



Inspections and Audits: Developing a cost effective approach



Converge White Paper Series

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Inspection:

Defining a cost effective approach

Inspection: A not so necessary evil

Whenever something is *checked* by someone, we are inspecting and organizations do a lot of it. It's become an industry all its own and a growth industry at that. Inspection activities include:

- ▲ *audits*, including financial, operational, performance, security, environmental, information systems, and health and safety audits,
- ▲ *quality assurance*, including the inspection and testing of incoming materials and outgoing products and services.
- ▲ *compliance inspections and audits*, to ensure practices and products comply with regulations or that the behavior of people conforms to policies and procedures..
- ▲ *testing*, chemicals and medicines for contamination or materials for hardness or similar characteristics,
- ▲ *grading of product*, such as establishing the grade of wheat, the quality of food products, the hardness of steel, or the quality of materials,
- ▲ *checking*, engineering drawings, designs and plans to determine whether they conform to standards,
- ▲ *inspecting 'as built,'* construction ensuring conformance to plan or drawings or existing machinery and equipment identifying faults representing a potential failure hazard,
- ▲ *reviewing* forms, contracts and other administrative items for completeness and compliance to procedures,

- ▲ *second guessing*, decisions and actions of employees, manager and executives, and
- ▲ *performance reviews* and evaluations of processes, projects, programs and people.

There's a lot of inspecting going on. Not too surprising as inspection, in one form or another, has become the immediate fall back solution to most performance problems or issues.

A defective product received by the customer yields a program of compliance testing of outgoing shipments. A water main break at a municipal utility results in more frequent inspections of the distribution system. A bad decision produces policy that all such decisions must now be referred to the VP for approval. An audit reveals discrepancies in project accounting and recommends more controls (policies, procedures) to ensure it doesn't happen again and, of course, more auditing to ensure the new controls are being followed.

This belief that problems can be efficiently addressed through inspection assumes:

- ▲ the inspection process is highly efficient at detecting and preventing failure, and
- ▲ the cost of inspection will be relatively low relative to the cost of the failure.

These assumptions don't always hold up. And while the frequency with which they do, or don't, hold up can be debated, beyond debate is when either assumptions fails, inspection

activity is waste. Phrased differently, if you don't know the prevention efficiency of your inspection program, or if you don't know the comparative cost of the inspection program to the cost of failure, then your inspection, auditing, assurance or whatever program, is economically irrational, a source of waste, and costing you money.

Economically irrational inspection is window dressing, making it look as though attention is being paid to an issue while avoiding the effort required to identify and address the root cause of the problem. Checking outgoing customer shipments, for example, avoids having to address problems with a process producing defective products. Inspection is the cost for having unreliable processes incapable of delivering product or service to the quality level required or demanded by the customer.

The nature of inspections

All forms of inspection processes are comprised of two basic tasks:

- ▲ measuring or describing outcomes (outputs or results), and
- ▲ comparing these to standards in order to classify the results (assess quality).

The final classification, quality assessment, may be simple pass/fail or something more complex. For example, product inspections and quality compliance audits are usually pass/fail where failure (defects or errors) means the product must be reworked or scrapped. Financial, internal control and cost effectiveness audits usually contain long lists of performance or compliance standards against which fail or pass classifications are assigned. Performance reviews tend to classify people according to some variation of; failing to meet, meeting, or exceeding expectations. Complexity can go up from there, when

grading food quality (grades of beef or wheat) or assessing the relative hardness or quality of steel.

But regardless of the number of classification categories, the purpose of all inspections, from the employee performance review, to the quality assurance program of a high tech manufacturer, and to the audit of a fortune 500 company's financial statements, the fundamental purpose of inspection is:

to describe outcomes relative to a standard in order to assess quality.

Limitations of inspection as enumerative research

By this definition, inspection is an enumerative activity.¹ As effective as they are at finding 'problems', (defined as a gap between the description of an outcome and a standard) they cannot, in principle, provide information of use in fixing those problems. Fixing problems requires identification of root causes and identifying root causes is the purpose of an analytic study. Enumerative studies, including inspections and audits, cannot contribute to fixing anything other than the blame².

The distinction between enumerative and analytic studies is important because many believe that *in addition* to identifying

¹ The distinction between enumerative and analytic studies is essential to understanding the limitations and applications of any research endeavour. Enumerative studies are effective at describing existing conditions but cannot make inference to the cause and effect system. Analytic studies are used to determine performance and cause and effect but cannot make inferences describing existing conditions. See Edwards Deming, *Out of the Crisis, The New Economics or On Probability As a Basis for Action*, originally published in *The American Statistician*.

² Augustine's Laws, By Norman Augustine, Chairman of Lockheed Martin Corporation.

error or otherwise classifying results, audits and inspections can also help determine the root cause of errors or of the results observed. This is not the case. Any form of enumerative research, including audits and inspections, is incapable of inferring causality - that is, determining the root cause of a performance issue. Hence Deming's observation that *quality cannot be inspected in*.

Making inferences about the cause and effect system, including identifying root cause, or establishing a performance level, is the purpose of analytic research. Enumerative research, meaning any form of an audit or inspection, may inform and support analytic research in one or more of the following ways:

- ▲ *Identify where best to initiate analytic research.* While inspections and audits cannot determine the factors that drive results, they can provide useful information as to where to begin looking for these root causes. Areas correlated with defects, for example, are useful starting points because there can be no causation without correlation³. This can save considerable time in the analytic research process.
- ▲ *Improve the quality of data used in the analytic research.* Enumerative research is all about providing accurate and reliable data describing current conditions. Improvements to data quality can improve the reliability of analytic research that relies on this data.
- ▲ *Provide a factual description of results against which analytic inferences should be judged.* Conclusions arrived at in the analytic research must be consistent with the

³ Although there can be correlation without causation, one reason why enumerative research, including inspections and audits cannot determine causation.

observed reality defined in the enumerative research - theory must consistent with observed reality or the theory is wrong. In identifying a root cause, for example, there must be a clear, rational causal chain linking it to the results obtained in the enumerative research (inspection or audit). If there isn't, if the root causes identified in the analytic research is inconsistent with observed results, then the root cause isn't.

The nature of error and inspection⁴

Murphy's Law states that if anything can go wrong, it will. Evans and Bjorn added, *No matter what goes wrong, there will always be somebody who knew it would*. These observations sum up much of the relationship between error and inspection.

More formally, Murphy's Law can be considered a pessimistic version of the *Law of Variation; variation exists in all processes and systems. It can be reduced but never eliminated*. The ever present existence of variation means that it is inevitable that errors will occur. This leads to *Deming's Law of Error: There are only two types of error:*

- ▲ *Type 1 is taking an action where none is warranted, and*
- ▲ *Type 2 is failing to act where action is needed.*

The only way to prevent Type 1 error is *never do anything*. The only way to prevent Type 2 is to *always do something*.

First Law of Inspections & Audits: An increase in the level of inspection always leads to a decrease in the amount of work

⁴ For ease of discussion we will constrain our definition of inspection to a two part classification of pass/fail where anything that fails is deemed to be an error. Nevertheless, what is said here is true for other, multipart classification systems as well.

done. Only Type 1 error is auditable because you can't audit a vacuum as there is nothing to compare to the standard. Therefore, the only people whose work cannot be criticized by inspectors and auditors, is the person that does no work. Because of this, an increase in the level of inspection always leads to a decrease in the amount of work done because there will be less to get criticized for.

Second Law of Inspections & Audits: The most likely finding of any audit is the need for more auditing. Over time, organizations tend to evolve towards greater levels of inspection and auditing. Any inspection that finds errors can make a case for additional inspections. Such arguments are hard to ignore. After all, what other errors have gone undetected for a lack of inspection? To inspectors, the need for more inspection is obvious as there are always more problems to find. That's why; *Two thirds of the earth is covered with water. The other third is covered with auditors from head office*⁵.

Third Law of Inspections & Audits: The level of responsibility/accountability confusion for any task increases with the probability of the task being audited. This, can be thought of mathematically as: $Resp_w = \frac{1}{1+(Prob_a)}$.

This states that the level of responsibility or accountability of any worker for a task is a function of the likelihood of an inspection or audit being conducted. Where the probability is 1 (100%), responsibility for the task is shared equally by the worker and the auditor.

Fourth Law of Inspections and Audits: The quality of work goes down as the level of inspections, including quality assurance,

goes up. Interestingly, this means that the quality of work done tends to be inversely proportional to the probability of an audit - a result that has been confirmed empirically. Human behavior being what it is, workers are increasingly apt to resort to a "*Let the inspectors find it*" attitude as the probability of an inspection increases.

A heuristic arising from the third and fourth law is that inspection should be done by those closest to the work being inspected. The best inspector is the person doing the task. This is a variation of the *parachute packer principle . . . the best parachute packers are those doing the jumping.*

Lessons for organizations

What are the implications of all this for organizations? There are some big lessons;

- ▲ Errors exist in all process. The only way to avoid auditable errors is to do nothing. Without an organizational tolerance for error, the level of inspection equals infinity. This reduces productivity to zero.
- ▲ The quality level of any process is inversely proportional to the level of inspection, auditing or quality assurance of the process. So is the throughput (amount of work done). This means that quality goes down as quality assurance activity goes up.
- ▲ The best inspection is no inspection. Using continuous improvement to error-proof processes or reduce defect rates is always more cost effective than inspection.
- ▲ If inspection is required, it should be done by those closest to the task or process. The best inspectors are those doing the work.

⁵ Augustine's Laws, By Norman Augustine, Chairman of Lockheed Martin Corporation

- ▲ Any inspection activity using inspectors (as opposed to those doing the work that is inspected) implies:
 - ▲ a lack of trust that decreases employee morale,
 - ▲ loss avoidance behavior that leads to a reduction in throughput, and
 - ▲ shared accountability that decreases output quality.
- ▲ The level of inspection (and the number of inspectors) is a negative indicator of process quality - not a positive one. Inspection is only required when your processes are incapable of performing to a standard.

The decision to inspect (or not) then, is one laden with organizational implications. Practical rules are required to guide management as when to use, and not to use, inspection as a means of assuring quality.

Inspection Decision Rules

While errors are inevitable, inspections are not. If economic efficiency, effectiveness and flexibility are of importance, the decision to inspect (or not) must be based on rational economic rules⁶. Otherwise, organizations will simply be involved in the generation of waste.

Decision Rules for Stable Processes

Fortunately, a comprehensive set of economically rational inspection decision rules exists to guide management action.

⁶ In certain instances, economic efficiency, effectiveness and flexibility are not of primary importance. For example, where there is a direct risk to human life. In such cases, two options are available: (i) conduct 100% inspection or (ii) equate k_2 in the equations that follow to ∞ .

Let:

p = average errors per lot

$q = 1 - p$

k_1 = cost to inspect

k_2 = cost of error

$\frac{k_1}{k_2}$ is the *breakeven quality* and will always be between 0 and 1.

Then:

If $p < \frac{k_1}{k_2}$, no inspection

If $p > \frac{k_1}{k_2}$, 100% inspection

There are two basic assumptions in these rules:

- ▲ Inspection is 100% efficient, that is, all defects or errors will be captured in the inspection process. If inspection is less than 100% efficient, this will effectively reduce the value of p , making inspection less economic. Adjusting p can be done by multiplying p by the probability (0-1) of an inspection finding an error.
- ▲ The process inspected is in a state of statistical control. This why the process histograms in *Exhibit: Situations defining inspection strategy*, display a bell-shaped pattern. Without statistical control, (bottom chart in the Exhibit) the value of p cannot be determined as the process has no defined capability.

The implications of these decision rules follows.

Only two inspection choices exist for stable processes.

For any process having a defined capability, a rational inspection decision will always be limited to 2 choices:

- ▲ 100% inspection,
- ▲ No inspection.

An implication of this is that sampling plans and schemes associated with inspections tend not to be economic and lead to waste and unnecessary costs.

Rational inspection decisions are based on cost *and* the probability of locating errors

Rational inspection decisions are always based on cost and the probability of finding error - both are required. The rational inspection rules work by comparing the breakeven quality (the ratio of inspection cost to the cost of error) to the probability of finding an error through inspection.

Many organizations inspection schemes are not rational. In practice, they tend to base the inspection decision on one side of the inspection decision rule or the other (p or $\frac{k_1}{k_2}$) by:

- ▲ **Making inspection decisions based on cost $\left(\frac{k_1}{k_2}\right)$ alone, that is inspecting wherever the cost of inspection is less than the cost of error.** This is equivalent to examining the *breakeven quality* without consideration of p . In practice, this strategy is typically used when k_1 is quite small relative to k_2 such as in large capital projects.

The rationale here is that with k_1 so small relative to k_2 , one might as well inspect because comparatively, it costs very little to do so. This thinking is biased in favor of greater levels of inspection rather than less. The result is organizations waste time, money and energy looking for

things they can't possibly find (although it makes people feel better having looked).

- ▲ **Making inspection decisions on p alone, that is inspecting where ever there is a likelihood of error.** This is the equivalent of pursuing inspection whenever the value of p is greater than 0 (which it always is) and ignoring the costs of inspection and of error (k_1 and k_2)

The rationale here is that errors are bad and, therefore, should be found. This is the thinking that guides audit and inspection departments from the Auditor/Inspector General on down. The implicit, unstated assumption in this logic, is that errors ought to be found *whatever the cost*.

Clearly, this strategy is also biased towards greater levels of inspection. An example is auditing forms for completeness. Plenty of errors will always be found, but the cost of failing to fill in Box C is almost always equal to zero.

Both alternatives are biased towards increasing the levels of inspection. This mean both non-rational inspection strategies produce three effects:

- (i) the simple waste of unnecessary direct inspection costs,
- (ii) unintended organizational costs (described earlier) including; reduced product quality, throughput and staff morale, and
- (iii) unwarranted management belief that quality has been assured as a result of the inspection. Often, just the opposite is true.

Inspection standards require a rational economic basis.

Any standard must have a reason for being - a rational economic basis for existence. This is required if k_2 (the cost of error) is to have any real meaning.

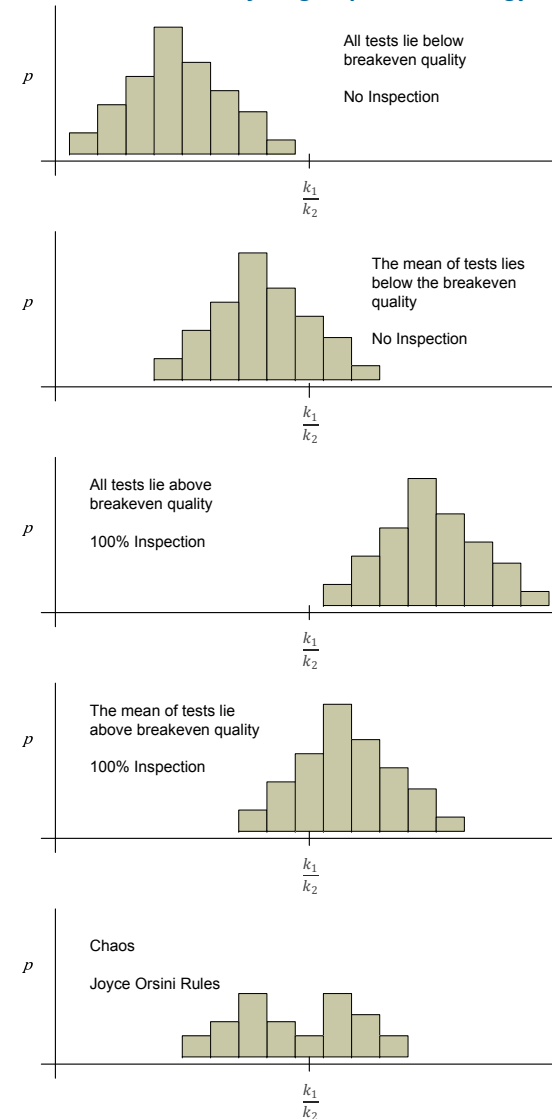
For example, a requirement that water pipes be a minimum of 1 meter below grade. It may be, for example, that pipes placed less than a meter below grade freeze and break with a higher probability than pipes more than a meter below grade. In such circumstances, a minimum 1.0 meter below grade standard for water pipes has this rational economic basis and k_2 can be fairly evaluated.

In practice, many standards lack this rational economic basis. At the time of writing, the Canadian Federation of Independent Business (CFIB) launched Red Tape Awareness Week with the story of a trucker fined \$690 for failing to have a permit for hauling an empty fuel tank. According to the CFIB, the Transportation Safety Services Division of the Alberta Government was unable to identify any purpose for the permit⁷.

In other words, a permit was required because a permit was required. The CFIB estimates the economic cost of such regulations to be about \$30 billion a year in Canada⁸.

A useful mechanism in determining whether there is a rational economic basis for a standard is the ease in determining a value for k_2 . If this leads to excessive debate and confusion, the less likely a standard has a rational economic basis. It is both instructive and somewhat entertaining to imagine a debate among transportation experts as to the economic cost of failing to carry a permit in the example above, or to imagine the type of evidence that would have been offered to determine this value.

Exhibit: Situations defining inspection strategy



Source: Adapted from Out of the Crisis, Edwards Deming, MIT, Center for Advanced Engineering Study.

⁷ Stuck in Red Tape, Calgary Herald, January 11, 2011.

⁸ This discussion of inspection and the need for standards to have a rational economic basis provides a useful definition of Red Tape - any regulation, standard, rule or requirement for which there is no rational economic basis.

The Rules for Unstable Processes.

The rules presented thus far have assumed that a value for p exists. This is true only when a process is stable and reliable. When a process is not reliable, there is no defined capability and therefore no value for p (see bottom graph in *Exhibit: Situations defining inspection strategy*).

When this is the case, use of the Joyce Orsini's rules represents a rational basis for an inspection strategy. The rules are:

If $k_2 > 1000k_1$ 100% Inspection

If $k_2 < 10k_1$ No inspection

Else;

a) sample 200 of the lot and accept if no failures found and inspect balance if any errors found,

b) use Anscombe's sampling plan, where the first sample is of size $n = 0.375\sqrt{N(k_2/k_1)}$ and subsequent samples are of size $n = k_2/k_1$ until the number of defectives falls below the number of samples taken.

where N is the size of the lot.

While rational, Joyce Orsini's rules still imply a significant higher cost than inspection rules associated with a stable and reliable process. This is the cost of failing to have a reliable process.

Inspecting the installation of clean water pipe.

In practice, Joyce Orsini rules make for an easy to administer inspection process that is economically rational even in the face of unreliable processes.

Let's take our water pipe installation as an example. Suppose that 10,000 meters of fresh water pipe has been installed in a residential neighborhood (N). The municipal water department

wants to ensure the installation meets the 1 meter below grade standard. The cost of inspection is \$50 meter. The cost of repair usually runs at \$1,000 per meter. The error rate inherent in the process is unknown. What should the department do?

Divide the installation into 50, 200m chunks on the construction drawing. Randomly select one of these chunks and then inspect it against the standard⁹. If errors are found, inspect the balance of the installation. If not, stop the inspection process and approve the installation. Simple and economically rational.

Alternatively, use Anscombe's plan. This would see an initial sample of $n = 0.375\sqrt{10,000(1000/50)} = 170$ meters of pipe. If no errors were found, the inspection would stop and the installation would be approved. If errors were found, random samples of 20m chunks of pipe installation would be inspected until such time as the number of errors found was less than the number of samples taken. At which point the inspection would stop. This is a little more complex, but still yields an economically rational alternative to the typical 100% inspection no matter what.

The only method of determining process capability is through the control chart.

Only a control chart can determine whether a process is stable or chaotic. Likewise, only through a control chart can the value of p for a process be determined. This means that there can be

⁹ In some instances management and/or engineers simply can't bring themselves to rely on a random selection process. While not strictly rational, I have found that allowing the inspector to select the *chunk* that in their opinion is most likely to contain errors, to be a useful means of gaining the approval and buy-in of the inspection group. As such, this should be considered as a useful element of a change management strategy.

no truly rational inspection strategy without a control chart for the characteristic being inspected.

Without a control chart, it is best to assume the process is chaotic and use the Joyce Orsini rules. At the same time, it would be productive to begin tracking p on an XmR control chart in order to assess process reliability and take the remedial action necessary bring improve process reliability and capability.

Implications for Management

Today, more than ever, organization are engaged in inspection activities, from materials testing to quality assurance to financial, environmental and health & safety audits. Much, and likely most, of this activity is waste.

As described, any non-rational inspection scheme is biased toward additional inspection. The inspection decision is typically driven by a *better safe than sorry* reasoning that ignores economic reality, the probability of detecting errors, or both. In the end, *better safe than sorry* is not only costly, but typically reduces product quality rather than enhance it.

Understanding this requires a shift in management thinking. Abandoning the command & control/hierarchical thinking that believes quality can be *inspected in* can be difficult to do. Fortunately, one only has to look to organizations that have abandoned this thinking in favor of systems thinking (such as that used in Lean) to see the advantages. Imagine production systems where inspections, audits and tests are unnecessary because the production system itself is error-proof. What would be the benefits of such a system? By how much would your costs decrease?

Most of us are familiar with the notion of error-proof strategies in our day to day lives. So familiar that we may fail to recognize

them as such. When the shift from leaded to unleaded gasoline was made, newer cars had nozzle receptacles that were narrower than older versions and nozzles for unleaded gas were made to match. This made it virtually impossible for owners of newer vehicles to incorrectly fill their tanks with leaded fuel. Despite the disappearance of cars using leaded fuel, this design characteristic is with us in every car and service station to this day.

A systems view of inspection supports the following improvement actions.

Review the rational economic basis for all standards.

Effective inspection requires inspection standards with a rational economic basis. Many standards lack this foundation. Part of this is due to the natural bias in organizations (described) for increasing inspection. This results in the constant addition of standards many of which have no rational basis.

The cure is to review these standards. Examine for their rational basis. Remember, this is not the same thing as asking whether people think inspection is a good idea. It is about determining the causal relationship between the standard and the cost estimate of k_2 . Where suspect, revise or eliminate the standard and the associated inspection.

Measuring process performance on the inspection characteristic using a control chart.

A rational inspection plan requires knowledge of process capability (or lack thereof). Further, a process cannot be improved, nor can improvement be demonstrated, if the current performance level is unknown. Ultimately, this requires the use of control charts because only the control chart can determine process performance/capability.

The use of a control chart will enable the application of the inspection decision rules. Where the process is stable, the inspection decision will be limited to either 100% inspection or no inspection depending upon the relationship between the cost of inspection, the cost of error and the probability of detecting the error. Where the process is not stable, Joyce Orsini's rules can be applied.

Move inspection as close to the work being inspected as possible.

Ultimately, the best inspectors are those closest to the work. The closer the better. Where possible, make those performing the work responsible *by* making them accountable for inspection. For example, pipe weld tests should be done by those doing the welding.

If this is not possible and another individual needs to do the inspection, that person should be as organizationally close as possible to the person doing the work - a foreman, supervisor, team leader and so forth. Independent audit and inspection departments can work, but only if using a decentralized model where inspectors work closely with those whose work is being inspected. Anything else, especially the functionally specialized inspection or audit department, is the death nail to quality because it produces shared accountability (Third Law of Inspections and Audits) and a, *Let's see if the inspector can find it attitude* (Fourth Law of Inspections and Audits).

Work with your suppliers.

When incoming goods, materials, products or services are being inspected by the customer, the customer should make every effort at working with the supplier to improve the suppliers process capability. This means working with the supplier,

teaching the application of control charts, arriving at rational economic inspection standards and so on.

Control charts on each supplier, and their performance, should be maintained. Audit and inspections can then be custom tailored to the performance of each supplier. If inspection costs and/or the costs to fix an error are transferred to the supplier, a strong economic incentive to improve process capability is built in. This only works, however, if the inspection plan is rational. Anything else will produce game-playing counterproductive to quality.

Get serious about quality.

Organizations can get bound up in hierarchical, command and control thinking when it comes to inspection. Such organizations are easy to detect - they equate an organizational commitment to quality with the level of inspection delivered such as through a quality assurance program. Such organizations:

- ▲ don't understand what quality is,
- ▲ believe quality can be inspected in,
- ▲ equate quality assurance with quality rather than what it is, an indicator of a lack of quality.

If organizations are going to succeed, quality needs to be taken seriously. In each step of a process, where the next process is the customer, customers must work with suppliers (and vice versa). Rational economic standards and operational definitions must be established so that the work can flow with both parties fully aware of expectations and requirements.

At times *working with suppliers* is seen as a soft touchy-feely stuff. Hopefully we have put that aside. There is nothing touchy-

feely about economically rational standards or $n = 0.375\sqrt{N(k_2/k_1)}$.

What is soft, is the warm fuzzy and vague (to the point of meaningless), thinking that equates quality with inspection. *We inspect everything* is not a sign of management concerned with quality. It is a sign that management just doesn't get it. Quality can't be *inspected in*. It must be *built in*.

Reliability & Trust

Reliability equates to trust or confidence. If a process performs reliably, we can trust it. Specifically, we can trust it to perform to a defined capability. If it isn't reliable, we can't trust it and must, therefore, inspect output to ensure poor quality is not passed on up the production or value chain or on to a customer¹⁰.

Reliability is a zero sum affair--the good and the bad must total to 1 or 100%. If the proportion of defects goes up, the proportion of good or acceptable product goes down. This has some important implications for trust.

The level of trust the organization has in the process (or the worker performing a task within the process) is inversely proportional to the probability of having an audit conducted on the output of the process.

$$Trust_p = (1 - prob_{ap})$$

The level of trust in a process is equal to 1.0 less the probability of an audit of that process. If the probability of an audit is 1, the level of trust in the process is 0.

This is why audits and inspections are viewed with suspicion by those working in the process being audited. Management may have the best of intentions, such as seeking to provide some level of quality assurance, but no matter how well intentioned, any inspection process will be viewed with suspicion because the inspection, by definition, represents a lack of trust or confidence in something or someone. It can't be avoided.

¹⁰ This means we must trust the inspection processes or else, create an inspection process to inspect the inspection process. Inspecting the inspectors occurs whenever work is subjected to multiple reviews or where multiple approvals are required through various levels of the organizational hierarchy. Somewhere, the inspections must stop because of Woodrow Wilson's Trust Principle: . . . *in any business, whether of government or mere merchandizing, somebody must be trusted.*

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