Chapter 12

Genichi Taguchi

All things are numbers.
(Pythagoras)

KEY LEARNING POINTS

Genichi Taguchi's definition of quality: the loss imparted to society from the time a non-quality product is shipped.

Key beliefs: statistical methods; quality as inherent in design; quality is a societal issue.

Principal methods: prototyping method; eight steps of parameter design; quadratic loss function.

INTRODUCTION

Genichi Taguchi trained as a textile engineer prior to his service in the Japanese Navy. He subsequently worked in the Ministry of Public Health and Welfare and the Institute of Statistical Mathematics. In that post, he learned about experimental design techniques and orthogonal arrays. He began his consulting career while working at Nippon Telephone and Telegraph.

His early work in the field of quality was mainly concerned with production processes, but during the 1980s he shifted his focus to product and process design. It was during this period that his ideas began to be adopted in the United States. Logothetis (1992: 17) describes Taguchi's contribution as an 'inspired evolution' in the quality movement by eliminating the need for mass inspection through his process of building quality into the product at the design stage.

Taguchi was awarded the Deming Prize and the Deming award for literature on quality. His best-known works are *Systems of Experimental Design* (Taguchi, 1987), and *Management by Total Results*, which he co-authored.

12.1 PHILOSOPHY

The two founding ideas of Taguchi's quality work are essentially quantitative. First is a belief in statistical methods to identify and eradicate quality problems. The second rests on designing products and processes to build quality in, right from the outset. Logothetis (1992: 13) sees Taguchi's view of quality as a negative, the cost of non-quality – that is, 'the loss imparted to society from the time the product is shipped'. Taguchi's prime concern is with customer satisfaction and with the potential for 'loss of reputation and goodwill' associated with failure to meet customer expectations. Such a failure, he considered, would lead the customer to buy elsewhere in the future, damaging the prospects of the company, its employees and society. He saw that loss occurred not only when a product was outside its specification, but also when it varied from its target value.

Flood (1993: 30) suggests that Taguchi's view 'steps back one further stage on the technical side', pulling back quality management into design. This is achieved through a three-stage prototyping method (Box 12.1). The first stage is concerned with system design reasoning involving both product and process. This is an attempt to develop a basic analytical, materials, process and production framework. This framework is carried forward into the second stage, parameter design. The search at this stage is for the optimal mix of product variation levels and process operating levels, aiming to reduce the sensitivity of the production system to external or internal disturbances. Tolerance design, the third stage, enables the recognition of factors that may significantly affect the variability of the product. Further investment, alternative equipment and materials are then considered as ways to further reduce variability.

Here a clear belief can be seen in identifying and, as far as possible, eradicating potential causes of 'non-quality' at the outset. This ties in with Flood's (1993: 32) view that Taguchi's work perceives quality to be a 'societal rather than organisational issue'. Flood further recognizes that Taguchi's method relies on a number of organizational principles (Box 12.2).

Clearly, Taguchi recognizes organizations as 'open systems', interacting with their environment. The emphasis on communication and control – the systems view – recognizes interdependence between processes, something which he has been criticized for ignoring. Logothetis (1992: 340) considers this unreasonable, and says that 'Taguchi, contrary to common opinion, does recognise interactions – saying: "If one assumes a linear model thinking it correct, then one is a man removed from natural science or reality, and commits the mistake of standing just upon mathematics which is nothing but idealism."'

Summarizing, there appear to be several beliefs running through Taguchi's work. The first is in quantitative methods, providing measurements for control. The second is in the eradication, as far as possible, of causes of failure at the outset. The third is in the societary cost of non-quality. The fourth perhaps reflects the third, and is the systems view of interdependence and interrelationship both within the organization and with its environment.

Box 12.1 *Genichi Taguchi's three-stage prototyping method*

System design

Parameter design

Tolerance design

Box 12.2 *Genichi Taguchi's organizational principles*

Principle 1	Communication
Principle 2	Control
Principle 3	Efficiency
Principle 4	Effectiveness
Principle 5	Efficacy
Principle 6	Emphasis on location and elimination of causes of error
Principle 7	Emphasis on design control
Principle 8	Emphasis on environmental analysis

12.2 ASSUMPTIONS

Assumptions which are considered to underpin Taguchi's approach will now be considered.

The first and quite critical feature is that he seems to assume that quality can always be controlled through improvement in design. While this may be the case for many aspects of manufacturing, its validity in the service sector must be questioned. Similarly, where products exhibit either natural characteristics – as in the case of food – or contain aspects of 'craft' skill – cabinet making, pottery or precious metal work – this may be inappropriate.

A second assumption relates to his attitude to people. Although Taguchi did value their creative input to the design and development process, he appeared not to consider them a significant factor in the production of quality goods. He says little or nothing about people or the process of managing them.

As already mentioned, the work has a clear focus on the manufacturing sector. Nothing is said about how to manage the quality process in service industries.

The next assumption is again quite critical. Taguchi seems to assume that the organization can wait for results – that delays between product conception and production will be acceptable. While these delays are to some extent inevitable, the contemporary market demands are such that they need to be minimized. 'Time to market' has become an absolutely crucial element in success for many organizations. For example, in pharmaceuticals the first in the market with a new treatment becomes the market leader and that firm's position is often then unassailable. The position is similar for information technology, where the most recent innovation tends to act as a key attractor for what the marketing people call 'early adopters' – and the innovator does attract a significant degree of loyalty. It is essential, therefore, if Taguchi's ideas are to be fully implemented, that they are integral to the product development process, not additional, and that the process is designed in such a way that 'time to market' is a key consideration. A conflict may arise between the business need to be fast into the market and the business need to achieve high quality. Adopting the Taguchi method after initial product design must be seen as unacceptable. It is suggested that quality parameters should be as much a part of a basic design brief as timing, markets and prices.

It is easy to see that much of Taguchi's work has been informed by his background in engineering and quantitative methods. What is less obvious is how his 'systems' perspective, with which there is no disagreement, arose. The adoption of a systemic view, while not apparently extending to the management process of the organization, is certainly a step forward from the work of many of his fellow gurus.

12.3 METHODS

The principal tools and techniques espoused by Taguchi centre around the concept of kaizen thinking – that is, continuous improvement. His backward step into the design process helps to ensure a high basic quality standard. Other than the 'quadratic loss function', the other statistical methods are common to many thinkers, and will be reviewed in the appropriate chapter. In this section, concentration will be on the following:

- suggested steps for experimental studies;
- prototyping;
- the quadratic loss function.

The suggested steps (Box 12.3) fall into the 'parameter design' (Logothetis 1992: 306) stage of product development. It is within this process that Taguchi utilizes people. This scientific method is very reminiscent of Deming's 'Plan, Do, Check, Action' cycle. This should perhaps not be surprising, given their common background in statistics.

The first stage is concerned with developing a clear statement of precisely what problem is to be solved. Taguchi considers it of great importance that the experiment should be exactly targeted. The second stage links with the first. It is important to determine what output characteristics are to be studied and optimized through the experimental process, and what measurements are to be taken. It may be necessary to run control experiments in order to validate results.

The third stage is brainstorming. At this point, all the managers and operators related to the product or process are required to come together and determine the controllable and uncontrollable factors affecting the situation. Here the aim is to define an experimental range and suitable factor levels. Logothetis (1992: 306) suggests that Taguchi prefers to consider as many factors (not interactions) as is economically feasible. Whether this represents a sufficient

Box 12.3 *Genichi Taguchi's eight stages of product development*

Stage 1	Define the problem
Stage 2	Determine the objective
Stage 3	Conduct a brainstorming session
Stage 4	Design the experiment
Stage 5	Conduct the experiment
Stage 6	Analyse the data
Stage 7	Interpret the results
Stage 8	Run a confirmatory experiment

involvement by people in the solution development process is debatable. It might be considered that they should be involved at all stages. Nonetheless, their involvement in experiment design, and their contribution of knowledge to the debate, must be considered invaluable. It is normally the case that those who actually perform a task know more about it than anybody else. The opportunity for them to articulate that knowledge in an informal session such as brainstorming is to be welcomed.

The fourth stage is experiment design. At this point, the controllable and uncontrollable (noise) factors are separated for statistical monitoring purposes. This is followed by the fifth stage, the experiment itself.

The sixth stage is to analyse the performance measures recorded, using appropriate statistical methods. This is followed by interpretation of the results, the seventh stage. This aims to identify optimal levels for the control factors which seek to minimize variability and bring the process closest to its target value. Prediction is used at this stage to consider the performance of the process under optimal conditions.

The eighth and final stage is to validate the results so far obtained by running further experiments. Failure to confirm results by further experimentation generates a need to revisit stages 3–8.

This whole process may be regarded as similar to the 'black box' technique used in cybernetics. In that case, altering inputs and monitoring the effect on outputs is used as a device for determining the function of a unit. This technique could be used from a 'macro' perspective in a production or manufacturing facility to determine areas of maximum concern for detailed analysis through Taguchi's methods. Interested readers should refer to the work of Beer (1981) for a more detailed discussion of this approach.

Prototyping is the technique which Taguchi uses to develop what Gilbert (1992: 24) calls the 'up and limping' prototype. This has already been seen in the review of Taguchi's philosophy. The technique consists of three stages. The first, *system design*, is aimed at applying scientific and engineering principles to the development of functional design. It has two elements, product design and process design. The second stage is *parameter design*. This looks at establishing process and machine settings that minimize performance variation. A distinction is made at this stage between controllable and uncontrollable factors (parameters and noise). The specification criterion is for optimization and is usually expressed as monetary loss arising from variation. The third stage is *tolerance design*. This is aimed at minimizing the total sum of product manufacturing and lifetime costs.

The quadratic loss function is Taguchi's principal contribution to the statistical aspects of achieving quality. The point of this calculation is to minimize the cost of a product or service. In this, a particular quality characteristic (x) is identified and a target value (T) set for it. Proximity to the target value is expressed as ($x - T$). The result of exceeding, or failing to achieve, T is a financial loss to the organization, hence the result must always be positive. This is achieved through squaring the answer, $(x - T)^2$. This result is multiplied by a cost coefficient, c, which puts a cost on failing to meet the target T. A further coefficient, k, representing the minimum loss to society, and with a value always greater than 0, is added. The sum represents the total loss, L, to society. Thus:

$$L = c(x - T)^2 + k$$

VIGNETTE 12.1 PROTOTYPING SERVICES

Taguchi's approach to prototyping products can also be applied to the service sector. It is common practice for service organizations to develop new processes or products and test-market them in selected areas, modifying them before a full launch through all outlets. This is a very similar approach to that which should be taken by manufacturing industry – although it often is not! It is much less common practice, though, to prototype other changes, particularly in the way that the organization is run. These changes, which may have much more substantial and long-term impact than a new service, are often developed in secrecy for political reasons and imposed overnight on a surprised workforce.

This is not the only approach to organizational change, and certainly not necessarily the most successful. In 1990, a major retail organization with many outlets decided that its distribution strategy needed to be revised to meet the changing needs of its customers, to enhance the effectiveness of service delivery and reduce costs relative to income. The organization saw the priorities as being in the stated order. The three strands were seen as directly correlated – that is, an improvement in either of the first two would increase income; a consequence of achieving the first two would be the third. Steps were also taken to directly reduce costs by eliminating inefficiency and waste within the organization.

A substantially revised organization was designed, based on 'natural' geographical and business communities. For each such community, there was recognized to be a 'lead' outlet offering a full range of services but specializing in more complex, higher-value activities requiring greater local expertise. The 'subordinate' outlets were focused on the precise needs of their particular community, taking the normal requirements of 99 per cent (approximately ±3 standard deviations!) of their customers as the benchmark. The relationships with the 1 per cent of exceptional requirements were to be dealt with by staff from the 'lead' outlet.

The principles and broad approach were agreed by the board of the organization and a series of 'pilot' communities were created. The new approach commenced with a prolonged period with one community, where the principles were put into practice for the first time. This was used as a 'learning' situation. The staff of the community were fully involved in the process. While the principles were strictly adhered to, the implementation process was filled with experimentation, reflection, critical review and modification. Once running satisfactorily, the test bed community was visited by representatives from six other communities. These visitors studied what had been achieved, including the mistakes, and with expert facilitation developed solutions appropriate to their own circumstances, providing altogether seven 'up and limping' prototypes.

Once 'tested to destruction' and suitably modified, the revised organization design was rolled out across the organization.

This use of 'live' prototypes, often called beta testing in the case of software products, is an essential part of successfully launching a major innovation. It is simply not possible to test every eventuality or identify every bug until the service is tested on real customers. It may be thought that this requires brave management. This author believes that a management which does not test its services in this way is foolhardy.

This may be viewed, in some respects, as a measure of efficiency and of effective utilization of resources. Of critical importance to its use are the correct selection of criteria and the accurate development of the coefficients *c* and *k*. If any of the values selected for the calculation is incorrect, then the whole process becomes useless.

12.4 SUCCESSES AND FAILURES

Like each of the other gurus whose work has been reviewed, Taguchi is accepted as having made a substantial contribution to the field. His books and his consulting indicate the wide acknowledgement of the utility of his approach.

Flood (1993: 32–33), suggests that Taguchi's work has the following strengths:

- It perceives that quality is a design requirement.
- His approach recognizes the systemic impact of quality.
- It is a practical method for engineers.
- It guides effective process control.

Its principal weaknesses are the following:

- Its usefulness is biased towards manufacturing.
- Guidance is not given on management or organizational issues.
- It places quality in the hands of the experts.
- It says nothing about people as social animals.

To look at the strengths, it can again be argued that Taguchi does not go far enough backwards into the design process. Quality parameters are to some extent already determined once the product has moved beyond the initial concept stage, since certain factors such as market and price range will often be decided at that point.

The recognition of the total cost to society of defective products is useful. However, since, as Flood suggests, little account is taken of the people or management process in the organization, the definition of 'total cost' has to be open to question.

That the method is developed for practising engineers, rather than theoretical statisticians, perhaps serves to make it useful. However, the validity of the quadratic loss function should be questioned if each application is not properly understood and underpinned by a validated statistical base.

So far as the weaknesses are concerned, Flood's assessment that the model is of no use where measurement produces no meaningful hard data can be supported. This perhaps limits its usefulness outside the manufacturing sector. That nothing is said about managing people and the organization is also agreed and is considered to be a major drawback to the whole approach.

Taguchi's failure to recognize organizations as social systems contrasts quite sharply with his recognition of quality as a societal issue. There is no explanation in his work for this. He appears to consider the people within the organization as 'machine parts' who will perform whatever function they are allocated to perform. No account is taken of human variability in the measurement of processes. Perhaps he regards this, unsympathetically, as noise!

12.5 CRITICAL REVIEW

There can be little doubt that Taguchi's work makes a substantial contribution to the quality movement. That contribution has, however, been focused very narrowly. His engineering and statistical background quite clearly underpins the approaches which he espouses, and this, to some extent, has limited the value of his work. He relies absolutely on quantitative measures of quality, and this makes his approach quite unsuitable for application to the service sector, where quality is often defined by observers at a much more subjective level.

On the other hand, his emphasis on quality of design and the process of prototyping are invaluable, even if perhaps not far-reaching enough. The impact on total (organization) cost of developing quality products and processes must not be underestimated. They will enable substantial reductions, if not eradication, of processes of inspection, rework and reject. Each of these items adds substantially to the operating costs of many organizations, and they often increase directly with the inadequacy of the design and development work.

Taguchi's lack of concern with people and managing organizations must be considered the second major flaw in his approach. He says nothing of how to implement his approaches, which from experience would meet major resistance in many organizations. The necessary reorganization and alteration of corporate structures, the shifts in power, and perhaps the change in budgets associated with his method would all be expected to generate substantial resistance within the organization. Handling this resistance is not addressed.

SUMMARY

The chapter has reviewed the work of Genichi Taguchi. Readers should refer to his original work (Taguchi, 1987) in order to develop their own appreciation of his contribution.

QUESTION

Taguchi believes that quality is a societal, rather than an organizational, issue. Consider whether this is a reasonable belief.