The Power Of Taguchi Methods To Impact Change In U.S. Companies

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The advancement of "quality engineering" as a technology to simultaneously reduce cost and improve quality was developed by the noted Japanese engineering specialist, Genichi Taguchi. Since 1960 Dr. Taguchi has received the Deming Prize in Japan on four separate occasions for his contribution to the field of quality engineering. On October 7, 1986, in Pittsburgh, PA, Dr. Taguchi received the most prestigious prize from the International Technology Institute: The Willard F. Rockwell Medal for Excellence in Technology.

This medal is awarded to a maximum of three individuals each year (no more than one from any continent) for excellence in technology. In particular, it recognizes the recipient's contributions toward the generation, transfer, and application of technology for the betterment of mankind. Following is a portion of the inscription on Dr. Taguchi's medal ". . . Taguchi's major contribution has involved combining engineering and statistical methods to achieve rapid improvements in costs and quality by optimizing product design and manufacturing processes. His methods represent one of the major advances in the history of manufacturing industries."

Many papers have been written over the past four years to evaluate the technical aspects of Taguchi Methods and to compare them with traditional statistical theory. Also, there have been a great number of debates in the U.S. promoted by well known statistical specialists. I believe the controversy has now been neutralized by success stories in the application of Taguchi Methods. However, some benefit has been derived through this controversy and debate. Traditional statistical methods are more in focus and "quality engineering" using statistics has emerged as a separate technology.

Advancements in traditional statistics have been promoted by J. Stuart Hunter, who received the Deming Award for Applied Statistics in December 1986. This award is for excellence in the application of statistics and we are very pleased that Dr. Hunter has been recognized for his work.

The American Experience

As one of the major advances in the history of manufacturing industries, Taguchi Methods are beginning to have great impact on changing the way U.S. companies operate to simultaneously improve quality and reduce cost. This paper outlines several changes currently being experienced in certain U.S. companies.

My first introduction to Taguchi Methods was at Nippondenso in March 1982. Professor Yuin Wu, who translated Dr. Taguchi's works, began supplier training for Ford in April 1983. Five years later, I am still learning about this technology, which is not covered in traditional statistical literature. (The term Taguchi Methods refers to parameter design, tolerance design, the quality loss function, on-line quality control, design of experiments using orthogonal arrays, and methodology applying for the evaluation of measuring systems).

Due to the recent popularity of Taguchi Methods in the U.S., many specialists are applying these methods. Few individuals really understand the concepts since this requires many years of application. (Today there are only six or seven specialists in the U.S. that have full Taguchi knowledge.) Many U.S. companies, however, have been very successful at applying Taguchi Methods. Therefore, a large number of specialists exist in supplier companies.

When Ford introduced this technology to suppliers (October 1982), ITT was the pioneer in case study development and they now have over 2000 case studies. Jim Pratt, ITT director of statistical methods, was the first supplier executive to fully appreciate the power of Taguchi Methods. Today he is a leader in this technology. Other companies who have learned these methods include Sheller Globe, Aerojet Ordnance, Allied, Ford, General Motors, Chrysler, Eaton, Dana, General Tire, Johnson Controls, Polaroid, Copeland, General Electric, Goodyear, Kelsey-Hayes, Mercury Marine, United Technologies, Flex Products, Diversitech General, Xerox, AT&T, Texas Instruments, Davidson Rubber, A.O. Smith, Allen-Bradley, Control Data, and the Budd Company.

Applications experts have emerged in each of these companies. Within Ford, there is a very aggressive effort to apply Taguchi Methods and develop case studies. Dr. W. H. Moore in the Body & Assembly Division heads up a special task force on Taguchi Methods, and she is one of the most knowledgeable practitioners in U.S. industry today. Bob Marshall, the Ford Body

& Chassis engineering director, is personally sponsoring the development of many case studies and the presentation of results in symposium type reviews.

There are over 6000 case studies in U.S. companies. Japanese companies are the leaders in the application of Taguchi Methods. Nippondenso, for example, completes over 2600 applications per year primarily to optimize product design. Most Japanese companies and several U.S. companies are using Quality Function Deployment (QFD) as the horizontal mechanism to identify conflicting design requirements where Taguchi applications would be most beneficial.

A good explanation of Taguchi Methods and QFD (see Fig. 1) was written by Bill Eureka, reliability manager for General Motors, CPC Group. Ford and Chrysler have written similar definitions which are being fostered by many supplier companies. (See the May and June 1986 issues of *Quality Progress* for more detailed reports on Quality Function Deployment).

During the past three years in the U.S., we have seen a significant change in quality thinking and in engineering technology through the application of Taguchi Methods. Although this change has developed slowly (due to statistical controversy), we are beginning to see where this technology will have a greater impact on U.S. products than any other individual concept or method yet devised.

To Impact Change

During a recent study mission to Japan, the president of Toyoda Gosei made some interesting remarks regarding change within a company. Mr. Nemoto told us that managers at Toyoda Gosei are promoted on the basis of change; how they were able to impact change in their job to help achieve company growth objectives (i.e., market share). He contrasted this with traditional U.S. managers who are evaluated on how well they perform within prescribed guidelines, specific areas of responsibility, and fixed budget levels. In fact, U.S. managers who go beyond their job to create change are considered mavericks and they rarely advance to higher levels in the company. U.S. executives are uncomfortable with managers who promote change!

The real value of Taguchi Methods is to impact change in U.S. companies. Traditional statistical theory has created very little change in 30 years. U.S. statistical specialists have been successful in maintaining the status quo for U.S. industries. In recent years there has been a modest change in company operations through the application of statistical process control (SPC). However, traditional Design of Experiments (DOE) has had no impact at all unless modified for the Taguchi

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Explanation of Taguchi Methods and Quality Function Deployment

Taguchi Methods and Quality Function Deployment (QFD) are major elements of an overall business strategy known as Total Quality Control (TQC). TQC is sometimes also referred to as CWCC—Company Wide Quality Control.

Total Quality Control originated in Japan as a means in significantly improving *business operations* through improved quality. One often misunderstood aspect of TQC is that quality encompasses not just product "goodness" but economics as well. The Japanese do not consider the NASA or military high-cost approach to be quality! This can be illustrated with the accompanying table.

		Quality	
		Low	**High**
Cost	**Low**	Junk	Desired
	High	Bad Business	NASA

The excellent Japanese companies have moved into the high quality/low cost quadrant through the use of TQC techniques, of which Taguchi Methods and QFD are the most powerful tools.

Taguchi Methods are a collection of techniques for reducing costs through reduction of variation, which will *always* result in quality improvement! The primary methodology is based on statistical techniques which Genichi Taguchi has reduced to a simple form that hourly production workers in Japan can readily utilize. Taguchi Methods allow designs and manufacturing processes to be optimized in a manner which makes them insensitive to factors beyond the manufacturer's direct control (such as environmental usages and customer abuse), resulting in "forgiving" designs and processes. Thus designs become easier to build and manufacturing processes become more capable, allowing for reduction (or elimination) of expensive inspection and rework operations.

Quality Function Deployment is a *business planning* tool which may be applied at any point in the business, but is most effective when initiated at the earliest stages of product development. When applied at this point, customer requirements are defined, and a sequence of plans evolve for ultimately identifying critical product characteristics and manufacturing process parameters—resulting in satisfaction of the original customer requirements.

The use of QFD and Taguchi Methods has been instrumental in helping Japanese companies to improve quality, reduce cost, cut product development time in *half,* and achieve major competitive market advantages.

Fig. 1.
Source: Bill Eureka, reliability manager for General Motors, CPC Group.

way of thinking. *It is the change that is important because without change we cannot improve the competitive position of U.S. products.* The balance of this paper will outline several changes that are developing within U.S. companies which are the direct result of Taguchi Method thinking and applications.

Change #1 — *Definition of Quality*

One of the most important changes in U.S. companies resulting from Taguchi Method applications is the redefinition of quality and the meaning of quality improvement. Since the central theme of parameter design is to reduce cost by reducing variability, the definition of quality can no longer be "conformance to specification" limits. The meaning of quality improvement, therefore, is changed from problem solving to reducing variability around target values. The important point here is how to measure quality improvement!

In the traditional U.S. way of thinking, you measure quality improvement by evaluating defect rates or the frequency of field problems. Through the use of Taguchi Methods, you measure quality improvement based on annual cost savings. Through parameter design, quality improvement is automatic and therefore need not be measured as quality but rather as cost improvement. Therefore, the whole focus of quality improvement is to reduce cost. Since other corporate performance indicators are cost-based, this more enlightened thinking transforms quality from a series of emotional encounters to a business strategy for all employees to follow.

As I mentioned earlier, there are now over 6000 case studies from U.S. companies on the application of Taguchi Methods. In quantifying the results of these case studies we rarely see quality (i.e., defects) as a measure of success. Usually results are evaluated on the basis of annual cost savings.

For example, let's take results reported by three separate companies: one large, one medium size, and a small company. Since March 1983, ITT has trained approximately 1200 engineers in Taguchi Methods and completed over 2000 case studies. They have calculated cost savings of $35 million from this effort. Sheller Globe, which has trained 120 engineers and completed 225 case studies, reports a $10 million cost savings. Flex Products, with 12 engineers trained and 75 case studies, shows a $1.4 million savings.

In some companies, there is resistance to case studies due to the cost and production interruptions of running experiments. At Dana Corporation, the first nine experiments cost $33,200 to complete but resulted in a direct cost savings of $447,000 (not a bad payback for low-level quality improvement effort). A large portion of reported cost savings is passed on to the customer, enabling these companies to be more competitive and gain larger market share. Quality improvement is automatic since the way in which cost savings were realized was through quality improvement (by reducing variability).

Although engineers at Bell Labs and Xerox were the first to experiment with Taguchi Methods in the United States, Ford was without a doubt the leader in changing company policy through this more enlightened way of thinking. In a March 3, 1983, Ford Motor Company policy letter, Mr. Peterson (then president and current chairman) stated, "Employees and suppliers must begin to think of the quality of products and services not only in the customer sense but relative to the quality of the processes that produce them. In this regard, we should focus on methods to reduce the variability of process output, not just meeting specifications".

W.E. Scollard, Ford vice president of engineering and manufacturing, led a company-wide effort to imbed this thinking in all activities. A statement from Scollard's presentation to all top executives at Ford on May 9, 1983, reads as follows; "Our new quality thinking should be reduced process variability around the nominal as an operating philosophy for never-ending quality improvement."

Leadership for the supplier was provided by C.D. Lauer (Ford vice president of purchasing) who in May 1984 declared that Taguchi Methods would form the basis for quality improvement and cost reduction in the future and all suppliers should become trained in this new quality technology. In May 1985, L. Ross (Ford executive vice president) directed that all engineers at Ford be trained in Taguchi Methods. Taguchi Methods are beginning to take hold at General Motors. An article in the January 1987 issue of *Automotive Industries* magazine quoted Gary Dickenson, the General Motors CPC engineering director, as follows: "We're using Taguchi Methods to improve aligning the front suspension. We have an eight-man team studying all variabilities such as tire pressure, hysteresis in the tire bead, and so on. I want all our people trained in Taguchi Methods."

I think this change in thinking about quality is truly a great advancement for U.S. industries and it is a direct result of Taguchi Method applications by supplier companies with leadership from Ford.

Change #2 — *Financial Control System*

The Quality Loss Function (QLF) for which Dr. Taguchi received a Deming Literature Prize has the potential for great change in the financial system of U.S. companies. The QLF creates an economic perspective which tends to redefine the traditional cost control guidelines under which most U.S. companies operate. Every major company has a financial system with payback-ratios for capital expenditure and product design improvement. If a quality improvement idea does not meet these guidelines, it cannot be implemented. Based on the traditional U.S. definition of quality (conformance to specification limits), these guidelines prevent improvement where part characteristics are within print tolerances (see Fig. 2).

The QLF quantifies annual cost savings as product characteristics improve toward target values even when they are within spec. This puts

a whole new economic perspective on quality and encourages continual improvement as a method to reduce costs.

For example, General Tire in Akron, OH, has been working for some time to improve tire conicity and reduce cost. Using the Taguchi Loss Function to evaluate internal loss by sorting as compared with loss by dispersion, they calculated a potential savings over three times the amount currently booked in the cost control system. This savings funded design and process improvements for reduced variability in tire conicity. As a result, General Tire is changing the financial system to recognize annual savings calculated by the loss function. This process opens up a whole series of opportunities to reduce costs by improving quality. Similar changes in financial controls are being implemented by Sheller Globe and several other supplier companies.

Change #3—*Engineering Target Values*

In order for Taguchi Methods of parameter design to be effective, the product planning function and engineering activities must establish target values to meet each characteristic of the "voice of the customer." Spec limits or tolerances which theoretically represent the "voice of the engineer" are no longer acceptable. This requires a change in marketing intelligence as well as engineering knowledge to develop target values which represent the best level for function, fit, or appearance.

When target values are established, the engineering function must be directed to optimize product designs early in the product development stage, especially where conflicting requirements exist. Trade-offs and compromises are eliminated where possible or moved to the very last stages of product development. Compromises made in the early stages—done in many U.S. companies—become built in and therefore preclude product optimization for robust function. This method forces a significant change in the way many U.S. engineering activities operate today.

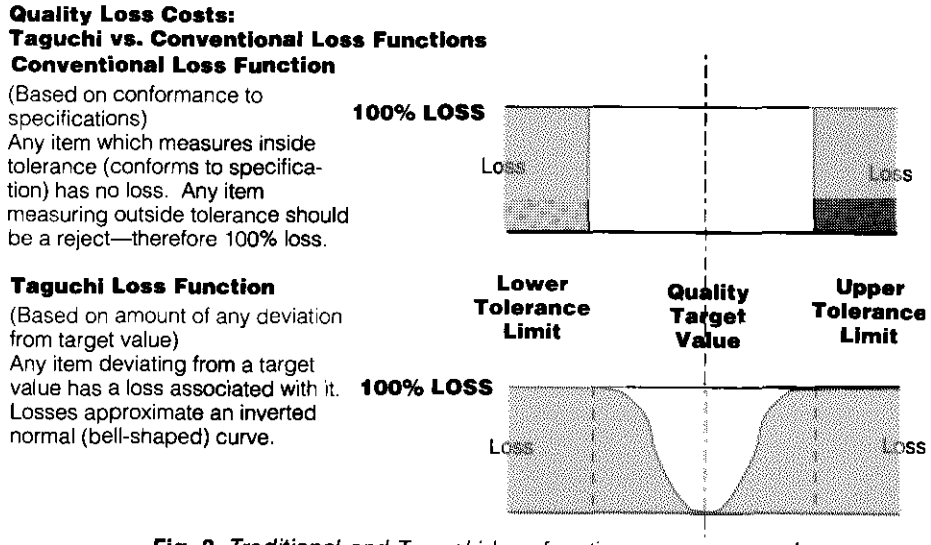

Fig. 2. *Traditional and Taguchi loss functions are compared.*

Change #4—*Manufacturing Process Improvement*

Taguchi Method applications result in significant changes to the manufacturing system. Traditional thinking in U.S. companies holds that parts within spec are OK and as long as parts are within spec, nothing further is required. Several changes that we see developing in U.S. companies which apply parameter design and on-line quality control methods are:

- *Continuous improvement through variability reduction (discussed in Change #1).*
  With the idea of continuous improvement, traditional quality control inspection using go-no-go gaging is replaced by target or best-value analysis. This change effectively re-directs quality effort from problem solving to reducing variability. It is very exciting to see all employees (product engineers, maintenance, tool set-up, line operators, etc.) change their thinking to focus on target values.
- *New guidelines for funding process improvement.*
  New guidelines for funding process improvement result from this change. The idea is to optimize existing machinery using parameter design *before* a project is approved for new, more modern equipment. Many U.S. companies are quick to fund new processes or tooling without first optimizing old equipment. At ITT for example, there is a revised guideline in several operational groups which prohibits capital spending until existing equipment has been improved using Taguchi Methods. Before a project is approved, the ITT plant manager must present a Taguchi case study showing how the current process operation and tooling was optimized. This guideline effectively reduces cost and improves process capability.
- *Less reliance on control charts and process capability analysis.*
  Companies which have implemented Taguchi Methods for on-line quality control have reduced the need for Statistical Process Control activities and changed the focus from quality control to cost reduction. Traditional SPC is not cost based and therefore tends to conflict with other in-plant cost systems. On-line quality control methods developed by Dr. Taguchi include cost equations to determine optimum inspection and testing intervals. Today only a very few U.S. companies understand on-line quality control technology while in Japan it is used extensively. Nippondenso is probably the most advanced in the use of these methods.

Change #5—*Horizontal Technical Interaction*

U.S. companies are generally strong in vertical deployment and weak in horizontal interaction. Taguchi Methods training and case study development, which requires cross-functional team interaction, creates great change in how a company operates to improve quality.

The traditional method of assigning problems to the areas most responsible for solutions and preparing reports on corrective action status simply does not work. It only serves to perpetrate emotional interaction and "finger pointing." Companies which foster team training in Taguchi Methods with case study development and presentation of results realize significantly stronger horizontal interaction. It is the most powerful internal change to maximize quality improvement and cost reduction!

The presentations of case studies to large groups of engineers and executives is an essential ingredient. When Dr. Taguchi first became a director of the American Supplier Institute, he insisted on case study presentations in a symposium format. (He was instrumental in developing this review method at Nippondenso). Since April 1984, after four such symposia conducted by ASI, we fully appreciate the value of this technique.

Several supplier companies including ITT, Sheller Globe, and Allen-Bradley are holding regular internal symposium-type reviews for Taguchi Methods. Chrysler held its first symposium in November 1986 and Ford began quarterly symposia in January 1987. Technical interaction is promoted through thousands of case studies presented in forums with top management. This effectively changes internal deployment from vertical (voice of the executive) to horizontal (voice of the customer).

Change #6—*Industrial Standards*

The application of Taguchi Methods tends to standardize as well as promote new quality technology. When evaluating QFD case studies in Japanese companies, it became clear where design engineers are using Taguchi Methods to establish part tolerances based on economic as well as functional considerations. The Japanese Standards Association is now developing General Tolerancing Rules for generic components based on cost aspects of dispersion, process capability, and the value of signal-to-noise ratios. Included is the variability of measurements with a corresponding assessment of cost. The first Japan Standards Association publication is entitled, *General Tolerancing Rules for Plastic Dimensions—JISK-7109.* Several U.S. supplier companies are conducting pilot studies of this standard to determine changes to be made in traditional methods.

Tolerancing in many U.S. engineering activities historically has been derived from rule-based methods from S.A.E. or S.M.E. standards. More often, however, tolerances are established through "engineering judgment" or provided by suppliers who have determined the "best we can hold" on a particular dimension. Therefore, we find significant variability in tolerances from company-to-company for generic processes and parts that are similar in function.

The important point is an economic one: Japanese standards using the loss function are derived to achieve the lowest cost and best quality simultaneously. The standardization aspect becomes an added advantage to improve efficiencies of engineering activities in a variety of industries. The establishment of General Tolerancing Rules based on economic as well as functional consideration results in a significant change through the use of Taguchi Method Technology. We see this change emerging in several U.S. companies including Ford, ITT, Sheller Globe, and The Budd Company.

Conclusion

New quality technology based on Taguchi Methods was first introduced to the U.S. automotive industry in March 1982. It resulted from a special study mission to Japan led by the author which was followed by many supplier applications. In the beginning, this effort was fostered by an aggressive Ford drive to improve quality and reduce cost. What evolved are fundamental changes in U.S. engineering and quality control methods which greatly changed in the operating aspects of U.S. companies. These operational changes will drive further improvement in the competitive position of all U.S. industries.

The American Society for Quality Control (ASQC) working in conjunction with the American Supplier Institute (ASI) will promote these changes through education, training, and case study development. The 1987 Annual Trend Forecast prepared by a special ASQC committee outlines how this organization can be most effective in assisting the transformation of U.S. industries. Although several strategies are outlined in this report, the first relates to Understanding New Quality Technologies. It is stated as follows:

"There is a desperate need to educate masses of engineers in Taguchi principles. Quality professionals and selected hourly workers need similar understanding, especially in loss function analysis.

"The society needs to take an aggressive role in this area. Colleges and universities need to be encouraged to familiarize their undergraduate and graduate students with these concepts. The society should consider functioning as in a role similar to the J.U.S.E. to take a firm stand on the education and training necessary for managers, engineers, technicians, and factory floor personnel, and to develop common material.

"The society should consider a joint venture with the American Supplier Institute in this area.

"In every case emphasis needs to be on the effectiveness of the education process. The case study approach should be utilized wherever possible rather than passive lecture type education . . ."

The ultimate benefit of Taguchi Methods education, training, and application will be to significantly shorten the product development cycle, improve quality, and reduce cost. As a result, many U.S. industries will become more competitive in world markets. The credit for this transformation and continued leadership is clearly due to aggressive applications by U.S. automotive supplier companies. To them we will be forever grateful.

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