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| **[Six Sigma: An analysis of process improvement]** |
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**INTRODUCTION:**

The Greek letter sigma is used as a measure of variation or risk, known as standard deviation. A standard deviation is the probability distribution of expected future results calculated in the mathematical field of statistics to equal 68.26% probability. In a manufacturing environment, sigma measures the capability of a process or product to perform defect-free or variation-free work at the established standard deviation rate, indicating how probable a defect is to occur. Thus, one sigma signifies that a process will be followed according to specification 68.26% of the time, meaning it will produce, on average, 3,174 defects per 10,000.

Mathematically, the graphical representation of standard deviation appears as an asymptotic bell curve with the required process specifications at the center of the curve. Two sigma, then translates to 95.46% probability or 454 defects per 10,000 processes. Most companies operate at three sigma, or at a quality standard of 99.74%, with only 26 expected defects per 10,000. A value of six sigma indicates that a process will not produce more than 3.4 defects per million, or a standard deviation of 99.99966 %, obviously a monumental hurdle to overcome.

The management philosophy of Six Sigma, then, is a data-driven methodology for eliminating or reducing defects or variations in a process. Six Sigma improvement processes attempt to identify and eliminate the root cause of defects or variations through the multi-step process known as DMAIC-R (define, measure, analyze, improve, then control, and replicate). The ultimate goal of Six Sigma is to achieve complete customer satisfaction through continuous improvement in quality. (Moore 38-41)

Although there are noticeable differences between manufacturing and service operations (often referred to as nonmanufacturing in the Six Sigma culture), the process improvement structure can be equally and effective applied to both. In manufacturing, it is common to measure the performance of products and processes as the improvement of quality and minimization of defect levels is always a primary concern. In nonmanufacturing, however, it is often a struggle to develop and apply measurements of quality since there is not a quantifiable product to measure; so, improvement by fact measurement can seem elusive. The challenge of any Six Sigma process is often encountered early as the confusion of goals and responsibilities is often revealed when flowcharts or process maps are developed in the measure phase. In nonmanufacturing, flowcharts or process maps are typically completely absent at the start of the process and must be created from scratch, adding an additional step toward a successful implementation. In both, the relationship between the business metrics and associated quantitative quality characteristics are frequently straightforward. (Does, van den Heuvel, de Mast, Bisgaard 177-182)

Six Sigma is best described by listing the characteristics that are common to the companies that have attributed the management technique to their continued success:

1. A focus on process and a focus on customers
2. An interest in process performance, at all levels, and a company-wide measure of process capability
3. Master Black Belts, Black Belts, and Green Belts (levels of employee experience, training, and accomplishment)
4. Black Belt projects that focus on the reduction of defects and/or the reduction of variation
5. Management by fact
6. Projects are related to business objectives
7. Senior management has clear vision, values, and objectives
8. Senior management objectives are deployed right down to the shop floor and the customer contact levels (Caulcutt 301-306)

**LITERATURE REVIEW:**

*6 Sigma: Driving Supply at Ford*

By Karen G. Moore

Abstract: Article profiles Ford Motor Company, which followed General Electric, Motorola, and Allied Signal, by embracing Six Sigma as one of the cornerstones of its business. Ford believed that this powerful, statistics-based methodology would help it eliminate defects, optimize processes, and produce significant financial results across the organization. Today, the company feels its faith in Six Sigma was well justified.

*Improving the Hospital Discharge Process with Six Sigma Methods*

By Theodore T. Allen, Shih-Hsien Tseng, Kerry Swanson, and Mary Ann McClay

Abstract: Article describes the application of a five-phase Six Sigma: define, measure, analyze, improve, and control (DMAIC) approach to streamline patient discharge at a community hospital. Within the context of the five phases, the team applied statistical process control (SPC) charting, process mapping, Pareto charting, and cause-and-effect matrices to make decisions.

*Why is Six Sigma So Successful?*

By Roland Caulcutt

Abstract: Article profiles Motorola, General Electric, Black & Decker, Honeywell, ABB, and Bombardier which have achieved impressive business performance in recent years. Their annual reports document such success. Furthermore, in several cases, their annual reports clearly attribute this success to having followed a Six Sigma strategy.

*Comparing Nonmanufacturing with Traditional Applications of Six Sigma*

Ronald Does, Edwin van den Heuvel, Jeroen de Mast, and Soren Bisgaard

Abstract: Paper traces the evolution of how the Six Sigma approach has, in the past, been predominantly used to improve manufacturing processes. Recently, however, Six Sigma is being increasingly applied to a wide variety of nonmanufacturing operations also.

*Lean Six Sigma in Higher Education*

By Ross Raifsnider

Abstract: Paper studies the Six Sigma approach in higher learning. As competition in today’s higher education marketplace is fierce, community colleges, four-year colleges, universities, and even higher education schools that offer online distance learning courses are all vying for the same students – and the revenue they represent. To find success, institutions of higher education must demonstrate that they can offer what others cannot.

*Solving Retail Problems Using Lean Six Sigma*

By Tony Curtis, Jin An, and Robert Gettys

Abstract: A study of the Accenture Process & Innovation Performance service line which takes an end-to-end, process-based approach to address key business challenges such as complexity reduction, lean manufacturing and operations, process innovation, strategic cost reduction, and growth through innovation, in order to create competitive advantage for clients globally.

**DISCUSSION:**

One of Six Sigma’s success factors is its reliance on a common language and common approach. Although, splinter approaches are arising everyday as the management process matures, the foundation is often represented by the acronym DMAIC. DMAIC stands for Define, Measure, Analyze, Improve, then Control. Growing ever-popular is an addition to the standard formula known as DMAIC-R which mimics the above and adds the Replicate phase to the end. Although this is understood in DMAIC, Ford Motor Co. is often credited with encoding the final phase as a solid reminder that this is a continuous improvement process (Moore 38-41).

*The Six Sigma Process of DMAIC-R: Define*

Before the improvement team can understand the problem to be addressed or improved, it must first *Define*. This phase establishes the measurable success factors, identifies both internal and external customers of the process, and details their expectations.

In higher education, each step of the DMAIC can be applied to document management. Thus, the Define phase can be explored by the example posited by higher education: schools look to improve the ways documents are created, stored, accessed and shared so they may accelerate and enhance work processes, share information more conveniently, and collaborate more effectively. The Define stage concludes with a list of specific goals and ideas such as: schools do not have a single view of complete student files from application to grave, it is difficult for staff to access or share information that resides only on paper. Moreover, paper-based work processes are slow, expensive, and cumbersome, which challenges the ability to support admissions. Plus, student access to profile information is frustrating for both student and staff support (Raifsnider and Kurt 1-10).

*The Six Sigma Process of DMAIC-R: Measure*

In order to establish that the process agreed upon by the improvement team is either working or not working, the team identifies quantitative and qualitative data collection techniques to *Measure* past, current, and future performance. This phase also highlights project opportunities and sets the established baseline to evaluate potential solutions.

In a hospital environment, the discharge process can be long and tedious as patients become impatient. A discharge study of a 204-bed hospital in Alliance, OH showed the discharge time was reduced from 3.3 to 2.8 hours and missing chart data was reduced by 62%. The improvement team had to create an approximate process map from scratch in the Define phase and sought to clarify the scope of the project and how to determine improvement through the Measure phase. The team developed a repeatable and reproducible Standard Operating Procedure (SOP) for discharge time. During the Measure phase, they realized that a set process had not previously been followed and time notation data for each step of the process was often unavailable. They were, however, able to determine a start time (when the doctor released the patient) and the end time (when the orderly signed the discharge document indicating the patient had left the building) in order to establish a baseline for comparison. As an interesting note, overnight discharge time was omitted from the study due to rare events not of critical interest that caused this relatively infrequent event (Allen, Tseng, Swanson, and McClay 13-20).

*The Six Sigma Process of DMAIC-R: Analyze*

The data tells a story. The *Analyze* phase is where the improvement team reads the story the data is delivering without pre-conceived notions. The team must determine how good, or bad, the current process is and where the largest opportunities for improvement lie by identifying the true root causes.

A key part of the Analyze phase is to discover and select factors (X) that potentially influence the quality characteristics (Y). In manufacturing, many factors are typically either controllable “knobs” on a machine or uncontrolled but quantifiable noise factors such as shift-to-shift or machine-to-machine differences. In nonmanufacturing, uncontrollable or non-quantifiable factors are typical. It is common to find that personal, family, psychological, and sociological factors influenced the mistakes (Does, van den Heuvel, de Mast, Bisgaard 177-182).

Accenture’s white paper in the retail arena serves as an excellent study into the Analyze phase for reducing damaged inventory. During early analysis of the data, the team’s Black Belt discovered that 30% of the return reason codes were incorrect. This discovery highlighted a problem much greater than initially expected; in that, the actual damaged inventory was 23% higher than recorded, the cycle time to process and clear some damaged inventory exceeded a year, and significant complexity was added to the store inventory positions. Analyzing the drivers of inventory using deep LSS tools such as Lean value stream mapping, process balancing, and advanced ANOVA statistical analysis, the team uncovered several critical root causes: 1) Multiple process failure points were uncovered before the damaged product inventory was placed in the cage; 2) cashiers were not trained on returns and exchanges; and 3) an audit process did not exist for damaged product reports (Curtis, An, and Gettys 1-12).

*The Six Sigma Process of DMAIC-R: Improve*

The *Improve* phase is where recommended solutions are implemented. The improvement team generates ideas, based on the imperial evidence uncovered in the previous steps, to improve the product or process. Selected ideas are first filtered from an impact & costs standpoint and then further designed & test piloted to see if hard data supports the expected improvements. Key factors of success during this phase are acceptance by end-user and realistic implementation of enterprise-wide change without degradation of current productivity levels.

In the Improve phase, functional relationships between quality characteristic (Y) and the factor (X) selected in the Analyze phase are established through experimentation. It is difficult to catalog specific examples of the Improve phase as it is dynamic, beginning with brainstorming techniques. Once creative ideas are generated, an experimentation process ensues using *The Scientific Method* learned in grade school. This has not been as well-documented by companies as the results of this phase have been. That said, the norm in manufacturing is to apply fractional factorial experiments to determine the effects of factors on the quality characteristics. If the new settings of these factors result in better performance, the factors are applied more broadly and eventually implemented plant-wide, then companywide. Improvements in nonmanufacturing are typically realized by eliminating negative influences of uncontrollable and non-quantifiable noise factors through intervention in the process (Does, van den Heuvel, de Mast, Bisgaard 177-182).

*The Six Sigma Process of DMAIC-R: Control*

The *Control* phase consists of assuring improvements are maintained long-term through institutionalizing improvements and documenting corporate memory & experiences.

The conclusion of the Improve phase is development of operating windows for the tested improvement factors 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. The transfer function, developed during the operating 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 (Does, van den Heuvel, de Mast, Bisgaard 177-182).

Ronald Does, *et al.* evaluated eight different nonmanufacturing projects at eight different companies throughout their study of the DMAIC process, Control phase:

1. Transportation Costs in the Logistics Department: the number of incomplete deliveries was controlled through additional training, documentation, and daily management intervention.
2. Cost of Absenteeism in the Human Resources Department: the number of days of sick leave identified through personal interviews and discussion with frequently absent employees led to a change in attitude and a substantial decrease.
3. Energy Costs in the Environment Department: the costs of energy was controlled by systematically eliminating leakage.
4. Cost of Ingredients in the Purchasing Department: the high price of ingredients was controlled by exploring different combinations of less expensive ingredients that maintained the same quality of the products.
5. Customer Satisfaction in the Service & Maintenance Department: response time was controlled through data mining and regression which discovered relationships between response time and type of request, the number of personnel, and their experience. Best practices already existent within the company were implemented companywide.
6. Product Demand in the Manufacturing Department: cycle time was controlled by employing fractional factorial experiments to develop new factor settings with better performance.
7. Inspection Costs in the Manufacturing Department: the defect rate of one of the more manufacturing like projects were based on visual inspection of product appearance. Since each product could be evaluated repeatedly as could the consistency or repeatability of the judges, defect rate was controlled by standardizing the QA process.
8. Warranty Claims in the Manufacturing Department: the field failure rate of product performance was difficult to identify. After considerable work, a link between the warranty costs and product quality characteristics was established and controlled with QA process implementation before field installation (Does, van den Heuvel, de Mast, Bisgaard 177-182).

*The Six Sigma Process of DMAIC-R: Replicate*

The *Replicate* phase does not apply so much to replicating the exact process previously undergone to additionally tighten that particular process as much as it is a philosophy of continuous improvement. The concept, then, is that senior management should find the next product or process with the second highest failure rate or perceived room for improvement and begin the DMAIC process anew on the newly identified product or process (Moore 38-41).

*Why the Six Sigma Process is So Successful*

An important feature of the Six Sigma culture is the existence of what could best be described as *management by fact.*  The performance of the process at the start of the project is recorded in a run chart or a control chart. Additional lines on this chart show the target for the project and a world class benchmark. As the project progresses, further points are plotted. At the completion of the project, the improvement is clear. The charts are prominently displayed alongside other diagrams and a clear explanation of what is being measured and how the chosen improvement actions were arrived at. Managers have been trained to expect this style of reporting. Most Black Belt level projects are related to the business objectives of middle management and the performance appraisal system is designed to encourage the commitment of middle management to the success of these projects. The company benefits from this only if the objectives of middle management are aligned with the vision, values, and objectives of the company.

The deployment of objectives is not a trivial task. It is not easy to set objectives for people at lower levels such that their resulting behavior will contribute fully to the achievement of top level objectives. Many senior management teams have produced inspiring visions and very worthy high level objectives; but, have then struggled to deploy these to lower levels effectively. Six Sigma companies have used these, and other approaches, to ensure that people at all levels understand how their work is relevant to the wider objectives of the company. It is made abundantly clear by management how each Black Belt project will contribute to the bottom line (Caulcutt 301-306).

As we see from these essential elements of Six Sigma, many are combinations of earlier initiatives: TQM, BPR, the Taguchi method. Black Belts within the Six Sigma companies have motivation; but, they also have opportunity and ability. Ability is assured by selecting high potential employees and giving them extensive training in statistics, problem solving, and interpersonal skills. Opportunity is assured by the company culture, which offers Black Belts the unwavering support of management.

The success of Six Sigma cannot be attributed to its novelty, as much of the approach is not new. Its strength lies in the combination of all the elements and the way they support each other. Those companies considering embarking on the Six Sigma journey will realize that success depends on every element singularly. However, success also depends on the interaction of the elements (Caulcutt 301-306).

*What a Successful Six Sigma Process Must Include*

The projects used in the above examples looked at incorporating the Six Sigma DMAIC sequence and discussed the differences and similarities between traditional manufacturing and nonmanufacturing projects. Each project mentioned used the following criteria:

* Is the project related to a business or a customer problem?
* Will the project reduce defects, scrap, and rework?
* Will the project deliver bottom-line results?
* Does the project have a high likelihood of being successfully completed on a tight time schedule (Does, Heuvel, de Mast, Bisgaard 177-82)?

Changes in management techniques and data analysis are powerful sets of tools that help build this necessary alignment of team members. During any project, project leaders must collect and use data appropriately to remove the possibility of decisions based on emotion or experiential anecdotes. With the many challenges in the business environment, use of basic project management approaches to gain buy-in and consensus are critical to predict success in all projects whether simple or complex. Questions often arise about why a simple project using a basic approach takes three months to complete. The project duration is usually driven by the scope, complexity, project leader’s experience & leadership, the strength of the LSS knowledge, and the leadership support of the project.

It is suggested that an accelerated improvement process is used within projects for faster completion of a particular phase or component. Some characteristics of an accelerated improvement approach include:

* A core team of six to eight cross-functional representatives with as many as 35.
* The pathway consists of a series of questions designed to drive the group to quick understanding of the problem, leading to solution generation.
* Questions are answered by small breakout groups, and each group reports back its best answers to the overall team.
* The overall team then discusses each answer and determines the best next steps.

Developing detailed follow-up action items with due dates and identifying ownership is imperative to success and the event is considered complete upon full implementation of the follow-up list and sign-off of the control plan (Curtis, An, and Gettys 1-12).

Six Sigma is driven by quality. There is an acceptable point of imperfection and any quality improvement made beyond that point is more expensive than the expected cost savings of fixing the imperfection. There is an overall framework that drives Six Sigma toward improving performance. Common Six Sigma traits include: a process of improving quality by gathering data, understanding and controlling variation, and improving predictability of a business process; a formulized DMAIC process that is the blueprint for Six Sigma improvements, and a strong emphasis on value. Six Sigma projects focus on high return areas where the greatest benefits can be gained and internal cultural can change, beginning with support from administration, management, and champion (Raifsnider and Kurt 1-10).

*Six Sigma is Not Just for Manufacturers Anymore*

The key to understanding Six Sigma and how it can be applied more broadly is to recognize that nonmanufacturing operations are also processes. Service Organizations process inputs from suppliers and provide outputs to customers, both internal and external. Chronic problems will linger unless they are put on the agenda and scheduled as projects for improvements 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. Then, of course, repeat the steps with a new process.

*Why Some Companies Fail at Six Sigma*

Companies typically start off well, generating excitement and great progress; but; all too often fail to have a lasting impact as participants lose motivation and fall back into old habits. Typically, failed improvement projects began with the formation of a team consisting of 10 to 18 members from various departments. A Six Sigma, or other improvement expert, was assigned to the team to guide and train them. At this stage, teams were excited to learn and apply what they were being taught. Team members collected data on the current working environment and, with the help of the Six Sigma expert, identified the changes they most needed to make to achieve their stated goal. The expert developed a “to do” lists that included action items, responsibilities, deadlines, and made sure needed resources were available. Top executives were paying close attention to the project at this stage and managers made clear to employees that the improvement initiative was their first priority, yet, other things that were not of the main focus began to slip. When the team reached its goal, the improvement project was declared a success and Six Sigma faded.

In the middle stage of an improvement project, when the Six Sigma expert moves on to another project and top management turns its focus to another group of workers, implementation starts to wobble. Teams found themselves struggling to maintain the gains they achieved early on. While teams at this stage continued to look for the flaws in their current working environments, they got bogged down trying to perform the statistical analysis previously handled by the expert. Some teams started spending too much time on the improvement project, which affected their ability to meet production quotas and other daily responsibilities. Team members started reverting to old habits. Then, the team’s performance stopped improving and started to regress. When reporting on the status of their projects, teams tried to make themselves look better by highlighting what they hoped to accomplish in the future, instead of what they were accomplishing now. Some team members became discouraged and started to doubt the benefits of the improvement strategies. In the final stage of a process-improvement project, team members found themselves unable or unwilling to tackle improvement tasks; so, the effort ultimately collapsed (Chakravorty).

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