QUALITY BEHIND THE SCENE (ALT F3)

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SUMMARY

There is too much cultist talk about the quality topic today. Vultures (mushrooming quality experts) are depleting valuable quality improvement funds. The delivered quality of automobiles seem to have improved. But at what cost? Actually, there are large gaps between produced quality and delivered quality costing lot of money. The gaps will continue to exist due to ineffective execution of quality science. The paper examines the issues related to ineffectiveness. If we don't take time now to understand the underlying issues, we will be facing a much bigger problem later.

INTRODUCTION

The auto industry popularized many quality concepts in the last decade. Its focus laid on concepts and methods, not on solutions to actual problems. The grand belief was that if people understand concepts and methods, improvements will soon follow. As we know today, the belief is not true to a great extent.

The auto industry forced the usage of quality concepts by making supplier quality improvement programs mandatory. Even now, when a new quality concept is created, it finds its way into the supplier quality improvement program. Training has been a popular vehicle to popularize the new quality concepts.

Even though the quality of the products has improved—it has not necessarily through the effective execution of quality concepts. Neither have we applied quality ideas correctly, nor have we applied them productively. To separate quality improvements from effective execution of science, we should ask, at what cost and in what manner has quality improved? Personal experiences suggest that, for the most part, quality improvements in the last decade can be attributed to: investment in available technology, 100% sorting, fat-trimming, and stressful attention. These are costly solutions.

Quality axioms which truly focus on quality improvement with the side effect of productivity improvement are not well executed. In fact, all the popular quality movements such as SPC, DOE, Taguchi, ISO 9000 standards, TQM, and others have hardly delivered 1% of their potential. In fact, the investments made in these quality movements by the industry is consumed by the vultures.

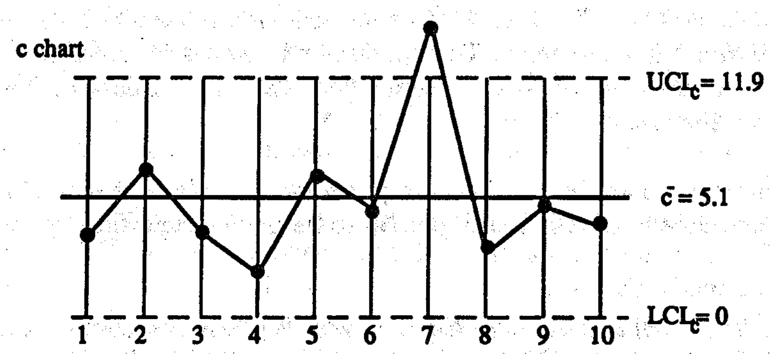
It is the purpose of this paper to go behind the scenes and establish the fallacies associated with the quality improvement claims without the mention of associated costs. As an example, let us say that Company X produced 100 units—95 good and 5 bad. Company X shipped the 95 good units to customers and diffused the cost of the 5 bad units within the accounting system. As far as the customers are concerned, the quality has improved, but at what cost? Nobody knows for sure. The quality science would try to understand the causes for bad units with the objective of reducing them from five to zero. The paper develops the thesis that we don't truly understand the forces behind quality improvement but we can say with certainty that it is not through the effective execution of quality science. Until we understand these forces, we will continue to see explosive quality articulation and vulturous consumption of funds available to improve quality. The conclusions developed in the paper make the case for drastic change in how we should view quality movements and execute quality ideas effectively.

QUALITY CONCEPTS AND FUNDAMENTAL EXECUTION FLAWS

Let us examine some of the fundamental quality ideas and the flaws in their execution.

Statistical Process Control (SPC). SPC is an extremely important concept in supporting any form of quality initiative. However, execution of SPC has been a farce. We just won't admit it. On the scientific side, even the basic premise of SPC is not well-understood. People who teach SPC have been bookish and have never actually executed SPC themselves. As a result, they have taught and plagued the system with many erroneous SPC applications. Let us look at two examples. Figure 1 shows an application of the c chart and Pareto chart as a single entity. The purpose of the c+Pareto chart is to select a problem category and solve it. Without getting into mathematical details, it is possible to assess the data on day 7 as an unusual occurrence compared to the data from the other days. This will force one to examine in closer detail what exactly happened on the 7th day. In the words of Dr. Shewhart, one can say that the assignable cause is present. Now when the question is asked to SPC teachers as to which category should be selected as a problem-solving candidate, nine out of ten responded Category 1. Another possible response is Category 5 for the following reason. Category 5 is symptomatic of instability. Anytime instability is present, it represents a malfunction. On the other hand, Category 1 is symptomatic of incapability. Incapability is present either due to a lack of process understanding or due to process structure limitations. According to Dr. Shewhart's principle, physical laws do not apply in the presence of a malfunction. That is, until the malfunction is removed, it is difficult to enhance the understanding of process physics. Which is the right answer? It is the author's interpretation that Category 5 is the first choice and Category 1 is the second choice. Why then is there an overwhelming response in Category 1 by SPC teachers?

Here is another scientific misunderstanding. There is an argument among SPC teachers as to the meaning of SPC. The argument is whether to control process variables or to display product variables on control charts. Here are a couple of quotes taken from pieces of SPC seminar literature: (1) "*Too many companies still do not apply SPC correctly. They monitor product variables instead of process variables, and, as a result, they find production quality problems too late....This SPC seminar will help you avoid such mistakes and show you how to proceed with confidence.*" (2) "*How many times have we seen ads offering extensive hardware for measuring various product characteristics and explaining that this is the way to perform Statistical Process Control? Unfortunately, however, we seem to be missing the boat on this one....While some product measurement is required, the real focus for SPC should be on the process side of the equation.*" Let us compare Dr. Shewhart's statement about the control charts with the preceding quotes. "*Based upon evidence already presented, it appears feasible to set up criteria to determine when assignable causes of variation in quality have been eliminated so that the product may then be considered to be controlled within certain limits.*" It is evident that Dr.



Day	1	2	3	4	5	6	7	8	9	10	Total
Defects per unit (unit size = 20)	4	6	4	2	6	4	13	3	5	4	51
Category # 1	/	//	/	/	//	/	///	/	/	/	14
Category # 2		/		/		/	/		/		5
Category # 3	/	/	/						/	/	5
Category # 4		/			/		/			/	4
Category # 5	/						/////				6
Category # 6		/				/	/			/	4
Category # 7	/		/		/		/		/		5
Category # 8			/			/	/		/		4
Category # 9					/			/			2
Category # 10					/			/			2

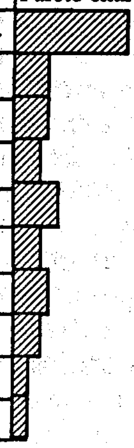


Figure 1. c+Pareto Chart

Shewhart is referring to displaying product characteristics on the control chart and using them as indicators of the process condition. Why then are SPC experts talking about display of product variables as after-the-fact SPC or a mistaken way to apply SPC? If you examine different processes, it would be almost immediately clear that only a certain class of process variables can be plotted. Secondly, from those that can be plotted an even smaller subgroup has been proven beyond a doubt to be directly related to the end result. On the contrary, product characteristics displayed on the control chart should help in the determination of which process variables need to be controlled and in what order of priority. Why is it then that controlling process variables became synonymous with SPC? If one wants to control process variables, call it good manufacturing practice and don't mess with the strategic idea of SPC.

The absurdity of SPC is extended on the execution side as well. Overwhelmingly, management considers SPC to be a tool for an operator. For this to be true, there are six action elements to be realized by the operator almost on an instantaneous basis. These six elements are measurement of output, summarization of output in statistical terms, graphical display of statistical summaries, interpretation of the graphical display, determination of physical action, and execution of that action. In less than one percent of the cases, the operator is in a position to execute all six elements instantaneously. Actually, with proper training and or computer assistance, the first three elements at most can be made instantaneous. However, the execution of the remaining three elements would extend over time. In addition, many more people would need to be involved. Why is this scenario not recognizable by management? The effective execution would consider the operator having the responsibility for the first three elements. The operator role would be more realistically defined as a custodian of SPC information rather than a controller. The side effects of calling the operator a controller are mostly negative.

With all this confusion about SPC, we cannot put forward a claim that SPC has delivered returns above and beyond investment. SPC is too important to be treated superficially as has been the case in many companies.

Design of Experiments (DOE) and Taguchi Experiments. We can talk about these two ideas together without demeaning the importance of either one. For the purpose of discussion, we can describe DOE as a way of investigating a certain class of problems in the most mathematically efficient way. We can describe Taguchi methodology as a subset of DOE with some philosophical emphasis. For the purpose of readers not accustomed to statistical terminology, we can describe DOE as a method of covering maximum investigative space with minimum tests possible. There is so much philosophical fuss about DOE that the true problems go begging. On a broader platform, the success of DOE depends on the translation of the actual problem from physical circumstances to statistical descriptions. If the translation of the actual problem is inaccurate, the whole DOE exercise delivers nothing. In fact, it has been said that the problem well-defined is half solved. One would think then that half of any DOE book would be devoted to a translation of the physical problems into statistical problem descriptions. This is generally not the case. The DOE books assume, and quite incorrectly, that the user of the DOE technique would somehow know that a statistical problem definition is an important prerequisite to benefiting from the DOE exercise. In general, a large number of DOE books even fail to warn the reader about this. In fact, to the best of the author's knowledge, there is no good book on how to translate physical problems into statistical descriptions. Thus, we accumulate large numbers of DOE exercise failures directly attributable to improper problem definitions. As an example, a team was looking at improving the integrity of a glued bond between papers. The variables they listed for investigation were moisture content of the paper, speed of the machine, pressure applied to the papers, amount of glue, heat applied to the paper, etc. The team had made the assumption that they didn't fully understand the effects of all the variables on the bond strength, and therefore a DOE exercise was warranted. They executed DOE with a few select variables from the list. Much to the team members' surprise, the DOE conclusions showed that none of the variables were important. Upon reexamination of physical circumstances, the team found that the papers in the machine were riding concave rather than flat. The concavity of papers was an abnormality for that operation. Thus the condition of papers turned out to be an important operational variable. The variables the team investigated were related to the process physics. At that point the team members began to understand that they should have attacked the concavity problem before they attacked the problem of process physics. Had the team made an attempt to define the problem before rushing into the DOE exercise, they would have discovered that concavity and process physics would have showed up as an instability (first priority) and a variation (second priority), respectively. This example illustrates that the need for a problem definition as a prerequisite to DOE cannot be overemphasized.

The second problem with DOE is more strategy oriented—meaning business strategy. There are three strategic issues in business which force us to look for speedy and less costly solutions. These issues are: (1) How do we know we are not already operating at an optimum level of hardware? To answer this question we do not have to start from ground zero. We will only look for certain classes of DOE designs. (2) To support the notion of less costly solutions, we first select those variables that require practically no expense. Then, we select those variables that require minor hardware modifications. Finally, we select variables that may require major hardware modifications. Thus, in business, we like to spend our money wisely by selecting variables in a hierarchical fashion. (3) To get to the solutions quickly, it may not be necessary to do a full-fledged mathematical DOE exercise, because the desired outcome becomes visible before all the planned tests are done. What is important is to recognize that the DOE is more of a thinking tool rather than a mathematical exercise.

A couple of comments on the Taguchi class of experiments: To a statistician, there is no drastic difference between so-called Taguchi experiments and DOE. It is a glamorization of the DOE concept under a different name rather than another DOE science. The more we talk about Taguchi experiments as a separate entity than DOE, the more we get closer to admitting our lack of understanding of quality methods, our ineffectiveness to integrate and execute quality ideas in our daily operations, and our wastefulness in debating the issues beyond their useful values. Let us talk about at least three ideas that are directly associated with Taguchi discussions. The first idea is *uniformity around target* as an operational definition of quality. In numerous engineering applications, this definition is a proven fact. One does not need to indulge in a one-day Loss Function seminar to understand the concept. Lack of understanding is evidenced by the poor execution of this concept by the big three automotive companies. These companies have imposed a $C_{pk} \geq 1.33$ on their suppliers and subsuppliers. The C_{pk} is an indicator of process performance with respect to the desired target and the specification range. It is an erroneous belief that processes with higher C_{pk} values will perform closer to the target. It is possible to raise the value of C_{pk} by reducing process variation and without moving the target at all. Thus $C_{pk} \geq 1.33$ by itself is an incorrect translation of the *uniformity around target* concept. A proper reflection of the *uniformity around target* concept would require $C_p - C_{pk} \approx 0$. The *uniformity around target* is a two-dimensional phenomena and it cannot be controlled with a single entity, namely, C_{pk}. Thus exists a dichotomous situation and a feeble argument in favor of $C_{pk} \geq 1.33$. The only interesting point is that the same people who advocate *uniformity around target* have imposed the $C_{pk} \geq 1.33$ requirement.

The second idea is *Robust Product or Process Designs*. That means designing products or processes such that they are least sensitive to uncontrollable variations of the influencing factors. To execute this idea effectively, we must elaborate on the word robust. To get robust product or process designs we must seek out or develop the latest technology and apply it at the most economical point in a system. In yet more micro-terms, what robust means is that one must understand the interaction between two influential variables, and design hardware in such a way that the least controllable influencing variable is inherently compensated by the product or process without human intervention. Let us see how industry has used this concept. All products at some point of initiation start as raw materials. We can claim that the variation in raw materials was created by God. Anyone interested in using raw material must develop processing methods that can deal with raw material variation downstream from the source. Thus, for those involved in developing processes to convert raw materials into finished products, it becomes an additional challenge to deal with the natural variation found at the source. Ultimately, the finished products arrive in the hands of the consumer and sometimes they fall outside his or her expectations. Thus, a problem develops to be dealt with. Therefore, any problem can be defined as elements bouncing between God and the customer. Where does the search for robustness begin? It is really a matter of execution strategy guided by the economics of investigation and ultimately the economics of implementation. It is not that we are unfamiliar with the idea of robustness, but it requires engineering competence to come up with creative ideas, and putting statistical investigation efficiency behind them to prove their worth. In the author's experience, in nine out of ten cases, for a chain of events that exists between raw materials and the finished products, it is economical to begin the search for the solution near the finished products and travel upstream toward the raw materials. Take an example of a chemical supplier with the problem of overfill and underfill at the final weighing station. The supplier sells 1,000 pounds of a chemical in a drum that weighs 50 pounds. He has designed the process such that when the drum is put on the scale, a chemical poured in. When the scale reads 1,050 pounds the cycle is complete. The problem comes from two sources of variations: the drum does not weigh exactly 50 pounds, and the chemical poured is not exactly 1,000 pounds. The previous studies at this site have shown that there is more variation in the drum weight as compared to the weight variation of the chemicals. Immediately, there are two ways we can look at this problem. We can either make the weighing process robust so that it is insensitive to the variations in the drum weight, or we can reduce the variations in the drum weight. The studies showed that drum weight variation is directly attributable to the steel thickness. So, to reduce the variations in drum weight, we will have to talk to the steel supplier. The steel supplier feels helpless because the contributing reasons for thickness variation seem to be coming from iron ore. Now we will have to talk to God, about why there is so much variation in iron ore. What would God say? Guess what? The problem got resolved by modifying the weighing process. The scale was programmed to read zero after the drum is placed on it. There are numerous actual case studies known to the author that would prove the search for robustness begins near the end result and systematically moves upstream. This is equally true when seeking robust ideas to deal with issues of product design or issues of business. The industry does not apply the idea of robustness effectively in the business cycle. To business customers, robustness has meant imposing tighter variations on suppliers above and beyond what makes economical sense.

The final idea associated with Taguchi discussions is *orthogonal arrays*. Most DOE are orthogonally arranged. In fact, orthogonal arrangement is synonymous with DOE. It simply means any pair of variables viewed simultaneously must cover the investigative space fully. The fame of the Taguchi orthogonal arrangement is that it requires fewer trials than the full factorial experiment. This is true of all fractional factorial experiments, not just Taguchi experiments. So what is so unique about things like the Taguchi L8 arrangement? Nothing mathematically. Actually, looking for uniqueness in the Taguchi L8 arrangements, users have really missed two other more important and costly issues. These two issues are somewhat interrelated. Let us say that there are seven factors being investigated in the L8 arrangement. People who have not solved many problems are not used to thinking about the cost of investigation. Can you imagine the cost of arranging seven variables as + and – eight different times in one experiment? Everybody thinks that the investigative variables come in the form of knobs that can easily be turned either + or – at whim. Suppose one of the variables is a die material. Is it affordable to have two dies made for the experiment? Rather, one must look for an alternate way to execute the same investigation with the idea of minimizing the investigation cost. Multiple regression is a well known technique for the class of problems where outcomes and variable fluctuations can be observed rather than experimented with in the DOE sense. In the author's personal experience, careful execution of regression studies have solved many engineering problems where DOE would have cost a great deal of money. Thus, the two issues are why don't Taguchi teachers talk about execution expenses in the conduct of the experiment and why is multiple regression not taught along with Taguchi teachings?

Thus, the DOE discussion leads us to believe that even though DOE is an excellent philosophy and tool, its poor execution has not allowed us to enjoy its full potential and associated claim.

Thus, we arrive at yet another conclusion. Investments in DOE and Taguchi discussions have cost us far in excess of the benefits.

ISO 9000 Quality System Standards. ISO 9000 standards are the latest and greatest of competitive tools which has spread like a Japanese kudzu. It has vividly demonstrated the existence of two quality camps much more so than any other quality movement of the past. One quality camp is system oriented. The other quality camp is improvement oriented. System orientation deals with perfecting a paperwork system that supports conformance quality. Improvement orientation is more focused on raising the level of quality in a productive manner. System focus is philosophical whereas improvement focus is action oriented. Improvement orientation not only produces immediate results but acts as a seed for system development and further gains. Figure 2 illustrates this point. The quality system camp has been obsessed with perfecting the quality system since the early 1940s. It has not succeeded in perfecting a paperwork trail for numerous reasons. ISO 9000 standards are simply another attempt by the system camp to prove its existence and worth. Quality improvement, of course, has a more scientific tone. Unfortunately, the improvement camp has not been able to perfect its approach to the quality problems either. People in this camp are frustrated with many issues related to quality science. The question boils down to a couple of strategic options. Remodel the paperwork system and quality will improve. Or enhance quality which will force you to improve the system to hold the solutions in place. Quality professionals in the system camp seem to be winning as evidenced by mad rush to earn ISO 9000 status. Actually, valuable resources of our nation are occupied in the ISO 9000 standards mania without any strategic considerations that can provide a balance treatment between improving quality and earning the ISO 9000 status. It seems like nobody wants to go there, but everybody is heading in that direction.

It would not be out of line to say that an unbalanced investment in earning the ISO 9000 status robs money from technological improvements. Only businesses that can benefit from ISO 9000 quality system models are the ones with entrepreneurial style businesses where an informal handshake used

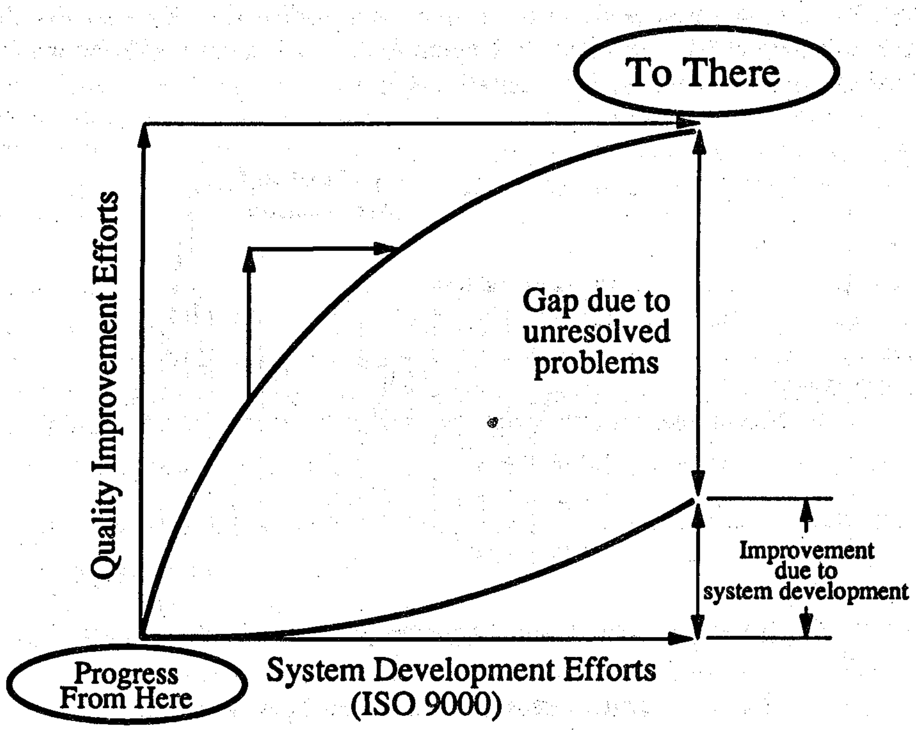


Figure 2. Quality Improvement Efforts versus System Development Efforts

to earn the business. In the world market, such informality has now reduced to pleasantry not good enough to prove sound quality practices or to earn a significant market share.

Total Quality Management (TQM). Another concept that engulfed the nation in the late 1980s was TQM. The resources tied up in trying to rearrange business under the TQM umbrella far exceeded the benefits that were realized. You can get only the conceptual description of TQM from TQM teachers and nothing more. TQM advocates are talking about rearranging the business without any experience of ever running any business. Actually TQM when correctly applied, has such penetrating power that it will reveal the wasteful habits and profitable shortcuts in any business. Which business or industry is willing to rearrange the beneficial shortcuts and correct wasteful habits? Most TQM talk is SEMINARial in nature, full of airport seminars and very little inherent change in the way we think about quality.

IMPROVEMENT CONCEPTS BEYOND MANUFACTURED GOODS QUALITY

There are many broad improvement categories beyond manufactured goods quality that can fit under the umbrella of quality discussion. At the top level these categories consist of improving quality, improving productivity, and reducing waste. The quality category can be subdivided into conformance quality and grade of quality. These categories help us focus our improvement efforts productively.

Next we take any product or service issue which is of interest to our customers. The customer can be the next person downstream, a government agency, or the world community in general. Now we find an index and a measurement criteria that will reflect the level and the behavior of this interest on an ongoing basis. We can now display this index in a graphical form as shown in Figure 3. Next, we determine what level we would like to achieve. The level to be achieved can be market-driven or leadership driven. We are now in a position to set out quality direction. Our quality efforts can be divided into three categories: (1) curb or control operational disturbances, (2) reduce variation, and (3) create a systematic movement toward a desired target.

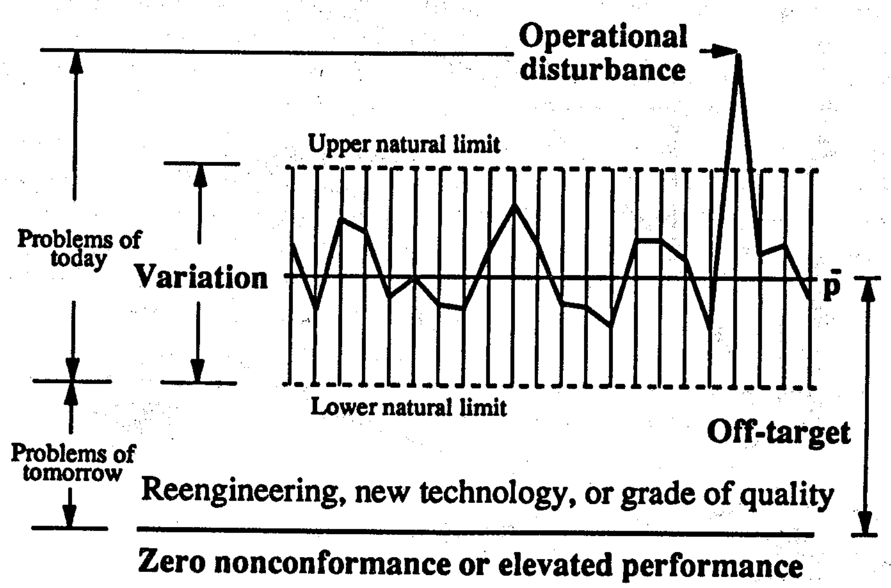


Figure 3. Problem Definitions from a Quality Perspective

Each one of the categories requires a different type and degree of effort. Control of *Operational disturbances* requires us to understand their nature, frequency, predictability, etc. Some disturbances are so obvious that all of these answers are readily known. Other disturbances are such that nothing is obvious and the investigation must follow. Nonetheless, once we know everything we need to know about the disturbances, we set out to prevent, control, correct, or contain these disturbances by using the latest technology possible. *Variation* reduction requires that we understand the variables involved in the current system. The variation problem can be divided into two subcategories: understandable and not understandable. The understandable variation can be further divided into economically correctable or not economically correctable. DOE strategies allow us to investigate these components effectively. Once the knowledge of the variation reduction is established, we once again seek the technology to upgrade the system to the next level. *Off-target* improvement can only be achieved by the system or the process which is much different than the one in current use. That means the introduction of new technology or an entirely different way of doing things. The current vocabulary that has entered the management arena is *reengineering*. It can also be referred to as raising the grade of quality—meaning meeting different expectations or different specifications than in previous use. Operational disturbances and variations together can be labeled as *problems of today* because they are related to the systems, designs, and processes that are in place today. Off-target problems can be referred to as *problems of tomorrow* because they can only be solved by changing the grade of quality, reengineering, or infusing new technology.

Once this framework is understood, it provides a no nonsense strategic path toward product or service quality improvement.

CONCLUSION

We can say that quality is a never ending journey in the context of improving the quality of life and remaining globally competitive. We can further state that this journey has to be productive to derive the end results desired. Quality science can add productivity to quality improvement efforts. The quality science focuses on an output condition to improve, upgrade, or reengineer the processes, products, or systems to bring them close to target values. The specific elements of the quality sciences are SPC, DOE, TQM, ISO 9000 standards, etc. These elements can be applied productively or wastefully. As illustrated in the paper, the quality ideas are currently applied wastefully, for the most part.

The interesting puzzle then is why has the United States automotive quality improved? Of course, if we ask the question, at what cost has quality improved?, then, we do not have indicators showing a clear victory. In any case, there are much broader forces and indicators acting on the scene that show the United States automotive quality has improved but do not show the cost associated with it.

Even though quality professionals, enjoy the world's attention on quality and even take a partial credit for improved quality in some sectors, they cannot clearly claim that it is due to an effective execution of quality science.

The only conclusion one can make is that there are much broader forces at work which beg further analysis. We must understand that QUALITY IMPROVED IN AN INEFFECTIVE WAY BREWS A MUCH LARGER PROBLEM SOMEWHERE ELSE. Let us challenge ourselves to understand these elusive forces and communicate to those who need to act. Until we understand, the quality may continue to improve by costly solutions and quality improvement funds will be consumed by vultures.

To enjoy quality improvement without applying quality sciences effectively is asking for a lot of trouble later on.

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