



# THE POWER TO KNOW® and innovate in manufacturing

## Yield management within a service-oriented architecture

Although manufacturing is very diverse, the concept of “yield” is of central importance because it affects value delivery very directly. The need to manage and improve yield requires us to deepen our understanding of the physical processes involved in manufacturing a product. Even in what appear to be simple settings, this is a complex problem, since it involves the interplay between product design and the production system (a specific set of processes supported by a chosen equipment base).

In this article I look, from a process perspective, at how so-called “service-oriented architectures” can support an enterprise-wide, integrated yield management strategy in a manufacturing company, fostering innovation and greater competitiveness.

### Value is yield

A simple but useful form of expressing value is:

$$\text{Value} = \frac{k_1 * \text{Quality} + k_2 * \text{Speed} + k_3 * \text{Flexibility}}{\text{Cost}}$$

This is attributed to Edwin Artzt of Proctor & Gamble<sup>1</sup> and is intended to relate to the “total” product (so that “quality” should be understood to contain elements of reliability, the capability of a product to remain fit for use). The coefficients  $k_1$ ,  $k_2$  and  $k_3$  define a value-based competitive strategy specific to a particular manufacturing niche. Note that although “yield” is not explicitly present, *it directly affects all of the terms that are present*, because:

- Higher yields mean lower *cost* (reduced scrap and waste).
- Higher (first pass) yields mean greater *speed* (no “hidden factory”).
- Higher (first pass) yields usually mean higher *quality* (right first time is best).
- Higher yields usually mean greater *flexibility* (less dependency on the equipment used).

The management of yield is important from the small scale (commissioning a new piece of equipment or increasing plant capacity) through to the large (introducing a revolutionary new product that requires a completely new production system). Also, although manufacturing is often portrayed as “cranking the handle” and therefore in a quasi-steady state, it is usually quite the opposite, being the sum total of many continual changes, some planned and some unplanned. Each of these changes, from the small to the large, can pose a threat to sustaining high, predictable yields: Even the changes that *are* planned often carry an uncertain level of risk, because yield is to some extent the sum total of everything that happens in manufacturing, and our knowledge of this must be imperfect. So, given that acquiring new knowledge is often painful and expensive for a variety of reasons, an important question is, “How can we develop and implement a learning strategy to safeguard high, predictable yields in manufacturing?”

<sup>1</sup> Edwin Artzt, Proctor & Gamble Quality Forum VIII, October 1, 1992.

## Process centering and innovation

In quality management, a consensus seems to have emerged about the usefulness and effectiveness of the so-called “process-centered” approach, supported by some kind of horizontal organization. A key idea of process centering is that the process is the fundamental management construct, and that management should be of the *commitments* made (either explicitly or implicitly) between customers and suppliers. In the case of managing yield, such commitments are usually expressed in terms of design, specification or engineering limits, and variations with respect to these limits.

by retroactive problem solving or by proactive improvement, the challenge remains the same, namely to use data to learn more about the system of production, the product design, and the interaction of the two. In this sense, problem solving and improvement are opposite sides of the same coin, and therefore simply different facets of an “innovation process” that should run in parallel with both TTM and TTC to safeguard yield. At the risk of sounding pessimistic, I will use the language of “problems” rather than of “improvement” in what follows, because, sadly, this is probably more familiar.

The panel lists some of the characteristics of data-driven problem solving. Of course, once some plausible relationships are established by inspecting and interacting with the data in the right way, follow-up studies can be carried out as required. The most powerful approach here is known as design of experiments or DOE. Essentially, given a set of objectives, DOE methods can explore the opportunity space in the most powerful and efficient way, learning the most with the least investment of resources. Indeed, DOE in design innovation continues to be an emerging application area, with the promise of providing manufacturing yields that start higher and are more stable.

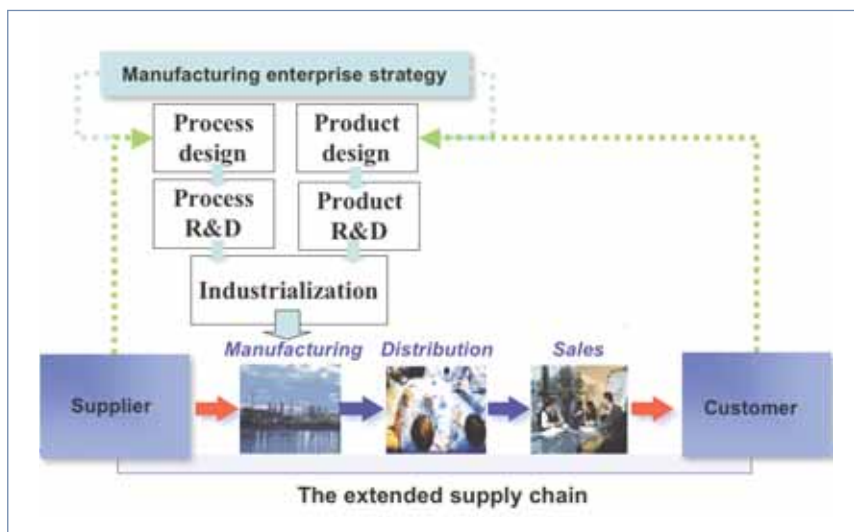


Figure 1: How do products originate?

Figure 1 shows schematically how new products originate. Ignoring the nuances of specific niches in manufacturing, we see two macro processes: One runs from top to bottom (variously called “time to market (TTM)” or “design and develop”), and one runs from left to right (“time to customer (TTC)” or “promise and fulfill”). Although useful, this picture is too simplistic, and in a crucial way, because it does not recognize the need for a learning strategy, as mentioned above. Note that learning, sometimes expressed as “know-why” rather than “know-how,” is intimately related to the notion of innovation: Whether driven

## Data-driven problem solving

The key point about problems is that there is no algorithm that is bound to find “the” or even “a” solution. Therefore, the best we can do is to use data to suggest clues and generate plausible hypotheses about why the yield has dropped or become more variable. Luckily, statistical techniques are very well suited to studying patterns of variability, so it is an unfortunate and well-documented accident of history that much of statistics focuses on the somewhat different problem of “hypothesis testing” rather than the “hypothesis generation” required to tackle yield problems.

Characteristics of data-driven problem solving:

- Low rather than high level of prior knowledge.
- Unfamiliar rather than familiar data context.
- Inductive rather than deductive.
- Exploratory rather than confirmatory study.
- Analytic rather than enumerative (Deming).
- Hypothesis generation rather than hypothesis testing.
- Unfolding rather than prescribed analysis workflow.

## What constitutes “a problem” anyway?

Managing yield has two aspects:

- a) Understanding, controlling and, if necessary, reducing the variation in characteristics in relation to various sets of limits.
- b) Understanding relationships between characteristics.

Indeed, we know we have a new problem precisely when the “actual” (the recent values of a characteristic) falls short of the “plan” (the various limits associated with that characteristic). Therefore, just to keep the status quo, any yield management framework has to pay careful attention to the definition and maintenance of limits, and to the associated alerts. However, there is also a deeper question here, namely, “Where do the limits themselves actually come from?” This is particularly important because in many, or even most cases, such limits are set without an adequate knowledge of b) above.

There are two possible ways to deal with this:

- To provide manufacturing with better limits from the start through innovations within the TTM process.
- To provide manufacturing with better limits as yield dependencies are learned through innovations within the TTC process.

Both have a role to play.

### An integrated yield management framework

We can now list some of the desirable characteristics of an integrated yield management framework:

1. Given that yield is the sum total of everything that happens to a product during manufacture, a yield management framework should provide an integrated view of all the data relating to product design and the system of production. To support the necessary learning and innovation, the means of providing this integration must be flexible and adaptive rather than monolithic (not least, because we may not know specifically which data we need when we start a problem-solving effort).

2. A yield management framework should also include a wide repertoire of exploratory techniques to allow the problem-solver to interact with this integrated data view, looking for the clues it contains.
3. The framework should provide a flexible system to calculate, manage and store the various sets of limits that process centering requires.
4. It should include a wide repertoire of statistical techniques to quantify the patterns of variation with respect to these limits.
5. It should have an automated alerting or early warning agent that flags exceptions when limit violations occur.
6. Finally, the framework should include state-of-the-art design of experiments (DOE) capabilities to explore and innovate efficiently within the opportunity space.

### Service-oriented architectures

Probably not by accident, the emergence and acceptance of the process-centering paradigm has been mirrored in the information technology world by the development of so-called service-oriented architectures (SOAs), a style of information systems architecture that enables the creation of applications by combining loosely coupled and interoperable services. The formal definition that allows the services to interoperate in a way that is independent of the underlying platform and programming language (for example, Web Services Description Language, WSDL) mirrors process centering; the interoperating services are the means to embody the contracts between customers and suppliers.

Although real-world adoption of these architectures will no doubt be pragmatic and incremental, it should be clear that SOAs can provide a more integrated, far-reaching and powerful yield management framework than

those typically in use, especially when the TTC process is disaggregated (see particularly characteristics 3 and 5 above).

### Summary

Yield management and improvement is central to any manufacturing company; it always has been. Recent advances in SOAs, along with the development of more effective tools that allow problem-solvers both to visualize and interact with highly dimensional data, and to explore the opportunity space efficiently, hold the promise of truly integrated yield management spanning the entire TTM and TTC process. The SAS Enterprise Intelligence Platform, which includes SAS/QC\* (Quality Control) software, interoperating with SAS client software such as SAS Enterprise Guide\* or JMP\*, allows you to make a rapid start with this approach today. Whatever niche you work in, SAS is the only single vendor that gives you THE POWER TO KNOW\* and innovate in manufacturing. ■

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# BIO

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