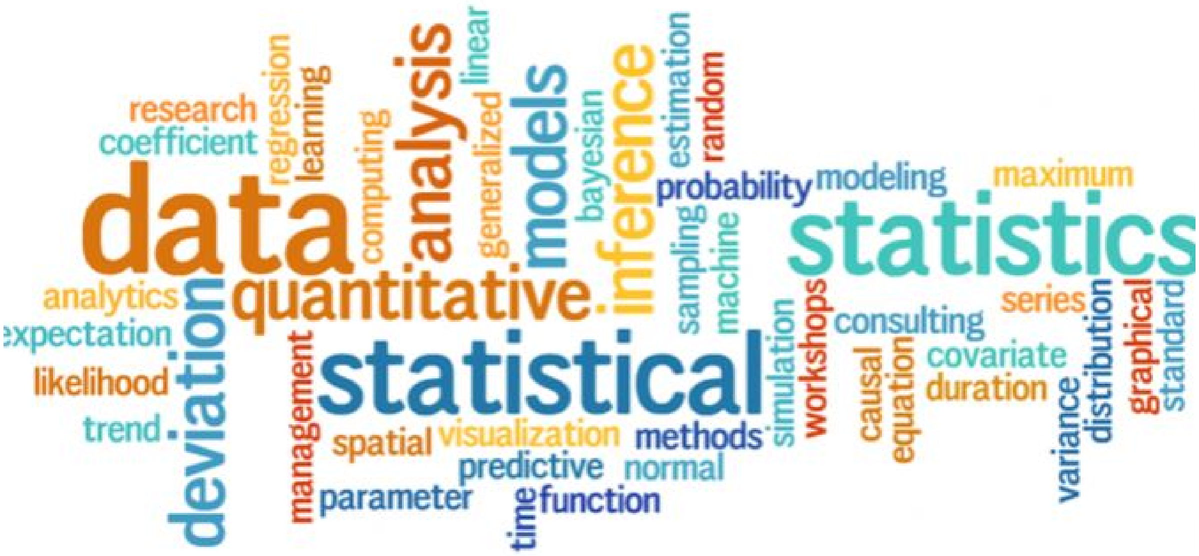


Essentials

Statistical Thinking

Variation is all around us, from the number of "widgets" manufactured in a production shift to the number of customer service calls handled in a day. In our personal lives, the amount of time spent driving to work is different each day, the weather forecast is rarely accurate and planes are often late. Like it or not, variation is everywhere. The world is not deterministic.

Variation can enter a process through its inputs, through the steps that transform those inputs into outputs. Variation typically originates from one of six sources (commonly known in industrial engineering as the 6 Ms):

1. **Manpower** - people have different ways of doing things, different skills and abilities
2. **Machines** – similar equipment does not perform exactly the same due to different patterns of wear, different uses over time, and/or different environmental conditions over time
3. **Materials** – variation exists from shipment to shipment of the same product from the same supplier and between suppliers
4. **Methods** – procedures are poorly written and training poorly delivered causing inconsistent methods of work
5. **Measurement** – the inability to accurately and precisely measure process inputs and outputs
6. **Mother Nature** – varying workplace environment (temperature, humidity)

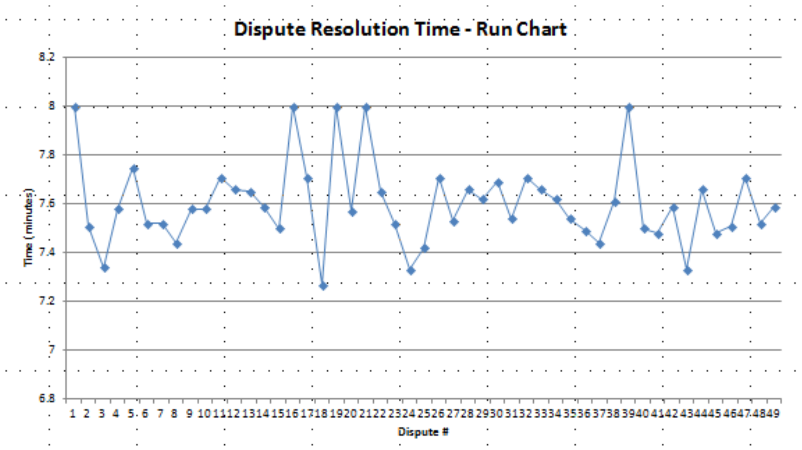
When variation is reduced, quality and productivity is improved.

"*If I had to reduce my message for management to just a few words, I'd say it all has to do with reducing variation.*" – W. Edwards Deming

Process improvement from a statistical point of view is working on either of two process characteristics:

1. Reducing variation through tighter control of the process (inputs and/or steps)
2. Improving the overall level (average level) by changing the process target which may also result in reduced variation.

The average is the central value around which the process varies. The average is calculated by summing all values together and dividing by the total number of values. The standard deviation is a measure of variation which can be thought of as the "typical" deviation of individual data points from the average. The figure below shows a process centered at 7.6 with a total spread or range of 0.7 (8-7.3).



To decide which approach to take to achieve process improvement, we need to understand the type of a variation present in the process. **Common cause variation** is inherent in the process; it is made up of small variations in the 6 Ms. **Special cause variation** is not inherent in the normal process; it is external to daily operation of the process. In manufacturing, equipment breakdowns, change of equipment operator or new supplier are potential special causes of variation. Calculating the average and standard deviation in the presence of special causes of variation can be misleading as they would not represent the typical performance of the process. Not all special cause variation is bad. Special causes may change the process for the better as well as for the worst. **Structural variation** is a blend of both common and special cause variation. It is inherent in the process but looks like special cause when the data is plotted; it has an identifiable source such as different structures on a machine (for example filling heads) or different time intervals (for example production shifts). Strategies for improving a process with common cause variation are to stratify, disaggregate and experiment to identify areas needing improvement and evaluate potential improvements. The primary strategy for improving a process with special cause variation is to isolate the problem, focusing on the data associated with the specific special cause event. Treating common cause variation with the special cause strategy is known as **tampering** and will create frustration in the workforce and potentially move the process away from its target, resulting in increased variation. Treating special cause variation as common cause variation will hinder process improvement.

All work occurs in a system of interconnected processes (process thinking). This provides the context for understanding the sources of variation and potential for improvement in an organization. Dr. Joseph Juran pointed out that the sources of most problems is in the process we use to do our work; 85% of problems are in the process and only 15% is due to the people who operate the process. Therefore, we encourage leaders to “blame the process and not the people” when working on improvement. We will explore the interaction between process design and variation in the next section.

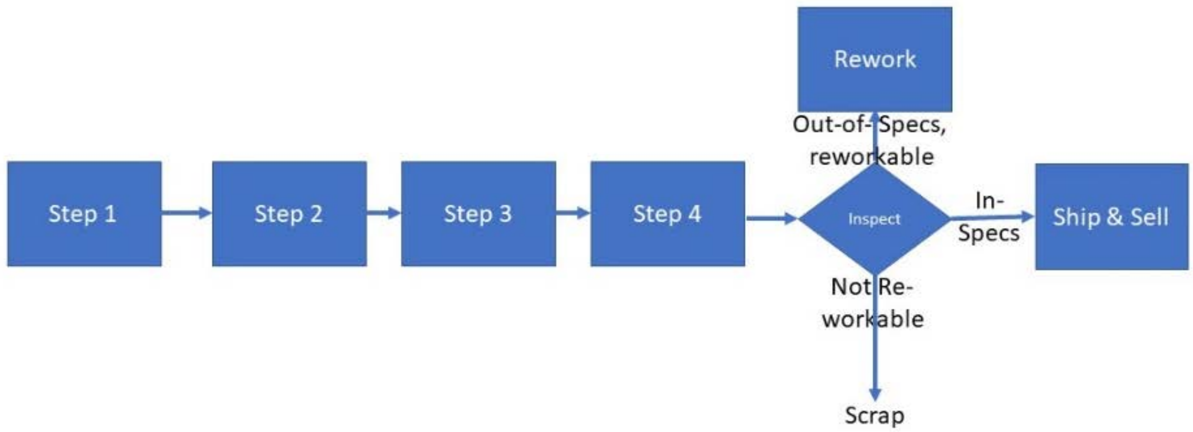
A good process is centered at the proper target with minimum variation around that target. The closer an item, is to the target, the better it is in the eye of the customer. As items move away from target, they cause economic loss (costs for longer machine set-ups and extra adjustments to machines to compensate for large variability).

Variation Complicates Processes

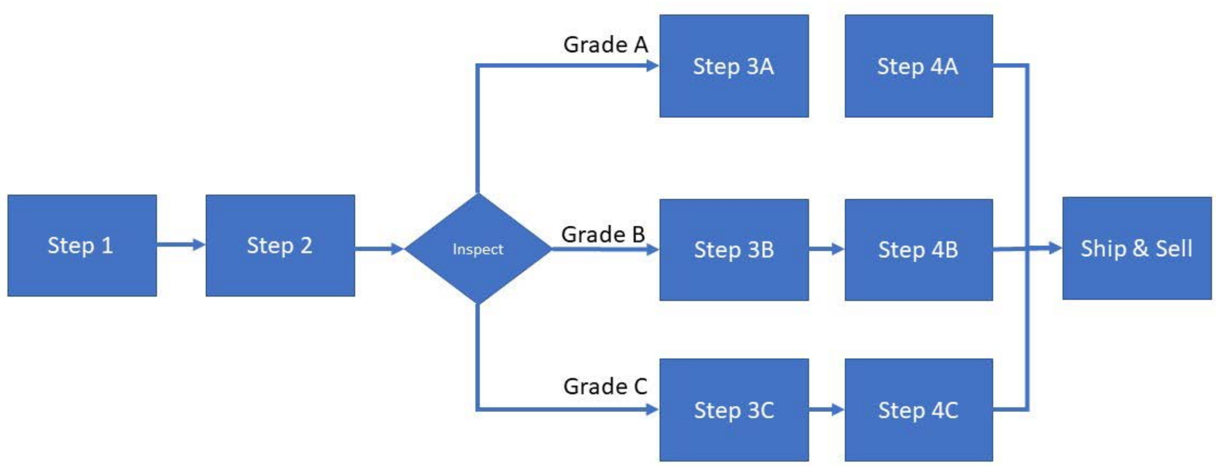
Variation exists everywhere – in every process, all the time. The more variation a process experiences, the more the process must adjust to account for this variation, creating waste (defects, overproduction, excess processing). This waste in turn creates more variation in the process.

Variation and processes are intertwined and can be difficult to separate as variation in a process can create additional steps in the process or alternative paths which make the process more complex and increase cycle time.

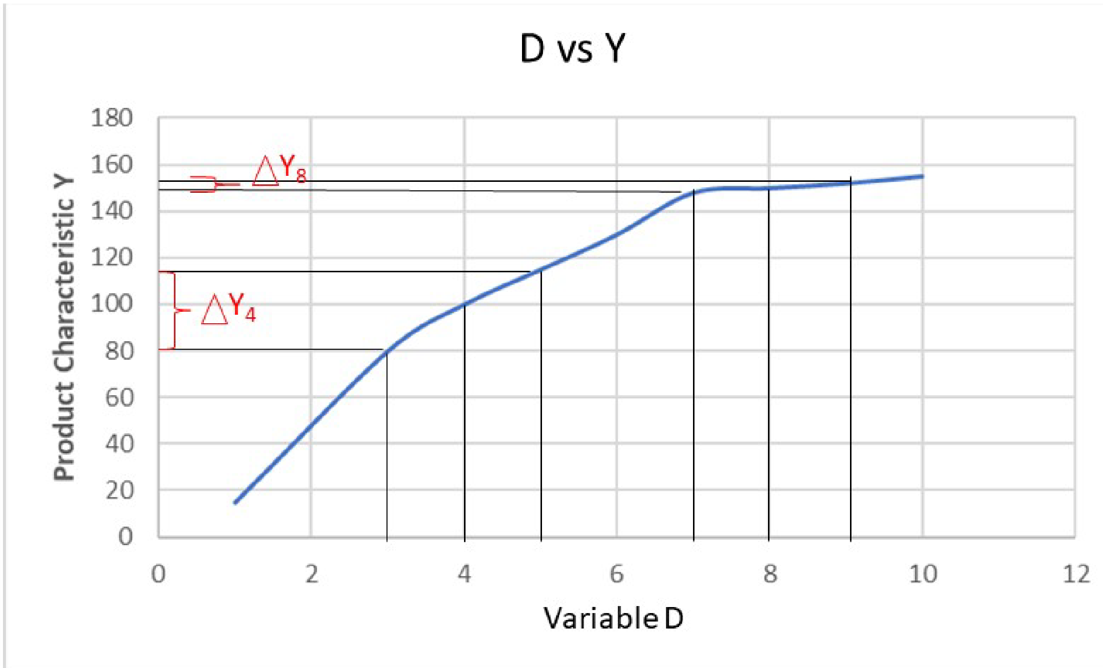
For example, let's consider a filling process with excessive variation beyond the specifications. Product below the lower specification limit does not meet legal requirements – selling the customer less product than advertised; product above the upper specification limit costs the producer income – giving away product above the advertised amount. Typically, a manufacturer adds an inspection step at or near the end of the filling process to check volume. Containers outside limits are reworked to add or subtract product to meet specifications. See the Figure below depicting this situation. If this rework is done at the same filling equipment used to initially fill the containers, scheduling and tracking of product through the filling operation becomes significantly more difficult. This is particularly problematic if the product is one that must be traced through the production process for health and safety reasons. If rework is done manually at another work station, this requires additional equipment and cross-trained workers – more cost and an opportunity for more variability to enter the process. If, in the process of handling the containers multiple times, the container breaks or is no longer able to hold the product safely, then the product and container must be scrapped – a waste of material, equipment time, and labor.



But, if excessive variation does not generate rework or scrap, but product that can still be sold as different grades or different products, this variation is acceptable, right? Let's explore that from a process and statistical thinking perspective…. At some point in the process, an inspection step must be added (for additional costs of testing equipment and labor) to segregate the product into the different grades and then route the graded product down different pathways for packaging that clearly distinguishes the grade or products. (See the figure below depicting this situation.) Each additional pathway adds costs of equipment, labor, and materials (for unique packaging), not including the cost the manufacturer may face in the market for having multiple products in the same space.



So, how does an organization prevent or at least minimize these impacts of variation? Through "robust" product and process design. In robust product and process design, the relationship between process variables (for our filling example, speed of the filling machine and temperature of the liquid) and final product characteristic (volume for the filling example) must be understood and modelled. The figure below graphically depicts such a relationship between, the product characteristic of interest, and D a process variable:



As D increases, Y increases with some curvature. Variation in D at the lower levels transmits to greater variation in Y than the same variation in D at higher levels; transmitted variation at D=4, Λ Y_4 is larger than the transmitted variation at D=8, Λ Y_8. The level or average of Y also increases. For our filling example, the manufacturer will need to choose between at least two alternatives: 1) Tightly control D to minimize variation; or 2) Increase Y to a higher level where variation in D has less impact.

The choice between these two alternatives will depend on many factors such as the ease and costs of controlling D, and the needs of the customer. Without understanding his relationship in the design phase, a manufacturer will fight variation in the process daily – frustrating workers, increasing costs, and potentially result in loss of customers.

There are many statistical methods available including design of experiments and regression analysis to model such relationships. The model can then be used to make design choices in the design phase where they have the least cost.

Let’s look at two examples of the impact of variation and how to use statistical thinking to improve productivity and profitability.

Example 1: Impact Lack of Statistical Thinking Has Across Organization

A small chemical manufacturer, XY has a simple manufacturing process, by chemical manufacturing standards. Chemicals are blended together for a specified time in a large mixer (without temperature or pressure applied for reaction) and then filled into cans, bottles and totes of various sizes, packaged and distributed. Variability in the fill weight reduces yield, creates rework and potentially costs the organization fines and customers. A container that is filled short (underweight) makes for an unhappy customer (paid for something did not get) and potentially results in legal fines if brought to the attention of state Weights and Measures officials. A container that is heavy (over-weight) gives product away and costs the manufacturer income.

Final product fill weight variability is primarily a function of equipment set-up and product viscosity. When SOS originally worked with this organization, they were setting up the equipment based on a theoretical calculation of viscosity based on the viscosity of individual chemicals in the blend. This calculation assumed no variability in raw material viscosity, which of course is not realistic. The product and process design engineers simply used the target viscosity from vendor specification sheets; it ignored variability from lot to lot of raw material. When raw material was used that was at the low (or high) end of the material specification, the blended viscosity varied from the theoretical viscosity and the equipment set-up caused over and/or under-filled containers. Additional variation in blend time, mix speed and/or temperature impacted variation in the final product viscosity.

How use statistical thinking to address this situation? First, recognize that variation exists in all aspect of the process when designing the product - raw materials, equipment, manpower, and time – then design the product and process to eliminate or minimize the impact of these variations. For example, a range of raw materials throughout the range of viscosity could be tested and used to calculate the viscosity used for equipment set-up. Or, the process could possibly be redesigned to better control blend time and speed based on raw material viscosity. This will likely cost significant money if current equipment lacks control capability and/or viscosity measurement at material receipt is time-consuming or expensive. Or, Purchasing/Procurement could work with the raw material vendor(s) to obtain raw materials within a narrower range of viscosities. Vendors would likely charge more for such material and it could necessitate additional incoming inspection/testing – more cost and time. Or, the viscosity measured for each batch at conclusion of the blend cycle to determine the appropriate filling equipment set-up. This last option was selected by this SOS client due to its ease of implementation – viscosity testing equipment was available in the blending area and testing could be completed easily and quickly by operations personnel.

This example points out that failure to incorporate statistical thinking at product design has ramifications in purchasing, operations, and the customer and potentially results in higher costs, more time, and unhappy customers.

Example 2: Impact Lack of Statistical Thinking on the Human Performance System

A printing plant operating three shifts, five days a week (Monday-Friday) was consistently unable to meet schedule within the five-day week. Since many of their print jobs were timed (books by popular authors with well-publicized release dates), the work could not simply be moved to the following week without major disruption to the customer. Workers would be required to work overtime on the weekends to get back on schedule. Crews may not know they were required to work the weekend until Thursday afternoon, making it difficult to make and keep family plans. Variability was having a negative impact on the workforce. Despite being paid overtime, employee absenteeism was high and retention low.

Analysis of press and bindery line throughput identified downtime as the primary factor creating the variability in throughput that led to missed schedules. SOS, working with continuous improvement/quality resources at the plant, trained operations teams to establish and use standard equipment set-ups ("make-ready") and to problem-solve equipment stoppages within their control using a 16-week structured variability reduction program. As a result, variability in throughput was reduced creating a 10% increase in sustained throughput allowing customer service to commit to new work with higher confidence it would be completed within schedule. This was noticed by customers and generated additional work for increased profitability.

Yes, operations personnel lost overtime pay, but when given the opportunity to be trained and to implement the variability reduction program, they jumped in and improved not only their daily work, but their work-life balance. Employee satisfaction and retention skyrocketed.

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