

QUALITY QUANDARIES

Comparing Nonmanufacturing with Traditional Applications of Six Sigma^{*}

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The Six Sigma approach has in the past been predominantly used to improve manufacturing processes. However, Six Sigma is now increasingly applied to a wide variety of nonmanufacturing operations also. This is an important development—there are potentially more benefits to be achieved in those areas than in traditional manufacturing, where decades of good work have already paid off.

The key to understand how Six Sigma can be applied more broadly is to recognize that nonmanufacturing operations are also processes; they process inputs from suppliers and provide outputs to customers. Consider, for example, accounting. A company's accounting department receives numbers and other information from internal suppliers (departments), processes the data and provides weekly, monthly, and quarterly reports (products) to customers (key managers). The accuracy of these reports, their clarity and timeliness, are primary quality characteristics. Any quality problem concerning the reports can have serious adverse consequences, often much more so than similar quality problems on the factory floor.

In this column, we will discuss the use of Six Sigma in nonmanufacturing processes/operations by reviewing

eight projects conducted in Dutch industry and facilitated by a team from the University of Amsterdam. The projects are listed in Table 1. In our discussion, we will try to highlight how these nonmanufacturing projects compare with more traditional applications of the Six Sigma methodology. It is our hope that this will help practitioners see that, with only minor modifications, Six Sigma can also be applied in nonmanufacturing.

A BRIEF OVERVIEW OF SIX SIGMA

Juran^[1] stated long ago, “All quality improvement takes place project by project and in no other way.” Chronic problems will linger unless they are put on the agenda and scheduled as projects for improvement by upper management. To make sustained progress it is widely recognized that projects should follow a logical sequence of steps: first define the project, then diagnose the problem followed by a proposed remedy, check that the remedy is effective, and finally institute controls to hold on to the gains. This simple logical structure, applied for centuries by country doctors, is similar to the Shewhart cycle of Plan, Do, Check, Act discussed by

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Table 1*A Sample of Six Sigma Projects from Different Business Areas*

Project	Business Problem	Quality Characteristic	Department
1	Transport costs	Incomplete deliveries	Logistics
2	Cost of absenteeism	Time of sick leave	Human resources
3	Energy costs	Energy expenditure	Environment
4	Costs of ingredients	Price of ingredients	Purchasing
5	Customer satisfaction	Response time	Service & maintenance
6	Product demand	Cycle time	Manufacturing
7	Inspection costs	Defect rate	Manufacturing
8	Warranty claims	Product performance	Manufacturing

Deming^[2] and is incorporated in the Six Sigma DMAIC sequence of Define, Measure, Analyze, Improve, and Control shown in Fig. 1.

We will use the five phases of Six Sigma to discuss the differences and similarities we have observed between traditional manufacturing and nonmanufacturing projects. Each of the eight projects in Table 1 was selected using the following criteria.

- Is the project related to a business or a customer problem (e.g., quality, productivity, reliability)?
- Will the project reduce defects, scrap, and rework (e.g., preferably more than 80% reduction)?
- Will the project deliver bottom-line results (e.g., more than \$150,000 on an annual basis)?
- Does the project have a high likelihood of being successfully completed on a tight time schedule (e.g., within 5 months)?

The projects were assigned to and led by carefully selected employees, who received intensive Black Belt (BB) training in the Six Sigma technology while working on the projects. The training, spread out over a four-month period, consisted of four one-week modules structured around the themes of “Measure”, “Analyze”, “Improve”, and “Control.” Once the selected employees had completed the training and successfully finished two projects, they received the title BB.

A SHORT DESCRIPTION OF THE PROJECTS

A brief introduction to the projects is in order. By nonmanufacturing, we mean any business process that does not produce a physical product but directly or indirectly supports the overall business mission. So defined, nonmanufacturing includes a broad spectrum of activities such as sales, marketing, after sales, service, payroll, provision of utility services, transportation, etc.

For each of the eight projects in Table 1, we have listed the most important quality characteristics and the related department.

In Project 1, the overall objective was to reduce transportation costs. Initially, several quality characteristics were considered such as the number of unnecessary express deliveries and the number of paid deliveries. However, a Pareto analysis indicated that the number of incomplete deliveries was the most costly category. The objective of Project 2 was to reduce cost of absenteeism. An analysis revealed that an excessive frequency of sick leave was a problem in certain divisions of the company. Thus, sick leave was the metric used to gauge the performance in this project. Project 3 was concerned with the reduction of energy costs. The focus was quickly

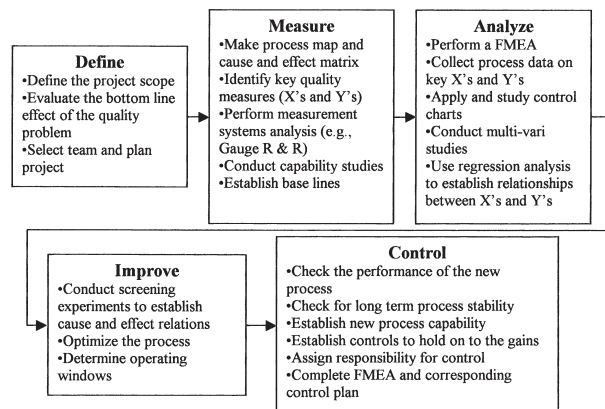


Figure 1. A schematic overview of the Six Sigma DMAIC process and associated tools.

shifted to the energy expenditure of air pressure compressors measured in kilowatt-hours per day. Project 4, conducted under the auspices of the purchasing department, was concerned with reducing costs of ingredients of ready-to-eat meals. In trying to select cheaper ingredients, it was required that the taste, smell, and appearance be comparable to the current meal. The service department in the company, where Project 5 was conducted, provides information about the products including complaints on response time. Thus, the focus of this project was on how to improve customer satisfaction. In a market that is rapidly growing, reducing cycle time of the production units is key to satisfy the market demand in Project 6. Inspection costs of a certain company were high because of the application of 100% inspection. Statistical sampling plans may be successful if defect rates are reduced drastically. This was the reason Project 7 focused on reducing inspection costs. By studying a company's warranty claims, it turned out that a component of a product had an excessive field failure rate. The component itself was an assembly of smaller components. Decreasing the failure rate reduced the warranty claims in Project 8.

On the basis of this sample of eight projects, we will discuss how nonmanufacturing Six Sigma applications compare to more traditional manufacturing applications. The discussion is structured around the five phases: Define, Measure, Analyze, Improve, and Control.

COMPARISONS: THE DEFINE AND MEASURE PHASES

Six Sigma is fundamentally a quantitative and analytic approach to quality improvement. However, when comparing manufacturing with nonmanufacturing applications, we have observed a difference in attitude towards using quantitative approaches. In manufacturing, it is common to measure the performance of products and processes. In nonmanufacturing, it is often a struggle to develop and apply measurements of quality. In manufacturing, the improvement of quality is always a primary concern. However, in nonmanufacturing, quality goals are often not even considered. For typical manufacturing type goals, the assignment of responsibility and accountability is clear and explicit and assigned to a specific manager and managerial unit. In nonmanufacturing, this is often not the case. Further, the line of responsibility is often blurred. For instance, the sick leave project (2) was conducted under the auspices of the Human Resources Department and the energy

costs project (3) by the Environmental Department. However, the departments that logically were in a position to do anything about the problems were not held responsible for poor performance.

The confusion of goal and responsibilities is often revealed when flowcharts or process maps are developed in the Measure phase. In manufacturing, it is common to find flowcharts or process maps already available before a Six Sigma project is initiated. Of course, they may need minor upgrading. However, in nonmanufacturing, flowcharts or process maps are typically completely absent. It is, in fact, common that those associated with a particular job do not think in process terms. Hence, it does not occur to them to apply process maps. Fortunately, that means quick gains are often possible because the process maps often generate new insights and resolve many problems.

In nonmanufacturing projects, the relationship between the business metrics and associated quantitative quality characteristics are frequently straightforward. Projects 1 through 5 provide good illustrations of this. For each of these projects, the metric was a count that was relatively easy to convert to monetary terms. This is in sharp contrast to manufacturing. Here there is frequently, at least initially, no clear and direct link between economic metrics and relevant quality characteristics. For example in Project 8, on the field failure of a certain product, considerable work was required before a link between the warranty costs and product quality characteristics was established. Many projects in manufacturing are related to improvements in product performance and the relationship to bottom-line business performance is not immediate.

In manufacturing, measurements are typically repeatable and it is common in the measurement phase to perform a gauge repeatability and reproducibility analysis. In Project 7, one of the more manufacturinglike projects, the defect rates were based on visual inspection of product appearance. Thus, each product could be evaluated repeatedly and the consistency or repeatability of the judges could be determined. However, nonmanufacturing measurements are typically not repeatable. For example in Project 1, the quality metric was the number of incomplete deliveries and in Project 2, it was the number of days on sick leave. Of course, it is possible to recount but strictly speaking, the measurements cannot be repeated. Typically, for this type of measurements, validity is much more an issue than repeatability. As illustrated with Projects 1 and 2, the metrics in nonmanufacturing typically are counts. Thus, it is often not appropriate to use traditional measurement system

analysis (MSA) techniques intended for continuous data. However, as was vividly illustrated in the U.S. Presidential election, 2000, counting is not easy. One important issue is the careful development of operational definitions (see Deming^[21]). For example, what does it mean that a delivery is incomplete? Or what constitutes a warranty claim? Clearly, we need to define explicitly and operationally the quality characteristics if the metrics are to be meaningful. In nonmanufacturing, the measurement analysis is therefore often a more general problem of data quality. Six Sigma should be extended to include verification of validity of measurements when used in nonmanufacturing.

In manufacturing, specification limits for quality characteristics are often specified by external customers. Tolerances are typically intervals determined through knowledge and experience and the objective is to guarantee that processes at the customer's end function smoothly or products may be safely used. However, in nonmanufacturing, even if they exist, specifications are often one-sided. In fact, reaching a target often makes more sense. For Projects 1 through 5, the goal was to minimize the quality characteristics; "hard" specification limits were not available or possible. Specifically, for Projects 1 and 2 the obvious target was zero. Of course, it may make sense temporarily to set upper limits for such quality characteristics to signal that any number above the limit is unacceptable. Such limits should then be reevaluated and revised on a regular basis.

In the Measure phase, capability and performance studies are conducted to determine the baseline useful for comparison with future improvements and to verify that the problem is adequately made operational, and even to be able to set objectives intelligently. However, without hard specification limits, capability and performance measures do not attain the same meaning as in manufacturing. Thus, for many nonmanufacturing projects, we frequently use measures of location and variation for the baseline rather than Cpk's.

The goal of Six Sigma is sometimes to reduce short and long-term variations. These concepts are relatively well defined in manufacturing. Short-term variation is commonly defined by batches, shifts or, more generally, by rational subgroups. Long-term variation includes the variability within and between several subgroups to indicate the overall performance of the process. In nonmanufacturing, we often deal with individual measurements. Hence, subgroups may be defined by a certain time interval, e.g., a week or a month. If additional variation occurs due to the differences in subgroups, it will require further analysis of the

underlying reasons. In some cases, seasonal effects can explain differences, as was, for example, the case for Project 2 and especially 3.

Another issue is that data from nonmanufacturing processes exhibit pronounced nonnormality, often because they are counts. In some cases, such nonnormality can be mitigated with transformations; for example, the square root for counts or the inverse sine of the square root function of proportions.

COMPARISONS: THE ANALYZE PHASE

A key part of the Analyze phase is to discover and select factors (X) that potentially influence the quality characteristics (Y). Although the methods may be similar in manufacturing and nonmanufacturing, the factors are often of a different nature. In manufacturing, many factors are typically either controllable "knobs" on a machine or uncontrollable but quantifiable noise factors such as shift-to-shift or machine-to-machine differences. For example, for Projects 6 and 7, the most manufacturinglike projects in our sample, the predominant sources of variability were the machine parameters influencing cycle time and the defect rate influencing inspection costs.

In nonmanufacturing, uncontrollable or nonquantifiable factors are typical. For example, in Project 1, concerned with incomplete deliveries, a number of psychological factors caused the mistakes. In Project 2, personal, family, psychological, and sociological factors influenced the sick leave. In Project 3, malfunction of the air pressure system caused leakage that accounted for most of the wasted energy. Finally, for Project 5, the amount of incoming requests increased the response time of the service and maintenance personnel. Many of these noise factors were hard to define operationally, making this a challenge we seldom encounter to the same degree in manufacturing.

COMPARISONS: THE IMPROVE PHASE

In the Improve phase, functional relationships between quality characteristics (Y) and the factors (X) selected in the Analyze phase are established through experimentation. Projects 6 through 8 all applied fractional factorial experiments to determine the effects of factors on the quality characteristics. New settings of these factors resulted in a better performance.

In nonmanufacturing, formal experimental design methods are typically less applicable. Part of this is

because we lack good examples. With creativity it is often possible to design even very fine experiments; the recent papers by Almquist and Wyner^[3] and Thomke^[4] provide a few examples and may signal an encouraging trend given their publication in *Harvard Business Review*. However, speaking in general terms, improvements in nonmanufacturing are typically realized by eliminating negative influences of uncontrollable and nonquantifiable noise factors through intervention in the process. Personal interviews with frequently absent employees led to a change in attitude and a substantial decrease of sick leave in Project 2. Systematically eliminating leakage in Project 3 reduced the energy expenditure. On the other hand, Projects 4 and 5 both used statistically designed experiments. In Project 5, data mining and regression were used to discover relationships between response time and the number and type of request, the number of personnel and their experience. In Project 4, different combinations of less expensive ingredients were investigated to maintain the same quality of the products.

COMPARISONS: THE CONTROL PHASE

In the Improve phase of Six Sigma, operating windows for the factors are established for use in the Control phase. If the key input factors (X) stay within these windows, it is expected that the performance of the quality characteristics (Y) will exhibit only minor variability around the intended target, preferably 6σ or a Cpk of 2. The transfer function, developed during the Improve phase, plays a key role in determining the operating windows. Appropriate control charts may be used to monitor the uncontrollable factors, providing early warnings about impending out of control situations. For the controllable factors, a proper setting within the windows will do. In Project 8, operating windows were established for the supplier quality characteristics. That had the single most important impact on the failure of the assembled product.

A transfer function is often not explicitly developed for nonmanufacturing processes. Instead, improvements are realized through intervention in the process. In nonmanufacturing, control charts are often developed to monitor the output quality characteristics (Y). In Project 3, control charts for the energy expenditure per day were set-up.

Mistake proofing in combination with failure mode and effect analysis (FMEA) and changes to current procedures are key to control and prevention in

nonmanufacturing. In fact, although FMEA was originally developed for physical products and manufacturing processes, we predict that this method is going to experience a renaissance in the nonmanufacturing area. It is a particularly potent tool for service-oriented processes. As examples of the type of control used in our sample, a better registration of the duration of sick leaves was instituted for Project 2. This shifted the burden to the government sponsored health insurance system, as it is the law in Holland, and averted the company from having to pay employees while sick.

DISCUSSIONS AND CONCLUSIONS

Nonmanufacturing is the new frontier in quality improvement. Such processes have great potential for economic saving and are ripe for quality improvement. A high volume of transactions often characterizes nonmanufacturing processes. Moreover, the processes are typically labor intensive and costly and the transactions are often not well defined. In fact, nonmanufacturing processes are usually not planned or designed and have frequently never been subjected to rigorous study. Further, nonmanufacturing processes are pivotal to the entire organization; errors and delays have serious downstream cost consequences; there are typically a large number of ways to make mistakes and high frequency of errors and rework is commonplace.

On the basis of the analysis of our sample of eight projects and our general experience in applying Six Sigma, we conclude that differences between manufacturing and nonmanufacturing do exist. The primary difference is mental; using quantitative methods in nonmanufacturing is not common and will frequently require an attitude change. However, in general, we consider the differences to be relatively minor. Clearly, as we discussed above, the emphasis may occasionally be different. However, it is our conclusion that Six Sigma's general approach to problem solving and the associated tools are applicable with only minor adjustments and can be used with benefit in both manufacturing and nonmanufacturing.

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