> Manufacturing Execution Systems

Everything you always wanted to know but were afraid to ask

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INTRODUCTION

Manufacturing Execution System, or MES, is one of those terms everyone talks about, but it means a different thing to everyone. This guide seeks to demystify MES once and for all.

Upon reading this guide, you'll understand:

1. What is an MES
2. Why it is a confusing term
3. Attempts at standardizing its meaning and why they've largely failed
4. Common features and functionalities of MES solutions
5. MES benefits and shortcomings
6. How to select and MES vendor

Before you begin reading, we must warn you: MES is a pretty boring topic and this IS an exhaustive guide, so before you begin make sure you've brewed a good pot of joe!

With this in mind, we've written this guide so that you can skip sections and go straight to the most relevant ones for you.

If after reading this you still have questions, please feel free to get in touch, and we'll do our best to answer the question and update this guide so it is more comprehensive.

Without further ado, let's get started!

What the heck is a manufacturing execution system?

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Manufacturing execution system, also known in the industry as MES, is software used in manufacturing to track and document the transformation of raw materials into finished goods.

More specifically, MES manage, monitor, and synchronize the execution of real-time, physical processes involved in manufacturing operations. To do so, they coordinate the flow of work orders with production scheduling and enterprise-level systems like ERP or product lifecycle management (PLM) systems.

MES work in real-time to enable the control of multiple elements of the production process, such as inventory, personnel, machines, and support services.

As such, they operate across multiple function areas, such as product definitions across the product life-cycle, resource scheduling, order execution and dispatch, production analysis, downtime management, quality, and materials tracking and traceability.

What the heck is a manufacturing execution system?

Manufacturers use the information provided by the MES to make better decisions, understand how the shop floor can be optimized, and continuously improve their operations.

By using a MES to track and document production, manufacturers can create “as-built” records that capture the data, processes, and output of the operations.

MES applications also provide feedback on process performance and they can support component and material-level traceability, genealogy, and integration with process history where required.

This is useful for anyone trying to continuously improve their operations, but it can be particularly critical for highly regulated industries such as pharmaceuticals, food and beverage, and aero-defense. In these industries documentation and proof of processes, events, personnel, and actions may be legally required.

What the heck is a manufacturing execution system?

That's all there is to it.

If that's all you wanted to learn, you can go and continue living your life!

However, if you want to understand why everyone seems to have a different definition of what an MES is, then read on.

CHAPTER 1

The origins of Manufacturing Execution Systems (MES)

The origins of MES

MES, as a term, came after the underlying technology it describes was already in place.

In the early 1980s, manufacturing task areas such as production planning, personnel management, and quality assurance--which are almost mutually independent--were equipped with dedicated data collection systems.*

At first, these data collection systems, such as labor time, Production Data Acquisition (PDA), Computer Aided Quality Assurance (CAQ), Distributed or Direct Numerical Control (DNC) and so on, were highly specialized and independent of each other.

However, in the 1990s manufacturers of such systems started “combining” features from associated fields, giving rise to “combination systems”. For example, logging staff work on a PDA and so on.

With the rise of these combination systems, it was possible to put together a data collection and evaluation system for many functional areas of a manufacturing company.

*The content in this section draws heavily from Jurgen Kletti’s “Manufacturing Execution System - MES”, published by Springer. This is perhaps the ultimate book on the subject.

The origins of MES

Over the course of time, three groups of data collection and evaluation systems formed: Production, Personnel, and Quality.

However, as you know, in the real world production, personnel, and quality are deeply related activities which can't really be separated. As these three groups emerged, so did the demand for the systems to be tightly connected and horizontally integrated.

Doing this integration at the corporate level didn't provide the data quickly enough to those running manufacturing operations--the people who needed it most. They needed a system that tightly integrated data from production, personnel and quality systems..

The resulting system included quality assurance, document management, and performance analysis elements. This became what we now know as a Manufacturing Execution System (MES).

The rise of the MES buzzword

Before the buzzword was born, MES was just software that promised to let manufacturers identify, evaluate, and react to production problems in real time--for the first time.

At first, these production systems were a mix of internally developed systems and specialized solutions developed by third party vendors.

But as the industry realized the benefits of using software to connect production and the enterprise, these systems began to proliferate and with them the term MES.

Since the term came after the systems were already spreading, it has come to mean different things to different people, depending on their role, the industry they work in, their MES vendor and other factors.

This is because the features needed in a process-oriented operation are different from those in a discrete manufacturing operation.

Likewise, the needs of a heavily regulated industry, such as Pharma or Aerospace/Defense, are different from those of less-regulated industries.

To meet the needs of each industry, vertical, and type of manufacturing, specialized solutions developed, all trying to capitalize on the MES buzzword.

With the rise of these systems came the modern day confusion about MES.

CHAPTER 2

Trying to standardize the MES definition

Trying to standardize the MES definition

If you've been in manufacturing long enough, you've probably come across standards such as MESA-11, ISA-95, the Purdue Reference model, and so on.

If you're in IT, chances are you or one of your colleagues is very passionate about one or all of these.

But if you are like the rest of us, all these terms just seem confusing and you wish there was an easy way to understand them.

If that's the case, we got your back!

We'll now demystify these standards for once and for all so you can impress all your colleagues next time you find yourself discussing MES over lunch. (They may also come in handy to put your kids to snooze.)

We'll now demystify these standards for once and for all so you can impress all your colleagues next time you find yourself discussing MES over lunch. (They may also come in handy to put your kids to snooze.)

So, why all the standards? The reason behind them is simple: as more vendors started riding on the MES buzzword wave, the term became increasingly diluted.

MESA, ISA-95 and other standards came about as an attempt from various organizations to standardize the MES definition.

The MESA Model - defining MES by function

MESA, the Manufacturing Enterprise Solution Association, was created in the 1990s in order to advise on the execution of MES systems and address their growing complexity.

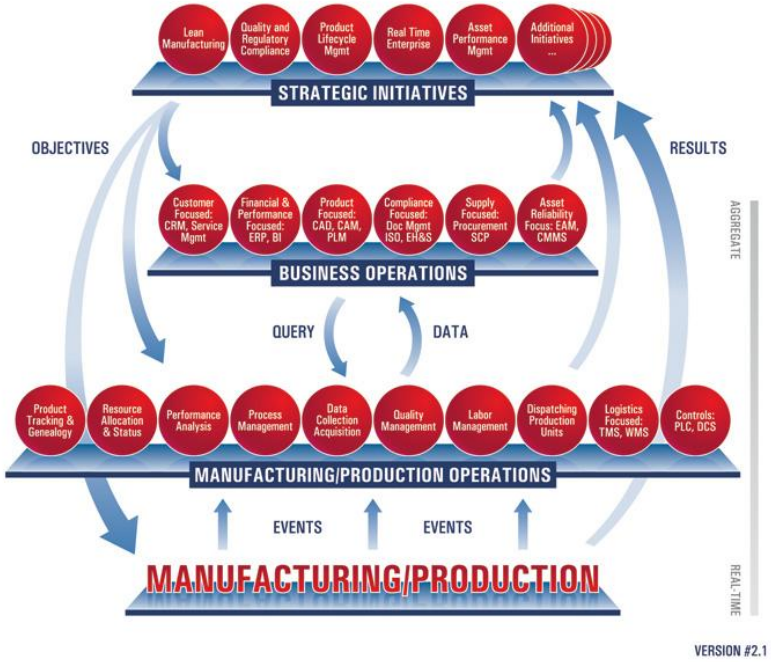
Their model is perhaps the most widely used in the industry as it dates back to 1997, when MESA formally defined the scope of MES through 11 core functions, called the MESA-11 model.

Though the actual model has gone several iterations over time, the one thing that has remained the same is that in order for a system to be an MES, it must have all the functional groups, or a reasonable combination of them.

The MESA Model - defining MES by function

That is, MESA defines MES by function.

Its current version, from 2008, spans from production, to plant operations, to business operations, and even to strategic initiatives such as lean manufacturing, quality and regulatory compliance, product lifecycle management, real-time enterprise, asset performance management, and others.



ISA-95 defining MES by system architecture

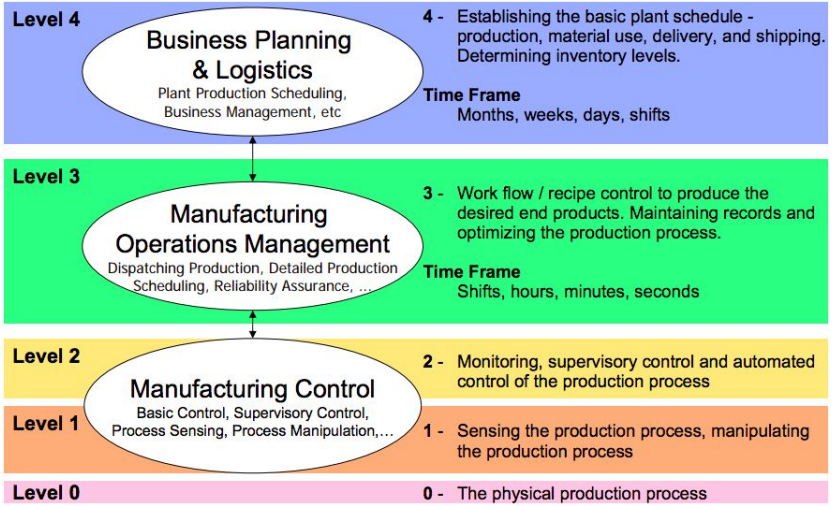
In contrast to the MESA model, which is fundamentally a business process model, the ISA-95 model is, in essence, an information model.

ISA-95 was jointly developed by the International Society of Automation (ISA), formerly known as the Instrumentation, Systems, and Automation Society, and the American National Standards Institute (ANSI).

The development of the ISA-95 standard began in 1995 when computers began to penetrate manufacturing's information and control systems.

The ISA-95 model divides production systems into 5 levels, based on the Purdue Enterprise Reference Architecture (PERA) model.

In this way, the ISA-95 standard helps define boundaries between systems. Intelligent devices, such as sensors, belong to Level 1. Control systems such as PLCs , DCS, OCS, belong to Level 2. MES, belong to Level 3. ERP to level 4.



Other attempts to standardize MES

The MESA and ISA-95 models are perhaps the more widely known and used definitions of MES. However, there have been a few other attempts worth discussing.

One is NAMUR, which was developed by a group of end users particularly involved in the process industry (chemical and pharma for the most part).

The reason this is worth highlighting is that MES definitions might vary from industry to industry as the regulatory and operational needs change between verticals.

For example, process verticals view MES as the machine and plant control systems, while discrete industries view the MES as more of an online information system, a feedback and control system for production.

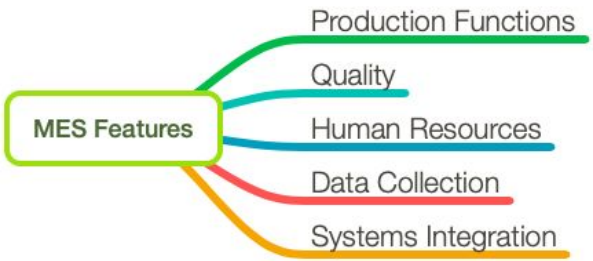
CHAPTER 3

Core Features of MES

Core Features of MES

We've seen that MES is a loaded term that means different things to different people.

But putting all these standards aside, we can define an MES by their most common feature areas.



problems, it encourages rapid iteration, decentralized decision making, smaller value delivered more often, and faster response to change.

Dispatching Production Units

Dispatch work based on global instructions from the Enterprise Resource Planning (ERP), adapted to meet resource availability, schedule requirements and capacity.

Process Management

Managing the production process from order release to work in process (WIP) to finished goods, including guided work steps and work instructions.

Product Tracking and Genealogy

Track where each item is in the production process, along with the source, unique identification of parts and materials as well as the equipment and personnel involved in handling it.

Resource Allocation and Status

Manage the allocation and status of resources including equipment, tools, materials and labor.

Data Collection and Storage

Collect data from production including end users, databases, or equipment, and store it on databases or embedded historians.

Quality Management

Integrate quality in the production process through in-process quality monitoring, corrective and preventive action (CAPA), verification and nonconformance workflows.

Labor Management

Manage the people involved in operations, from staff work time logging to personnel qualifications and certifications to labor scheduling and escalation management.

Performance Analysis

Define and track key performance indicators (KPIs), perform advanced analytics and provide dashboard displays and datasets for performance monitoring and reporting.

Of course, depending on who you ask, these core functions might vary slightly.

Gartner, for example, considers resource management, manufacturing process management, operations intelligence, and planning/scheduling, as “extended” MES functionalities.

The takeaway from this should be that just because a vendor calls their software MES, doesn’t guarantee they’ll provide all these features.

So when evaluating if an MES is the right solution for your company, make sure you identify all the use cases you want to tackle with the MES and check if the vendors you are evaluating offer those features - just because some vendors do, doesn’t mean they all will!

CHAPTER 4

MES Benefits

Benefits of Manufacturing Execution Systems

We've gone over the different definitions of an MES, and we've seen the main features that characterize an MES.

If you've read this far, you might be wondering what are the MES benefits or value drivers. Namely, why do manufacturing companies adopt these systems.

The shortest answer to this question is what is sometimes referred to as the 6R Rule of manufacturing: **"A product will not be created in the most economically efficient manner unless the right resources are available at the right quantity at the right place at the right time with the right quality and with the right cost throughout the entire business process"**

MES help meet the 6R rule of manufacturing. Below we go into the most common value drivers of MES.

Data Acquisition and Consolidation

MES facilitate the acquisition and consolidation of data from systems such as production planning, personnel management and quality systems, that were designed as almost mutually exclusive and independent from each other, but which in reality need to work closely together. This ability to collect and consolidate data from different task areas and make it available to the people running operations was one of the first value drivers of MES, as we saw above.

Production Visibility for Better Decision Making

MES can provide near real-time production visibility that helps manufacturers make better decisions. This level of visibility helps improve operations throughout value streams.

For example, production job progress tracking can help with inventory planning, production scheduling and accurately inform customers when orders will be ready and estimate labor cost for each job. Machine data collection can help you estimate OEE, which can help you increase machine utilization. Non-conformance management can give you insights into root cause of quality defects, and so on.

Reduce mistakes throughout your operations

MES can help reduce human error throughout production. Work instructions, for example, can provide audio-visual guides to technicians performing work and help them prevent mistakes. In-process quality verification can help identify and fix quality issues before they move downstream. Personnel qualification management features can help ensure that only the right people with the right skills perform certain jobs, to avoid safety and quality issues.

Increase Productivity with Better Data

MES provide the right information to the right person at the right time, which in turn helps increase productivity. For example, if technicians have the right machine settings or the right machine program to run, they can run processes faster. If they have the right work instructions, they can speed up the production of a given widget.

Increase Machine Utilization and Uptime

MES can collect machine data to help manufacturers determine their true levels of utilization. They can also improve machine utilization by ensuring the right tools and resources are available in production, and that machines are set up, run and maintained accordingly and their tools calibrated in a timely manner.

Paperless Factory

In a factory, any piece of metal that doesn't have a data record is usually regarded as scrap in accordance with certification rules. This results in a high level of written output, starting with preparation of the work order, printing hard copies of the job papers, work instructions, material issue slips, trial orders, routing cards and so on. In general, the paper trail left by an order going through production is considerable. In fact, it is estimated that the printing costs for manufacturing alone are around 5% of sales volume (source: MES - Springer). Adopting an MES can help companies digitize all these slips and achieve paperless production.

Improving the information flow between stakeholders

Beyond the printing and paper costs, there is the risk of not having up-to-date information in production. Using the case of work instructions, for example, there is considerable organizational and administrative overhead involved in preparing, updating, distributing and managing the documents. With an MES, at least you can tell which work instruction is the latest one. Furthermore, other systems such as ERP don't post information quickly enough to be able to control production. With an MES, you can improve communications between production and enterprise level management.

Orchestrate communication between smart machinery

As the shop floor is taken over by digital machines, IoT enabled sensors, and other technologies, there is an increasing need to manage the communication between all of these systems. Though most MES systems were conceived before the age of cloud and IoT, they are increasingly trying to fill this gap (albeit with various levels of success).

CHAPTER 5

Challenges of MES

Challenges of Manufacturing Execution Systems

As we've seen, MES are largely beneficial to manufacturing operations. They help increase productivity, reduce quality issues and gain visibility to make your operations more efficient.

However, MES are not perfect. Like all systems, they have important drawbacks. Some can be avoided by choosing the right vendor, but others are simply part of the way the systems work.

Below we go over the main drawbacks of MES:

Implementing an MES is a slow process

Since the MES is such an all-encompassing system, implementing it is usually a major undertaking that needs to balance the interests of stakeholders from across the company. Given the high licensing costs associated with MES and the many stakeholders that will be using it, even the most agile manufacturers will need to spend months scoping their MES needs, evaluating vendors, and drafting POCs, and then several more months implementing the systems in their production, customizing it, etc. These timelines imply that time to value will be on the months-to-years timeframe. In fact, according to Gartner, average implementation time for an MES is 15-16 months.

MES are rigid, so they can be hard and expensive to customize

MES are rigid systems with narrow, clearly defined features and system architectures. Unless you are adopting a custom-built MES, which can be very expensive and even slower to implement, you will need to customize an off-the-shelf solution. This is difficult, time-consuming, and expensive. Custom-built MES configurations based on MES tool kits can run high ratios of license-to-service dollars, often upwards of 1:5. That means for every $10,000 spent on licenses, you may actually be spending $50,000 in services.

Unless you're getting a custom built MES, you'll need to change your workflows to fit the MES

Given the rigid nature of MES architectures, it is often easier to change your operations to fit the MES rather than change the MES to fit your operational needs. Of course, this has a cost. Not only do you have to change your operations, but you may also end up with processes that are not necessarily the best for your operations simply because your MES doesn't support other alternatives. Adopting subpar processes can have long-term costs that far exceed the benefits of the manufacturing execution system altogether.

The rigid nature of MES makes it difficult to change systems as your operational needs change

Modern factories need to be flexible in order to adapt to changes in the market, customer demand and continuously improve. However, due to their rigid architecture, MES can slow down the rate of improvement because they need to be customized in order to fit the new processes. This can cause MES to fall behind the needs of operations. In fact, according to Gartner, one of the top 5 reasons why manufacturers change MES is because their vendors aren't flexible enough to adapt to current needs of the business.

MESs are built for IT, not the shop floor personnel

Even though the MES is used by production personnel, the system itself is built for IT to own, deploy, customize and manage. This means that unless you have a background in software development, you won't be able to customize it to fit your needs. The problem with this is that the people closer to operations--those who understand the needs of production better than anyone else--cannot contribute to the improvement of the MES. Furthermore, it introduces tribal knowledge within IT and can cause business discontinuity problems if IT staff leaves.

MES isn't moving with the pace of technology

The industrial Internet of Things (IIoT) and cloud computing are among the most promising new technologies in manufacturing. However, MES was conceived prior to these new technologies, so most MES providers are lagging behind incorporating these on their solutions. In fact, Gartner estimates that only 50% of MES solutions will include industrial IoT (IIoT)! Furthermore, most MES were built as on-premise solutions. Though some vendors are starting to offer cloud based solutions, they are well behind other solutions or industries in this regard. According to Gartner, one of the top 5 reasons why manufacturers switch MES systems is because the legacy MES was technically obsolete and didn't offer features needed by the company.

MES have a blindspot for human data

It's estimated that human errors account for around 22% of what goes wrong in a factory; poor training for 15%; and equipment and material problems for 19%. Unfortunately, MES aren't necessarily the best system to deal with these issues. Even though you can attach work instructions to MES work orders and keep track of training certifications, creating detailed, IoT enabled work instructions isn't the primary goal of the system, so you'll likely need additional software to complement it.

MES pricing is prohibitive for small and medium manufacturers

MES usually have large upfront investments with recurring maintenance fees. These, coupled with slow time-to-value, result in long payback periods which make MES inaccessible for small and medium sized manufacturers. Furthermore, even if you are a large manufacturer and can afford an MES, manufacturers have reported changes in the licensing structure that cause extensive unplanned costs over time. According to the Gartner study we mentioned above, one of the top five reasons manufacturers change MES is because of financial benefits offered by new systems.

Chapter 6

Choosing the right MES vendor

Choosing the right MES vendor

According to Gartner, the MES market is largely mature with almost 80% of the revenues coming from North America and Europe. In these regions, the MES market is largely a replacement market.

Though leading vendors continue to add new capabilities to their MES, the core functionalists have remained mostly the same for the past 20 years and many are lagging behind on implementing new technologies such as cloud and IoT.

The top reasons why manufacturers seek to replace their MES are, according to a joint study by Gartner and MESA are:

1. Existing MES is technically obsolete
2. Existing MES doesn't offer functionality needed by the company
3. New MES offers financial benefits
4. Changes in company's business made older MES no longer fit the company's needs
5. Legacy MES was not flexible enough to adapt to current needs of the business

Function Specific Applications

Some manufacturers are avoiding MES altogether and opting for function-specific applications. For example, manufacturers only looking for quality modules on an MES, are increasingly adopting enterprise quality management system instead. Similarly, manufacturers looking for MES with good work instructions features, might choose a software vendor that specializes in that instead.

Either way, when evaluating MES alternatives, manufacturers can choose between function-specific applications, customized MES, commercial off-the-shelf MES or a home-grown MES.

Custom-built MES

A custom-built MES solution is designed to accommodate specific operational processes. The coding and functionality of a custom MES solution can be catered to unique industry needs. These solutions can offer manufacturers the most tailored features to their needs, but are quite expensive to build and maintain.

Commercial Off-The-Shelf (COTS) MES

Commercial Off-The-Shelf (COTS) MES are ready-made systems refined to a level of compliance and best practice that is not typically achievable with a custom solution. The licensure and maintenance costs of a COTS MES solution are also significantly lower in comparison to customized MES, which is why most companies opt for them. When selecting commercial off-the-shelf solutions, bear in kind there are 4 kind of vendors:

1. ERP Vendors: These vendors offer broad portfolios of solutions across application categories, such as manufacturing resource planning (MRP), human capital management, customer relationship management (CRM), PLM and/or supply-chain management. Examples of these vendors are Epicor Software, IQMS, Oracle, Plex and SAP.
2. PLM Vendors: They offer portfolios of applications across the product life-cycle, such as product design, product simulation, and quality. Dessault Systemes and Siemens are examples of this kind of vendor.
3. Automation Vendors: These vendors sell MES in addition to SCADA/DCS applications. ABB, Aveva, Emerson, GE Digital, Honeywell Connected Plant and Rockwell Automation all are automation vendors with MES offerings.
4. Pure-play MES vendors: These vendors have a specific focus on MES, either as a stand-alone company or as a software division of an industrial company. Forcam, Applied Materials, Nomuda, PSI Metals are among the vendors in this category, with a dedicated manufacturing software focus

DIY MES

Finally, you can opt to build your own MES. This DIY route used to be the preferred one at the dawn of MES. In fact, many of today's vendors started as home grown solutions that were later commercialized. However, in recent years there has been a resurgence in the DIY route.

According to Gartner, there are several reasons manufacturers choose to pursue a Do-It-Yourself MES.

First, the total cost of ownership of custom built or off-the-shelf MES is high. Second, the implementation complexity is high as well, averaging 15 to 16 months. Lastly, the emergence and growing popularity of Manufacturing App Platforms such as Tulip now let manufacturers extend their existing MES or build their own systems from scratch more quickly and cheaply than ever before.

Chapter 7

Conclusions

Conclusions

In this guide, we've gone through the history of MES, the evolution of the term, the various attempts at standardizing its definition, the benefits of adopting the technology and the common pitfalls of MES.

We've seen how MES have changed manufacturing and how new solutions such as function-specific applications and manufacturing apps are starting to emerge as alternatives to shop floor software.

Though the future of MES is unclear, one thing remains certain - as long as the functions required to manage manufacturing operations continue to exist, systems like MES will continue to have a place in shop floors around the world.

Tulip, the Manufacturing App Platform, is empowering the world's leading manufacturers to improve the productivity of their teams, the quality of their output, and the efficiency of their operations. With Tulip's no-code platform, manufacturers can empower those closest to operations to digitally transform their shop floors and gain real-time visibility into the people, machines and processes involved in production--all in a matter of days.

Learn more and try Tulip risk-free for 30 days at tulip.co.