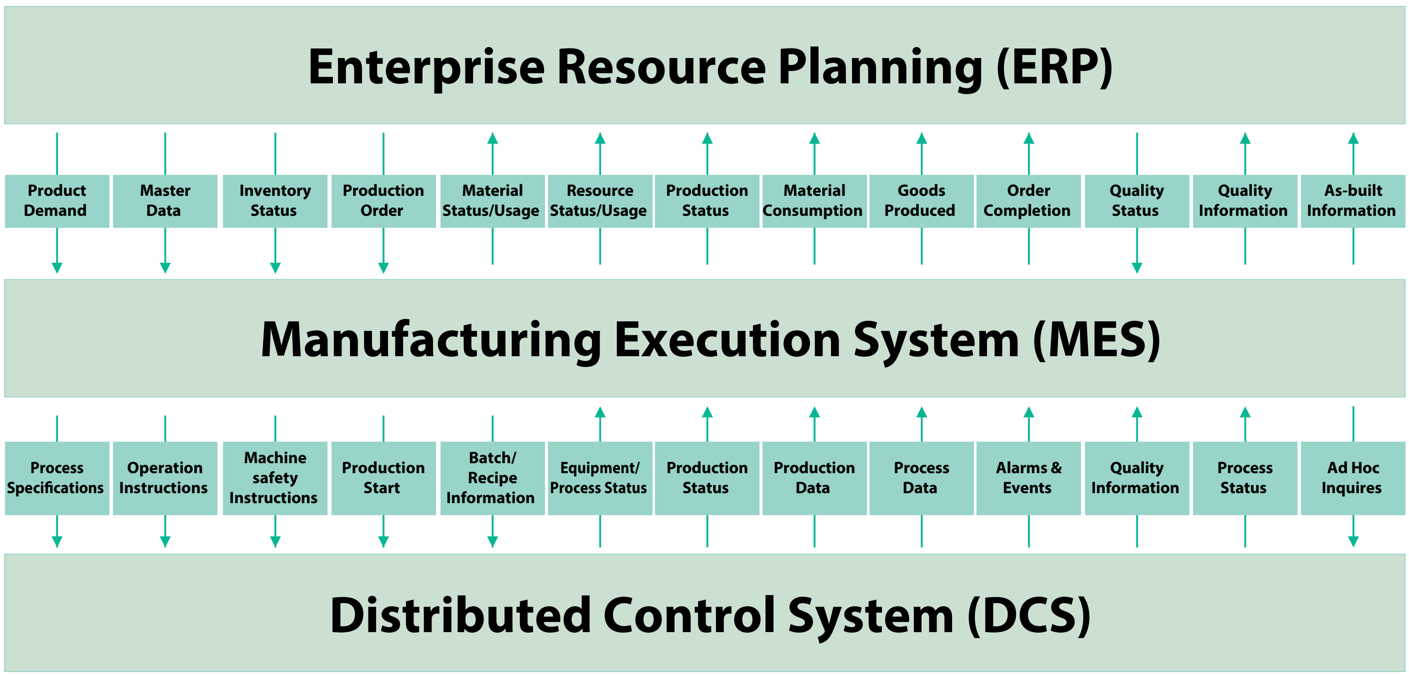
However, this involves integration of disparate systems: disparate MES with multiple areas of IT systems including ERP, Master Data Management (MDM), Asset Management System (AMS), Supply Chain Management (SCM) and Enterprise Data Warehouse (EDW). The MES should be integrated with control functions and data historians for the collection, integration, processing, archiving and report generation of both current and historical information on the production process.

The integration must cater to global standards as the basis for data structuring, alignment of standards of production information, definition of functionalities, enterprise hierarchy model, structure of the information flow, format of data messages, object and activity models and master data management to ensure information integrity.

Recommended approach for integration

The journey toward an integrated approach is neither easy nor quick and can last a few years depending on the starting point and digital goals. So, where does the journey towards integrated architecture begin?

If integrating heterogeneous systems is the goal, then interoperability is the means to achieve it. However, an industrial enterprise deals with many machine languages called protocols. Therefore, handling connectivity, integration, information exchange is a major challenge. This problem is compounded by legacy systems prevalent in factories and the coalescence of multiple protocols in the different domains of operation, viz. OT-IT-ET-IoT (Operation Technology Information Technology, Engineering Technology and Internet of Things). While these domains come with a set of protocols for interconnectivity, they effectively result in non-interoperable silos because of their proprietary nature. It's therefore critical to find ways to communicate with a multi-vendor, multi-protocol environment.



Unified interoperable architecture

While manufacturers grapple with this reality, the only way to work around the problem is by setting up a unified approach that is platform-independent, flexible and adaptable for moving data between diverse infrastructures. Open standards such as O-PAS (Open Process Automation Standard) and OPC UA (OPC Unified Architecture) are developments in this direction. They establish a secure and reliable data exchange platform between the plant floor and enterprise applications, promising to make interoperability significantly easier to manage and more reliable to implement. Such a concept can simplify the communication between field devices and higher layers of the enterprise to enable 'global' interoperability across plant floors, from sensors, controllers and mixed platform process control, different manufacturers and across operating systems, right through to management.

The modeling capability provides the basis for semantics where components, machines and systems are defined in a standard way to be interpreted by software agents, services and other interfacing systems. The sophisticated information model is comprehensive for defining complex information allowing efficient modelling of the complex multi-level structures. Furthermore, it allows implementation on small devices (micro-controllers) to a large enterprise or cloud-based infrastructure, allowing a dedicated controller to interact with complex, high-end server applications freely. OPC UA TSN (OPC Time Sensitive Networking), which adds real-time functions, makes it possible to use OPC UA for precise real-time applications in converged OT/IT networks. For legacy systems, this can be realized using a middleware, which handles the necessary abstraction of the network layer. With the introduction of Service-Oriented-Architecture (SOA), industrial automation systems combine the benefits of web services and integrated security.

Reference Architectural Model RAMI 4.0 and Platform Industry 4.0 group have thoroughly analyzed OPC UA in the 'Communication Layer' category and confirmed its relevance for Industry 4.0 implementations. Such a unified architecture is therefore viewed by industry as the de-facto communication technology for future production operations.

Adoption of industrial cloud

Industrial cloud has the potential to be the next big thing. It is built around industrial devices and OT to handle complex, data-intensive scenarios with high-speed, low latency, high fidelity and complete security. The ability to efficiently use cloud services for industrial enterprises is becoming an increasingly critical differentiator with flexible industrial cloud configurations.

An industrial cloud instance must certainly address the specific requirements of the industry it is designed to serve. Due to the security, data use, and flexibility requirements, most industrial enterprises are inclined towards private cloud deployment models. However, hybrid or community cloud models are recommended to balance the highly specialized needs of the plant floor with the advantages of cloud technologies. Further, it must manage vertical integration within specific industries, support standardized communication protocols with bidirectional information flow and ensure high security.

In order to efficiently manage data from field devices (machines, sensors and actuators), processing data at the edge, is a critical pre-requisite. This is achieved using Edge or Fog Computing and is one of the key elements of I 4.0. The resulting edge platform brings integration, intelligence and storage near the devices. The data is processed at the proximity to the devices (the edge), allowing data to be processed without significant delays. First, real-time relevant data is collected and analyzed on the edge. Then, only the necessary information is forwarded for further processing which leads to scalable cascaded data selection and load balancing for the relevant systems.

Thus, the edge architecture can also efficiently manage the distribution of resources and services for computing, storage, control and networking anywhere along the continuum from field devices to cloud. It reduces the data density on the servers and maintains security compliances. Flexibility and interoperability are significantly improved with a service-oriented approach, which also enhances the abstraction of software components. The service-oriented approach provides more flexible deployment from industrial clouds and continuous integration through all levels, including cloud, fog and edge devices.

Connecting machines and equipment – both locally and more importantly, across multiple locations – not only breaks ground for new business models but also boosts efficiency throughout the production processes – from engineering to cloud-based operational data analysis to dependable predictive maintenance strategies for greater availability and less downtime.

Opportunities missed or benefits gained?

Integrated production operation is important for the following reasons:

- **Integrated control:** ability to integrate control is the biggest advantage.
- **Transparency:** drive transparency and gain real-time visibility into production operations.
- **Coordinated:** activities across processes are synchronized for smooth working.
- **Rationalization:** the processes are planned to be performed in sequence or as a routine. Therefore end-to-end information flow is well regulated.
- **Productivity increase:** minimizes idleness and helps in raising industrial output.
- **Cost Control:** cost control is made possible by fully utilizing various inputs and by increasing output and lowering overheads
- **Optimized:** optimum utilization with precise controlling of resources, assets and processes, and loading effects.
- **Turn over time:** production time is kept at optimum levels, thereby increasing the turnover time.
- **Inventory optimized:** there is no over-stocking or under-stocking.
- **Flexibility:** higher and flexibility and accommodates near real-time changes, if necessary.
- **Performance:** better performance with interoperability between cross-functional systems.
- **Conflict management:** balance conflicting key performance indicators (KPIs) among individuals and departments.
- **Advanced planning:** advances in machine learning make it possible to adapt and update forecasts in real-time, enable advanced planning and scheduling and facilitate leaner operations and create new opportunities in overall production management.
- **Digital foundation:** drives digital transformation by enhancing information flow and in the process creating a robust data foundation.

About the Author

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He heads the 'Industry 4.0 Centre of Excellence' and led the development of 'Industry 4.0 Maturity Index' in a consortium led by Acatech (German academy for Science and Technology), together with scientific partners from leading universities and research institutes. Prior to this current role, he was leading the 'Asset Management Innovation Centre' for Infosys Labs.