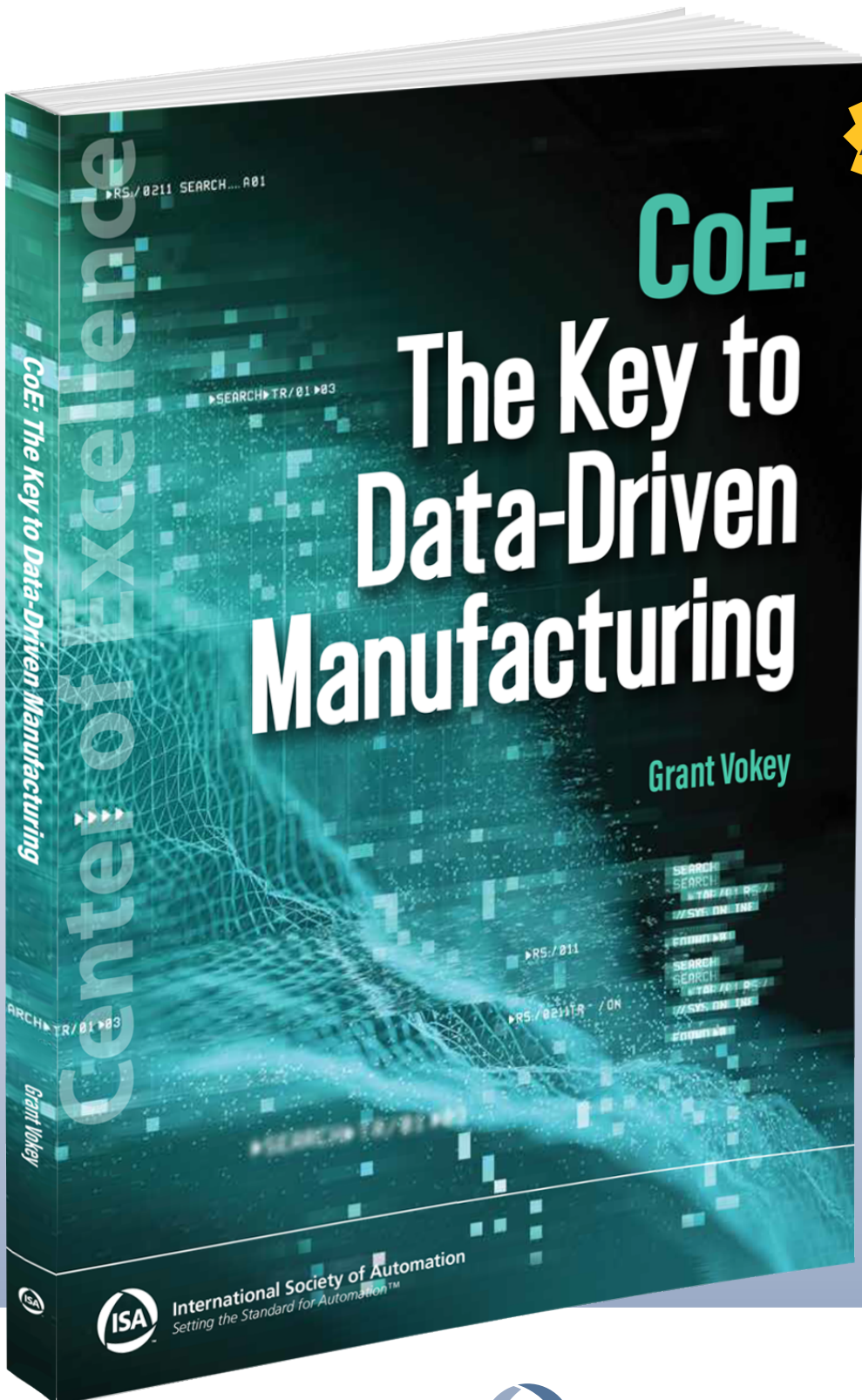


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CoE: The Key to Data-Driven Manufacturing

Grant Vokey



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Printed in the United States of America

ISBN-13: 978-1-64331-225-5 (print)
ISBN-13: 978-1-64331-226-2 (ePub)
ISBN-13: 978-1-64331-227-9 (Kindle)

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ISA
3252 South Miami Blvd, Suite 102
Durham, North Carolina, USA 27703
www.isa.org

Library of Congress Cataloging-in-Publication Data in process



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About the Author



Grant Vokey is the principal consultant for Vokey Consulting. With 20 years of diverse manufacturing operations experience and an additional 15 years of integrating information technology (IT) systems into the manufacturing floor, he has developed a strong understanding of how manufacturing companies work and the information needed to operate at world-class levels.

Grant's experience, coupled with continuous training and 10 years as a Certified Operations Manager, has also provided him with an excellent understanding of industry best practices and best-in-class utilization of manufacturing execution systems (MES). Using this knowledge, he has been a subject matter expert for developing industry-leading MES applications/solutions, a program manager for multiple MES programs, and a lead consultant on implementations of MES in various verticals (electronics, industrial equipment, automotive manufacturing, and metal fabrication).

Grant has developed a reputation for providing sound, practical advice and direction that make a difference to his clients and the MES industry as a whole.

Preface

During a youth leadership course I took many years ago, I was introduced to a game that was intended to show the importance of good communication (many of you probably remember it). The game involves a group of people, and one person quietly tells the first person a message. Each person, in turn, whispers that message to the next person until the last person is given the message. The last person shares the message they received with the group, and the group compares that message to the original one. Like others in the group, I was amazed at how much of a difference there was between the first and last versions of the message.

Over the years, I have noticed a pattern of that kind of miscommunication in manufacturing companies. I have observed these issues throughout the companies, on both the business side and the manufacturing side. These issues have had a significant effect on initiatives for implementing any aspect of change management. However, from what I've seen, manufacturing operations management (MOM) seems to have more than its fair share of potential scenarios for miscommunication.

Why does this scenario play out so often in companies?

The specific answer to each independent observation is, of course, too narrow to be of value in a general context. But when I have stepped back from any particular issue, I have found that there were questions that could be meaningfully asked in a more general context.

In this book, I present some of the more general issues I found on the manufacturing floor and offer some ways to avoid or correct them. I primarily provide direction in creating a team within Manufacturing Operations whose purpose is minimizing the occurrences of these issues. Is it a lofty goal for a book? Maybe. Or maybe I might surprise you.

1

Introduction and Overview

Anyone who works in manufacturing quickly learns that change management is a big deal in the industry, to such an extent that consulting in change management in different industry segments provides a more than reasonable income for many. Think about how many consulting companies specialize in the Lean, Six Sigma, ISO-9000, or Theory of Constraints change management methodologies. Not to mention the number of people employed in manufacturing companies whose sole focus is change management as it relates to continuous improvement (CI). Also note that each of the mentioned change management methodologies started in manufacturing and was then recognized as being of value to the rest of the company. All of this indicates the importance of change management to manufacturing in general.

Yet many manufacturing company executives have expressed frustration with their company's inability to sustain CI for longer than the period of the original initiative to implement one of these change management methodologies. In addition, many senior operations managers have expressed some disappointment in the results of implementing any of the change management methodologies (or at least they expected considerably more out of the implementation than was achieved). In industry surveys as recent as 2020, up to 70% of companies have been disappointed with the results of their CI programs.

No, this is not yet another book on CI. I'm not going to tell you about a *fantastic new methodology* or that any particular methodology is better than another. Each methodology has a particular scope of operations it is meant to help improve, and each has its place.

I will say that it is not the particular methodology that is important (sorry to burst the bubbles of all those consultants); it is the combination of methodologies and the correct coordination of resources that make a difference. And to properly coordinate those resources, you must provide them with the “tools” in a program management context to enable them to develop. However, that raises a question regarding *how* to coordinate those resources.

My first book, *MES: An Operations Management Approach* (co-authored with Thomas Seubert), discussed using a manufacturing execution system (MES) to coordinate production and production support activities from an operations management perspective, and we provided some guidance on using the ISA-95 standards as a template for MES implementation. I’m happy that the book is now being reviewed for use by universities in master’s-level courses for industrial engineering (specializing in manufacturing engineering). After spending more than 20 years implementing MES, I am surprised at how little growth there has been in understanding how to tie MES implementation to a company’s CI program and in the ability of companies to manage these programs to be sustainable.

In this book, I provide an overview of the different characteristics of manufacturing management at the production floor level, how to use those characteristics for operations management, and how many of the latest trends in analysis and access to real-time data are actually of value. I also explain how to develop a coordinated approach to use these characteristics and some general “operations management tools” to create a specialized team to lead manufacturing companies into a long-term sustained program for continued improvement in manufacturing capability. This is not a step-by-step instruction because the detailed implementation of any sustained program is specific to each company, and this is not a book about quality management (there are many good books that cover that topic). I do, however, provide guidance on implementing a sustained program and explain some of the characteristics of manufacturing processes that enable the guidance that I provided.

Although the problems of change management are common to many industries, manufacturing industries have particular concerns. Not only do changes have to be made in the way the business operates (the business processes), but the same types of changes are needed at the production floor level as well (the manufacturing processes). Because of the detail to which manufacturing processes must be defined, the interactions between business processes and manufacturing processes, and the effect on the quality of even seemingly small changes, change management in manufacturing operations management (MOM) has a deeper level of complexity.

Many companies that have been repeatedly successful in implementing required changes have attributed that success to first implementing a formal process management program and a formal team to manage the *normalization* of processes in general, and then managing *both* the *changes in process* and the *process of change*.

In this book, I look at process management from a MOM perspective and cover the structure and implementation of a process management team within that MOM context.

In this chapter, I use the term MOM in a general context. In later chapters, I will get into more detail about the definition of MOM from an industry point of view.

Also, within that same general MOM context, many manufacturing companies have found that MES can play a significant role in the effectiveness of the process management team and of MOM in general. For that reason, this book also includes a general overview of MES functionality and how it supports MOM in process management as well as production efficiency and CI, and how an MES is a major component of successful companies' Industry 4.0 initiatives. As part of the Industry 4.0 discussion, I explain why creating an Industry 4.0 strategy is vital to manufacturing and how using data provided by smart sensors, machine learning, and automation is an integral part of an Industry 4.0 initiative.

Overview of Company Planning

To initiate planning, Operations senior management must understand their current state of affairs (capacity, process management capability, production planning, etc.). Hopefully, senior managers have been following the activity of the departments under them and already have that *current state* visibility. On a separate track of activities, Sales and Marketing will look at the company's current market position and work with Product Engineering to better understand the characteristics of the product line (current and upcoming), and they will determine what changes are needed to maintain or improve the market position. They will then develop an action plan for the company to achieve the desired changes in their market position. Once Sales and Marketing have their *plan of attack* for market gains and Operations understands the current state, it is time for them to come together for sales and operations planning (S&OP). They will determine what must change in the current state of operations over the course of the next year or more to support the sales and marketing plan, or they must determine what must change in the sales and marketing plan because of things Operations cannot support (e.g., as a result of capacity or resource issues). This is considerably



This is an excerpt from the book. Pages are omitted.

2

CoE and Data-Driven Management

In Chapter 1, “Introduction and Overview,” I reviewed the planning aspect of manufacturing operations management (MOM), reflected on the importance of having data that is up to date and accurately presents an understanding of the “current state of affairs” in manufacturing management at the manufacturing floor level and the senior management level, and started to introduce the basic functions of a CoE. In this chapter, I discuss the aspect of data integrity in more detail and go deeper into the function of a CoE from the perspectives of data and process integrity. I also examine the changes in operations management resulting from the increased availability of data.

When interpreting the data from a MOM perspective, it is important to also understand that the information presented in MOM reporting represents a physical context of operations. Work-in-process reports represent the status of physical products that are moving through the production floor, inventory reports represent the physical material that is on hand, and resource status reports represent human resources and physical equipment that are available on the floor with the equipment’s actual physical state of operation. Part of ensuring that the reports provide accurate information regarding the physical status of manufacturing is to confirm that the data used to create these reports accurately models the physical entity it is representing. Of course, this is true for all aspects of manufacturing operations reporting, but reporting at the planning level (e.g., enterprise resource planning—ERP) is summarized and delayed to some extent (depending on the report) and therefore loses accuracy. Getting accurate data

models for these entities is critical for the integrity of the information reported from planning and from order execution, quality, facilities, and inventory management.

When companies try to compare the operations of one plant to those of another (or even one line to another), it is also important to ensure that the data used in reporting is consistent between the lines or plants. Then there is a need to interpret both the data and the reports similarly. Relating back to Chapter 1, without implementing a standardization program, a comparison of reports from one plant to those of another would offer little credibility.

Just as important are the transition of data from one operations level system to another via information technology (IT) interfaces and the continued correct interpretation of that data from one system to another. The difficulty, as touched on earlier in this chapter, is this: As data moves from the shop floor level (the equipment and production execution levels) to the MOM IT and enterprise systems (MES, ERP, and advanced planning systems), it becomes more aggregated and summarized. This aggregation tends to change the context and the accuracy of the information created using that data. Each system has created data objects (the collection of data structures that are used to represent a particular entity) to define an entity (e.g., an operation name) in the context that is common to the level of user for a particular system.

Let’s look at an example of a data object at different system levels.

In Figure 2-1, the term *Operation* on the ERP routing is compared to the term *Operation* in an MES. When defining Operation 1010 in the ERP, the data object would be defined to include all material, resources (and their utilization), and labor compared to the process *segment* of ASSEMBLY1 and INSPECTION1 of the MES routing. However, on

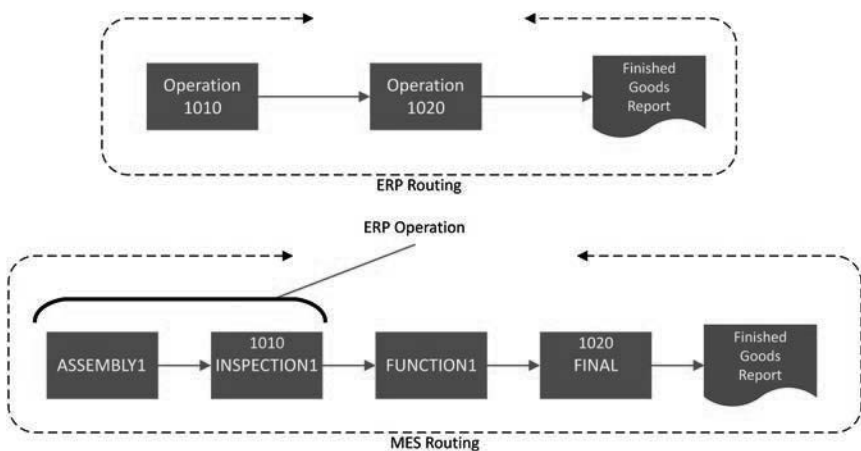


Figure 2-1. Operation data objects (ERP versus MES).

the MES routing, ASSEMBLY1 would be defined to include only the material, resource usage, and labor for that specific step in the routing, although the data objects would be referred to as an *Operation* in both systems. As data is transferred from one system to the other, the interface (and the people working with these systems) would have to recognize and properly interpret these differences.

The tendency for data (and the information created) to *drift* in integrity becomes greater if the company has multiple plants and the context of the data changes slightly from plant to plant.

As a result, it is important that the team designing the data models and interfaces for the system also have an in-depth understanding of the processes the systems are supporting. In addition, the team that is designing the processes that support the business and product manufacturing should have an in-depth understanding of the general information that will be needed to support the processes (from an operations point of view) and the data models that will be needed to create that information. To prevent confusion within the many groups of operations, a best practice within systems management is to develop a “data dictionary” to maintain the correct interpretations within the company.

In a recent industrial survey conducted by Tech-Clarity titled “The Manufacturing Data Challenge” (copyright 2020), of the 300 companies surveyed, 80% listed “consistent management of data in all plants” and “integration between equipment, plant, and enterprise” as being “important” or “critical” to data management. Of course, they are also critical to process management and business management. Ensuring that data from manufacturing and the reports created from that data are consistent throughout the manufacturing floor and across all plants requires implementing standards as discussed in Chapter 1. These include standards in the data models that represent the manufacturing floors, standards in the information or reports that are created to inform operations personnel of the “current state of affairs,” and standards in the management training to interpret those reports. Standardizing the data consistently across multiple plants and keeping it that way requires a dedicated team (i.e., a CoE).

What Is a Center of Excellence?

In Chapter 1, I introduced the CoE from the context of manufacturing operations. It is important to understand that a CoE for one industry (e.g., manufacturing) will be different from a CoE for another industry (e.g., consulting in general). In consulting, a CoE might be the expert-level knowledge for the field in which the consultants are consulting (e.g., experts at the inner workings of a particular MES application) and

3

Process Management, Continuous Improvement, and the CoE

Imagine that you have been hired by a discrete manufacturing company as a manufacturing engineer. Your first job is to define the process that is required to manufacture a new product. Creating (or documenting) a process covers a wide range of activities and includes things such as the sequence of steps that are required to make the product and the material that will be processed at each step. In other words, it covers how to build whatever subassemblies are required, how to attach those subassemblies or raw components to the main product, or how to use some of the bulk material as part of the processing. Documenting the process also includes defining what tools and equipment will be used at each step. As the manufacturing engineer, you have figured this out and understand the entire process of manufacturing the product. Now you are ready to start defining a production line . . . or are you?

One of the primary factors that makes manufacturing difficult to manage is *variation*. But why is variation such a problem? In the next section, I present a very simple

product, establish a simple process to manufacture it, and then dive into the many things that can cause variation within that process. I invite you, the reader, to review the processes that I have defined and look for issues that may be of concern for an actual manufacturing floor. Because there will always be some aspect of variation, effort must be made to determine whether specific kinds of variation are significant or not. When implementing a continuous improvement (CI) initiative, a great deal of effort must go into analysis to isolate the effects of each aspect of variation and determine whether the specific cause of variation is a concern. In this chapter, I discuss the aspects of manufacturing processes that can cause variation and provide an example of a controlled methodology for CI. I also discuss additional responsibilities for the CoE.

Let's get started.

Product BOM (bill of material):

- 2 in × 2 in × 1 in deep plastic case (qty. = 1)
- 2 in × 2 in × 1/4 in plastic lid (qty. = 1)
- 2 in × 2 in rubber grommet (1/8 in thick) (qty. = 1)
- #6 × 1/2 in Phillips wood screw (flat-head, self-tapping, zinc) (qty. = 4)

Tools:

- #2 Phillips screwdriver

Assembly Process:

1. Place the plastic case in the work area (open side facing up).
2. Place the rubber grommet on the edge of the plastic case (matching the edges of the case).
3. Place the plastic lid on top of the rubber grommet (aligning the screw holes of the lid with the screw holes of the case).
4. Using a Phillips screwdriver, manually insert and screw down each of the screws until tight to fasten the lid to the case.
5. Place the completed case in a holding bin next to the work area.

The flow diagram of the process is shown in Figure 3-1.

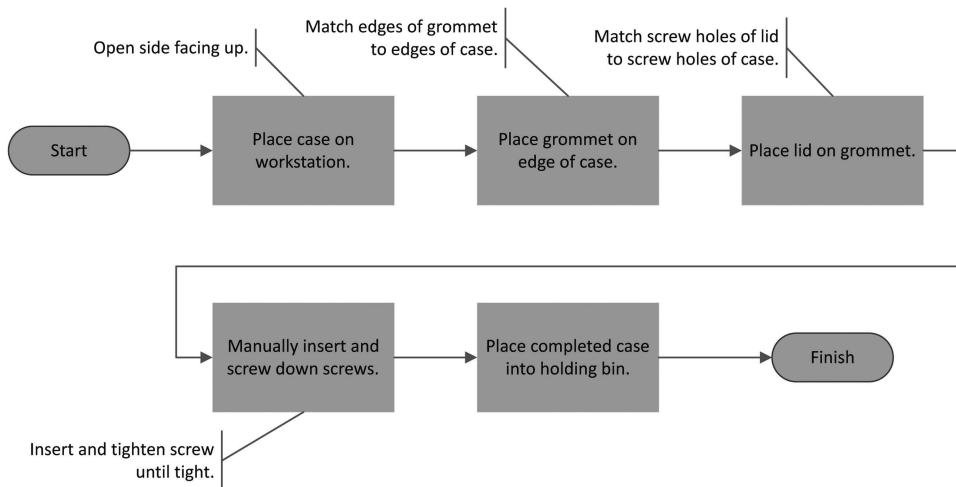


Figure 3-1. Simple process flow diagram.

One would not be faulted in thinking that the preceding instructions are pretty thorough and could be used to manufacture consistently.

However, one of the first issues that would arise relates to the instruction “screw down each of the screws until tight.” Just how tight is *tight*? This subjective term can mean many different things to production operators, and how tight the screws actually need to be, depends on the product’s application (where and how the case will be used). For example, if the instructions are for an electrical box for use indoors, just having the lid *snug* (which is another subjective term) may be enough. However, if this box is to be used underwater and is expected to be airtight, the “how tight” expression must be a lot more descriptive.

If the case is being used underwater, there would need to be a detailed expression of “how tight” which is usually a measurement of the amount of torque that is applied to the screws. To provide this instruction, the tool required is a torque driver and not just a Phillips screwdriver. With the instructions for *using* the torque driver, there is an additional process requirement to set the torque driver to the correct setting. But how accurate is the setting? When you set the driver to 0.2 ft·lb, for example, is that setting 0.2 ft·lb or 0.20 ft·lb (defining the resolution of the setting)? Another issue is that the torque driver may have the resolution in the setting, but is the setting calibrated against a national standard? Therefore, when it is set to 0.20 ft·lb, is it accurate and not 0.25 ft·lb when compared to a national standard?

This was supposed to be a simple process, and the instructions seemed good. What is going on here?



This is an excerpt from the book. Pages are omitted.

4

Industry 4.0 and Data Mining

If you have been part of the manufacturing industry in recent years, you have probably heard the terms *Industry 4.0* and *data mining*. So far, I have discussed process management and quality management issues and have reflected on the CoE as part of the management program. I have also discussed the changes needed in manufacturing management to be more “data driven.” But what is it about manufacturing that makes data-driven management so important, and why is Industry 4.0 such a significant part of that management?

Data Sets and Data Models

In the “Going from Symptom to Cause” section of this chapter, I discuss the difference between fixing an issue or implementing mitigation. It is always better to fix the root cause than it is to implement a mitigation strategy. However, there are times when a mitigation strategy is necessary. For example, mitigation might be called for when more investigation is required to determine the root cause and a control is needed in the meantime, or when it may simply be too costly to implement a root cause fix and a mitigation strategy is the only viable option. Whether it is part of a mitigation strategy or part of an investigation into a root cause, there is a need to know *when* something is happening.

Whether a nonconformance or a specific series of process characteristics occur, we need to be able to define what those characteristics look like. If the issue is physical, you can describe it in size, color, hardness, or some other physical aspect. However, when we want a computer system to find or detect something, we must be able to

describe what it looks like in data. Describing an instance of something from a data perspective requires looking at what is called a *data set*. When there is a commonality to several concepts, and as a result, their data sets share common characteristics, defining the structure of those common characteristics within their data sets is called a *data model*. For example, each time an oven drifts lower in temperature, there is a starting temperature, an ending temperature, and a rate of change in temperature. This data for a specific incident of drift is a data set. If we wanted a computer to detect the drifting of the oven temperature, we might describe it as “a negative change in temperature of 5°C or more over a series of 10 readings (the number of readings may represent a time duration),” this description would be the data model for detecting that change.

Building data models is not new. Scientists, statisticians, and other professionals have been analyzing data sets stored on paper (the earliest form of a database) and creating data models (usually in some form of mathematical equation) for a long time, long before the digital age. What has changed is the use of computers and electronic databases to store large volumes of data sets and the ability to quickly analyze these data sets to create and validate complex data models.

As computing power is becoming relatively cheap and commonplace, more detailed data sets are increasingly accessible, and programming and using data models are becoming much easier. Through the field of data science, we learn more about the interactions between different activities via analyzing data sets and then creating (and understanding) the interactions via much more complex data models. But what does all this mean to a manufacturing plant?

Manufacturing Characteristics and Why Data Mining Works

There are some differences between manufacturing for the process industry and manufacturing for the discrete industry (*Ok... when you get into the details, there are a lot of differences*), but the characteristics that make data-driven management so important are common to almost all manufacturing industries. The first characteristic is that unintended variation is bad. Some might say that variation provides a kind of uniqueness to each product and may be aesthetically pleasing. However, in manufacturing, each of those *variations* is an opportunity for product failure, and because failed products do not sell and can damage a company’s reputation, *variation should probably be avoided*. In extreme cases, the inability to control variation can cause a company to go out of business.

In defining a production line, many production steps are broken down into small segments that are each performed by a different operator or machine. When you remove

variation, you get a highly repetitive set of operations that combine to, hopefully, build the correct product exactly the same as all the previously built products and you minimize the likelihood of nonconformance. If there are manual steps in the process, the goal of the manufacturing engineer is (or should be) to cause the operators to develop muscle memory for these highly repetitive steps. This makes it easier for the operator to detect if something is different and possibly out of place. A good production operator will recognize the importance of this muscle memory (even if it is to allow them a chance to talk to others while on the line without making mistakes.) But if most manufacturing engineers understand this, where does the data relationship come in?

When all the operations and steps in the manufacturing process are mapped out, the result is a highly sequenced instruction that defines not only the process for production to follow but also all decision points, the criteria for making decisions, and a definition of the outcome of each step in the process. It is a “model” of the physical activity needed to successfully produce a product. The problem is that unless we have the entire process videotaped, we are not able to determine to what detail the process was followed. We then turn to computer systems. As we look for information technology (IT) and operational technology (OT) systems to replicate this physical model (both for process control and for data collection), it is important to be able to *define the physical model as a data model*.

With today’s technology, there are more and more ways to have sensors that can provide data that will then characterize each step in the process in greater detail. When all this detail is mapped out for each product’s serial number, we can see in the reporting (depending on how we visualize the data) the occurrence of small variations. For example, the reporting can show when a production operator got distracted for a moment and did not quite follow the process, or it can show when a machine that has been running for a long time is starting to drift in its repetition as a result of wear.

Recognizing that there are always going to be small variations that happen during a process, the manufacturing engineer must be able to determine whether these variations resulted in a nonconformance of some sort because many of these variations will not be substantial.

If there are a lot of small variations, it becomes harder to determine *which* variations are significant.

Hopefully, there is a limited number of variations that are significant in the process, but this will depend partly on the plant’s maturity in process management. And it is important for the manufacturing engineer to remain focused on the significant variations that are causing the most grief (remember the Pareto principle). If there are a lot of small variations, it becomes harder to determine *which* variations are significant, and as the focus of improvement moves to increasingly subtler variations, a combination

5

The CoE in Maintaining MOM/MES

In this chapter, I discuss key aspects of the ISA-95 series of standards and how they relate to an MES. In one form or another, there will be a team of people in the manufacturing and information technology (IT) departments that will have a major influence on selecting an MES application. This team will be mandated to become experts on how the MES application will influence the production floor. Therefore, developing this team into a full CoE can significantly help with an MES program in the long term. I also address some key information that a CoE must understand in selecting and maintaining an MES.

Manufacturing Operations Management

Chapter 6 includes a detailed discussion about the functionality of an MES from a manufacturing operations perspective. However, to understand an MES operationally, one must first understand the details of MOM... *(and, no, I'm not talking about your mother, but it is frequently pronounced the same way).*

There are a few industry points about MOM that must be clarified and some misconceptions that must be rectified. First, what does MOM mean? A couple of decades ago, a committee was formed by the International Society of Automation (ISA). It included some major manufacturing companies from around the world and some major enterprise software providers. They started to work on the ISA-95 standards in an effort

to help guide the manufacturing industry, software vendors, and consulting firms to create a common understanding of the generic processes that would be needed to manage manufacturing best practices and how manufacturing IT systems were to support those manufacturing management processes (or *activities* in ISA-95 terms). One result was a set of tasks and the relationships between those tasks (ISA-95 Part 3, *Activity Models of Manufacturing Operations Management*). To have a common format to describe these activities, the activity models were presented as a set of *Unified Modeling Language (UML) activity model* diagrams. The highest-level model is the manufacturing management activity model shown in Figure 5-1.

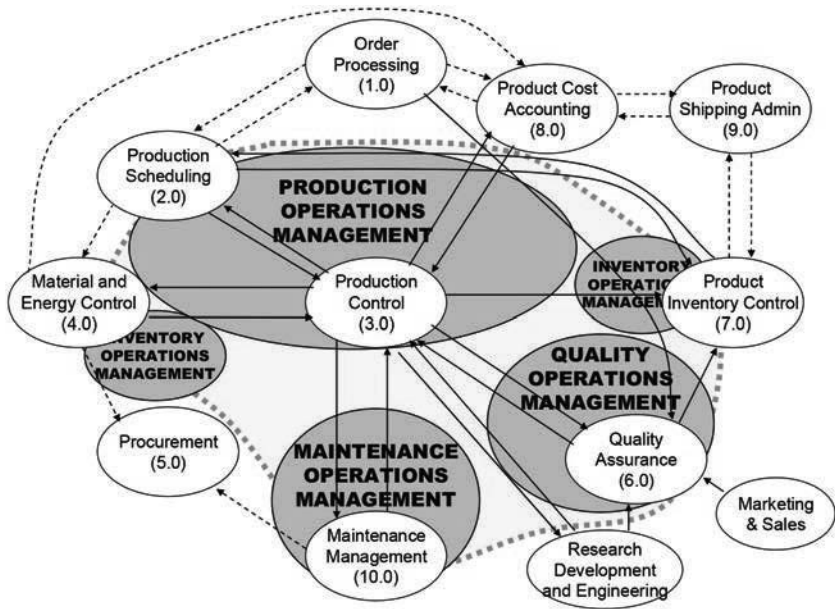


Figure 5-1. ISA-95 manufacturing management model.

Activity Models of ISA-95

This activity model presents 10 groups of tasks (activities) that are needed to manage a company’s manufacturing operations. It also includes interactions between research and development as well as marketing and sales, although these functions are not part of the operational perspective. Each numbered oval in the diagram represents a set of specific tasks that are grouped within the context of the company’s operations. In the ISA-95 activity models, relationships are indicated by arrows, that show *dependencies* between these groups of activities. A manufacturing company would use this model for the following purposes:

When an activity in the model is not defined by the company, it can be viewed as a gap in the company’s defined business processes.

Because it is not recognized in the company with a formal process, it is likely being performed in an uncontrolled and highly variable manner.

- Identify the need to specify business processes that may be missing within the context of these activity groups to support the company as a whole
- Define the roles of company personnel who will perform these activities
- Define the possible process-level interactions and communications (not to be confused with IT-level communications between systems) that are needed between groups (meaning the people in these groups must work together and talk to each other)

The model can also be used to help define the requirements that the company's IT systems would need to support. Whether these groupings represent any specific *department* in a company is not determined by the model. That is determined by how a company wants to structure the organization. However, if a company was to compare the model of its *internally defined business processes* to the ISA-95 manufacturing management model, it could indicate the need to define additional processes or add skills that are missing from the company's staffing.

One concern that a company may have is that when an activity in the model is not defined by the company, it can be viewed as a gap in the company's defined business processes. In all likelihood, the company has people who are performing that activity; however, because it is not recognized in the company with a formal process, it is likely being performed in an uncontrolled and highly variable manner.

On the IT side, a software vendor could use the model to plan for functionality that would be needed within the software packages and to define needed IT communication between groups of functionalities within the software.

Another part of the ISA-95 standards is a full set of data objects (ISA-95 Part 2, *Objects and Attributes*, which defines the data models related to processes). This is to be used by manufacturing companies to plan the data collection requirements in a process and by the software vendor to help define the schemas the software package will use in supporting manufacturing. Be aware that a full explanation of the ISA-95 Series of Standards is outside the scope of this book. The full definition of all the parts in the ISA-95 standard series is available at isa.org. ISA also publishes several books that provide guidance on applying the standard.¹

1. *The Road to Integration: A Guide to Applying the ISA-95 Standards in Manufacturing*, second edition, by Bianca Scholten and Dennis Brandl; *Manufacturing Execution Systems: An Operations Management Approach*, second edition, by Tom Seubert and Grant Vokey; *The MOM Chronicles: ISA-95 Best Practices Book 3.0*, Charlie Gifford, editor; and *The Hitchhiker's Guide to Manufacturing Operations Management: ISA-95 Best Practices Book 1.0*, Charlie Gifford, editor.



6

MOM and the Functionality of an MES

Chapter 4 touched on some of the important functionality of an MES. In this chapter, I take a deep dive into MES operational functionality. I also discuss the differences between MES designed for supporting process manufacturing and MES designed for supporting discrete manufacturing. Later in the chapter, I offer some details regarding integrating an MES to the enterprise level and to shop floor equipment.

MES for Process and Discrete Manufacturing

There are two primary reasons for the differences in MES for process manufacturing versus discrete manufacturing. The first is the relationship between the material to make the product and the conversion process used to manufacture the product. The second is the concept of cost savings in manufacturing in large quantities and how those quantities are reflected in the production process.

These differences drive differences in the type of equipment used and in managing production execution, and, therefore, the design of the MES capabilities that support these manufacturing models.

Some industries (e.g., meat production and semiconductor) have manufacturing models that may create variations in the examples provided in this chapter, but those industries will not be covered in this book.

Process Manufacturing

The two concepts outlined in the previous section, for the most part, play out in process manufacturing as taking a large quantity of a material (or in pharmaceuticals, a large quantity of a mix of materials) and processing that large quantity to create a bulk quantity of a product, then dividing the bulk quantity into smaller segments of the same material (or mix) that is sold. For example, if a pharmaceuticals manufacturer attempted to mix the required materials in a quantity small enough to create a single bottle of vitamins, the cost of material handling in such a small quantity would make production costs far too expensive. (Imagine trying to mix a bottle of materials in quantities measuring in milligrams.) Mixing in larger quantities and then separating the quantity needed for each vitamin pill is far less expensive and easier to control. This concept holds true for all products made via process manufacturing.

Figure 6-1 presents an overview of a food processing line that is similar in structure to many process manufacturing models. Like the pharmaceuticals example, the raw materials are processed and mixed in large volumes by equipment designed for that purpose (tomatoes are processed and mixed with spices to create a slurry of tomato sauce). As it would be highly impractical to process a single tomato at a time, all equipment in the line is designed to process material in large batches (in some cases, in a continuous flow of product).

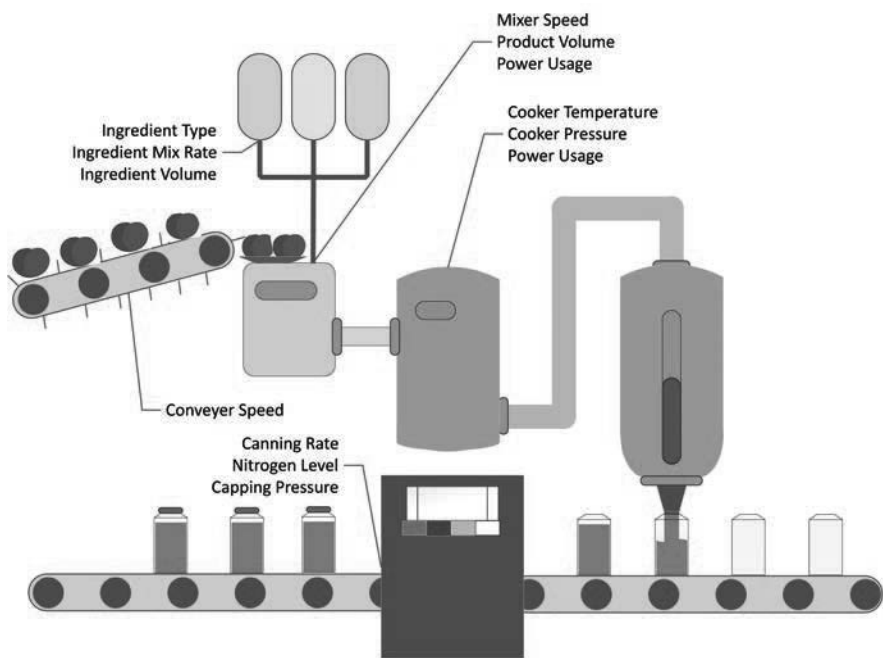


Figure 6-1. Overview of manufacturing in a food production process model.

With this process, it becomes impossible to determine which process characteristics that were affected by a single tomato or to identify a specific activity for a single bottle of tomato sauce. After processing, the large batches are dispensed into smaller units (bottles of tomato sauce) depending on the production order requirements, with each of the smaller units having pretty much the same characteristics. In this kind of manufacturing environment, the same batch of bulk material (the vat of tomato slurry) may be used to create end products in various sizes (e.g., 32-oz bottles or 120-oz bottles), and the quantity of each production unit size is controlled by its own production order. In this production model, the batch of bulk material is processed by a production line that has been set and dedicated to the batch. As a result, the batch ID of the bulk material is an important data element, as is the line that produced the bulk material. Because this information is needed for traceability and is recorded at the bulk material level, the smaller containers of the end product would be labeled with the batch ID or lot number of the original bulk material (the tomato slurry). As all the bulk material was processed by the same equipment and followed (more or less) the same process, the parameters for equipment operations are important over the processing of the entire batch. This context of equipment operations may be the same for multiple production orders, or any single order may have end-product containers (jars of tomato sauce) from different bulk batches. If some parameters of the process are out of specification during the bulk material processing, that is frequently a reason to scrap the entire batch of bulk material because separation of “good bulk material” from “bad bulk material” may be impossible.

So, how does this model of manufacturing affect the design of an MES application?

MES in Process Manufacturing

In process manufacturing, an important factor for consistent product is to ensure that the equipment that processes the large volumes of material operates repeatably. Whether the line is producing 32-oz bottles or 120-oz bottles, it is the relationship of production parameters to the bulk material that is important. As these pieces of equipment will sometimes perform a single operation for a relatively long period (possibly hours or days), the critical relationships are the operating parameters of equipment to the expected recipe parameters with little regard for the particular production order or the format of the end product to be produced (which size of bottles of tomato sauce). The recipe will define the specific equipment to be used, the parameters of the equipment to be set, and the volume of material (ingredients) to make a specific volume of the bulk product. In some cases, equipment may be designed to perform multiple operations in the recipe to reduce handling and moving bulk product from one piece of equipment to the next. Conveyor systems (or product piping) are commonly used to move large volumes of bulk product.

7

The CoE in Strategic Planning and Management

At the beginning of Chapter 1, I provided a brief discussion on sales and operations planning (S&OP), which many manufacturing companies use to align the operations activities with the sales and marketing aspirations. The purpose of S&OP is, of course, to ensure that the sales and marketing activities are being supported by the operations activities (which makes sense, if only more companies did it). In a manufacturing company, however, a wide range of strategic execution activities can be performed in operations, including inventory management and distribution, customer satisfaction improvement, and others. Other than customer satisfaction, I believe that the most significant activities will be related to manufacturing operations.

In this chapter, I review some strategic planning methods from a manufacturing company perspective and present explanations as to why it is important to have a CoE actively engaged in the strategic planning process.

In strategic planning, it is important that the planning be based on the capabilities of day-to-day operations (*business fundamental activities* in the Hoshin Kanri planning methods) and the more significant capability improvement plans (*breakthrough activities* in the Hoshin Kanri planning methods). At the same time, with manufacturing operations, it is necessary to plan day-to-day operations and capability improvement activities for both the manufacturing processes *and* the business processes. Although there is something to be said for initiatives to improve the methods for distributing

and managing finished goods inventory, for example, and designing a product with features that are needed by the customer (otherwise, the customer will not be interested in the product), if the planning and improvements in manufacturing operations are not effective, the other initiatives will fail as well. The quality of the product will suffer and/or the cost will be too high, leaving customers with little desire for the product. With that line of thought, some companies have well-designed products but still fail to deliver in terms of well-manufactured products. Quality, availability, and cost of the products are all directly affected by manufacturing.

The issue with the strategic planning process of S&OP is that although it drives reconciling operational capability with Sales and Marketing objectives, it does not define *what to reconcile* very well, and most companies focus on capacity (planned and needed) as the main area for strategic planning. In addition, many companies' strategic plans are frequently stated as financial objectives (this has also been my perspective, albeit based on limited observation), and top management then leaves it to department heads to define how those financial objectives are to be met. Frequently, activities in one departmental plan conflict with those in plans from other departments because each department head tries to drive their own objectives.

A couple of the key concerns about strategic planning and executing these strategic plans are ensuring that the information used is correct and up to date, and that the correct direction has been set in the objectives to be accomplished. Having clear visibility of performance measures "from the shop floor to the top floor" will help ensure that the planning and execution of the right activities have been established from the start.

When strategic planning is taken to the expert level provided by methodologies like Hoshin Kanri and/or balanced scorecard (BSC), the availability of data (and the integrity of that data) becomes even more important. (A further explanation of Hoshin Kanri and BSC is provided later in the chapter.) However, when looking at the strategic planning for the MOM environment, it is important not only to have data but also to have the context of that data understood. This is where using systems like an MES comes into play, and ensuring the context and integrity is the role of the CoE.

Real-Life Experience

Working as a newly appointed manufacturing manager, a colleague of mine (I will call her Jennifer) was participating in her company's planning cycle for the first time. In previous planning cycles for the company, the primary measures used were the cost per unit and total throughput of production. Based on this information, the company had plans to increase capacity via automation (which initially sounded like a good idea). In investigating the situation, Jennifer found that from a purely cycle-time point

of view, the production floor should have had no problems meeting planned capacity requirements with its current resources, and she had requested a hold on the decision to automate parts of the production floor. After a little further investigation, Jennifer showed that the production floor currently had a first-pass yield (FPY) of only 60%, and there was no means to determine the typical number of repair cycles needed to get a production unit back into the normal production flow. (The lack of numbers for repair cycles is a common issue for many companies.) Jennifer's presentation to senior managers showed that the issue with the production floor was not capacity but quality. Jennifer then suggested a change in the strategic direction based on stabilizing processes and improving quality based on FPY, a common quality marker for manufacturing. She also suggested running a series of design of experiment (DoE) initiatives on a single line to test this direction.

After taking several months for the initiative to stabilize processes (reducing variation) and several cycles of continuous improvement to bring FPY up to 83%, Jennifer found that the production floor was not only meeting capacity requirements but was also operating at just over 76% utilization. This demonstrated that with current resources, they had some wiggle room to meet current demands. After presenting the results of the DoE initiatives to senior management, the automation plan was put on hold (there may still have been a need in a couple of years), and a new initiative to roll out the process improvement and quality initiatives to the remaining lines was implemented.

The primary point of this real-life example is the importance of visibility and context in data and information for efficiency at the operations level and at the senior management levels for strategic planning.

My experience from years in manufacturing operations management has been that many department leaders and analysts do not understand the significance of ensuring the proper alignment of objectives from the department level to the mandated objectives of the senior manager's strategic planning. I have had colleagues ignore strategic directions from senior managers two to three levels higher and start on initiatives without considering that they were in direct conflict with the company strategy. Their line of thought was that it was (in their opinion) "a better direction to take." The issue with this mismatch is that the senior management may or may not have the right strategic direction, but they are responsible (and accountable) to stockholders for the company's direction. By not following the corporate strategy, my colleagues were causing confusion in the results of any reporting measures for the strategy (like any variance in process, they were adding noise to the reporting results) and therefore making it harder for senior management to determine whether the strategy was working or not.

In the last couple of decades, a few strategic operational planning methods have been developed. Most of them were derived from two of the more prominent methods: Hoshin Kanri planning (created from the Lean initiatives) and BSC (originally developed by Robert Kaplan and David Norton and published by the *Harvard Business*



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8

Connecting the Dots

In previous chapters of this book, I discussed what a CoE is, how a CoE can be structured as it relates to different industries (particularly a manufacturing floor), and different methods of introducing a CoE into a company (e.g., developing a CoE as part of other initiatives like Lean or ISO-9000, or as an MES implementation). I have also presented several topics with the intention of providing insight into the core of each of these topics as it pertains to manufacturing and MOM.

In this chapter, I expand on the subjects covered earlier in this book and describe industry best practices that I have found useful and *why* they are considered best practices.

Is It Best Practice or Common Practice?

The first issue I want to clarify is the difference between *best practice* and *common practice*. I have attended far too many presentations from consulting companies describing ideas they refer to as *industry best practices*, only to find that they were simply common practices within that industry. Usually, the so-called best practice was actually a common practice used to take a shortcut in process or product traceability management. The shortcut would tend to summarize information (and lose details of that information) but because everyone used the shortcut, it was considered acceptable to the industry.

An example of a *common practice* in discrete manufacturing is using “phantom” bills of material (BOMs). In this scenario, a subassembly must be completed before it is assembled into the main product. However, the subassembly only contains a few

components, so the assembler who installs the subassembly is usually tasked with making the subassembly first at their workstation, one at a time, before assembling the product. At the planning level, the material and processes for making the subassembly would be included in the activity that accounts for installing the subassembly, i.e.: the planning BOM at the enterprise resource planning—ERP level would include the consumption of material, labor, and any other minor resource used to make the subassembly in the ERP-level operation and to install the subassembly. In this scenario, all aspects of making the subassembly are considered a “phantom” of the higher-level assembly. The reason for using phantom BOMs is to simplify planning a production run. One of the issues with phantom BOMs is the potential of losing visibility of the subassembly quality before it is assembled into the product. In some cases, the process of putting together the subassembly first is so reliable that it is not worth worrying about, but this is not always the situation.

In this case, *best practice* is achieved when interfacing MES and ERP systems. At the ERP level, the material and labor are included at the higher product level but are identified as “phantom material.” When the planning BOM is sent to the MES (or, in some cases, validated against a manufacturing BOM), the *phantom level* (material and process) is separated into a specific process at the MES level.

Change (how the floor changes and the rate of that change) is unique to each plant floor and depends on how willing the manufacturing floor culture is to accept change.

Understanding the difference between best practice and common practice can be critical to quality management and is essential at the CoE level. It is also important to ensure that any consulting firms hired understand this difference. If a team member (whether part of a consulting team or

internal for any initiative) starts talking about a “best practice,” it is worth challenging them to explain *why* it is a best practice; if they are unable to explain the *why*, they may be describing a common practice instead.

The Maturing Manufacturing Floor: Changes Post–MES/CoE Implementation

In a few chapters, I introduced directions for change “as the company matures” after implementing an MES and/or a CoE, but what are the changes that a company experiences?

An important aspect of change a manufacturing floor will experience is that change (how the floor changes and the rate of that change) is unique to each plant floor and depends on how willing the manufacturing floor culture is to accept change. In the

years that I have been working as a consultant in the MES/MOM sector, I have met company employees who found that change is exciting and helps to make the job more interesting. I have also met employees who resisted change “tooth and nail” (as the saying goes). The number-one rule that must be accepted is that change is inevitable. For people who are associated with a changing environment in one way or another, I offer the words of a colleague of mine: “Change is going to happen, so you must either lead, follow, or get out of the way.” With any initiative (e.g.: Lean, ISO-9000, MES, or CoE), there will be changes. Some of the changes will be simple process changes and easy to adopt. A company’s ability to do well with these initiatives is not related to which MES is implemented or whether it is implementing Lean or Theory of Constraints; the companies that succeed in implementing an MES (or any other initiative) recognize and help implement a change in *culture*.

When a manufacturing floor implements formalizing a process (by implementing an MES, CoE, or any process mapping methodology), the first hurdle the initiative’s team will face is the recognition of how chaotic the manufacturing floor is at first. Without a defined process (and the constant verification of that process) using formal process management methods, the production operators on the manufacturing floor will self-optimize. They *will* develop through repetition a process of doing the work that “works best for them at that operation.” In reality, it is not an *optimized process* but a *familiarized process*, and each production operator will *familiarize* a process in their own way. Therefore, when the process documentation begins, there should be no surprise about how much variation a process has. It is important to capture (document) these variations and why they are performed.

While defining and implementing the initial process, the key aspect is to make the process repeatable and to gain an understanding of that process’s characteristics (capacity, fallout, cycle times, etc.), as discussed in Chapter 3. As part of the cultural change, the production operators must learn to follow a process as diligently as possible and not fall back on their “familiarized” process. This is an area in which an MES can help by ensuring that steps are taken in a specific sequence. Because this is likely to be the first time that detailed process characteristics are measured, the next hurdle for process formalization is accepting the characteristics the MES reports. There will be attempts to discredit the characteristics that have been recorded, and in some cases, the method of data collection and/or the data interpretation may actually be wrong. The MES does not record and report on the correct data; *it reports on the data it is told to report on*. If there are errors in the data collection and interpretation, then there must be an effort to improve the data collection or the interpretation—*do not get rid of the system or process*.

It is only when a process is repeatable *and* reproducible that it is considered stable.

Abbreviations

AI	artificial intelligence
ASN	advanced ship notice
ATO	assemble to order
BOM	bill of material
BPM	business process management
CI	continuous improvement
BSC	balanced scorecard
CMM	capability maturity model
CoE	Center of Excellence
COO	chief operating officer
COTS	commercial-off-the-shelf
DHR	device history report
DoE	design of experiment
ERP	enterprise resource planning
FPY	first-pass yield
HMI	human-machine interface
IIoT	Industrial Internet of Things
ISA	International Society of Automation
IT	information technology
KPI	key performance indicator
LCL	lower control limit
LIMS	laboratory information management system
LSS	line-side stocking
mBOM	manufacturing bill of material

Glossary

BOM: bill of material. A list of materials and the quantity of each that are used to make one unit of a product.

BOP: bill of process. A list of operations and/or tasks that must be performed to make a production unit.

blue printing. The part of an implementation project that analyzes the current state of a manufacturing plant's operation and determines the vision of a future state. It then compares that current state to the vision of the future state and creates a roadmap of changes to achieve the future state.

DFM: design for manufacturing. A design methodology that focuses on designing a product in a manner that optimizes the capability to manufacture the product.

ERP: enterprise resource planning. The aggregate of processes, systems, and data used to manage the ongoing capabilities of a company as a whole (or enterprise).

IIoT: Industrial Internet of Things. The interconnection of sensors, instruments, and other devices networked together with industrial applications running on various computing devices to support manufacturing, energy management, and other industrial purposes.

IoT: Internet of Things. An extension of Internet connectivity into physical devices and everyday objects (cyber-physical devices). These devices are embedded with

electronics, Internet connectivity, and other forms of hardware (such as sensors); they can communicate and interact with other devices over the Internet and can possibly be remotely monitored and/or controlled.

ISA-95: International Society of Automation ISA-95 Series of Standards. These standards contain an information technology (IT) model linking the processes of the shop floor to the top floor of manufacturing.

just-in-time. A process in which manufacturing scheduling is tightly managed to minimize any gaps in time from the launch of production and delivery of any unit to the expected demand of the end product.

LSS: line-side stocking. An inventory stocking methodology that places small quantities of material stock at a workstation-level inventory location. It is used to ensure easy access to material that will be needed within a short time window.

M2M: machine-to-machine. Early concepts of IIoT used to reference the communication events directly between two or more machines without a central database system.

mBOM: manufacturing bill of material. A list of the raw material (components) required to manufacture a single unit of the product being manufactured, including data that is important to the manufacturing process, such as operation of consumption, process, or genealogy data to be collected.

MES: manufacturing execution system. A system used to monitor and control the activities and resources of the manufacturing floor in a company (or enterprise).

MESA: Manufacturing Enterprise Solutions Association. An international not-for-profit community dedicated to improving business and manufacturing practices through optimized application and implementation of information technology (IT) and best management practices.

MOM: manufacturing operations management. The aggregate of processes, systems, and data used to manage the ongoing activities on the manufacturing floor as defined by the ISA-95 MOM activity model.

NPI: new product introduction. The aggregate of processes, systems, and data used to manage the ongoing activities of bringing a product from concept to market.



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