ASHCROFT INTERNATIONAL BUSINESS SCHOOL

PRODUCT AND SERVICE DEVELOPMENT

and

Quality Function Deployment

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ANGLIA POLYTECHNIC UNIVERSITY

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Abstract

Successful innovation of products and services is a vital element in competitive advantage. The first part of this paper identifies and examines six key themes, or principles, in this activity. In the second part a specific technique for design and development ~ Quality Function Deployment (QFD) ~ is described in the form of a step by step guide.

PART 1

Introduction

Commercial organisations stand or fall on their ability to supply their markets with products and services that customers want to buy, and which can be produced and delivered at a profit. But customers' needs and wants are not stable; they demand a steady stream of new and enhanced products. Organisations which can manage the innovation of new products and services effectively stand to gain significant competitive advantage.

There is a considerable body of published advice, from both academic and practitioner sources, to which managers involved in the development and introduction of new products and services can look for guidance. From this body of literature six recurring principles of good practice can be identified (Gray, 1996):

1. The *'voice of the customer'* informs every stage of the development and introduction process.
2. Fast time to market is a key objective.
3. Cross-functional or multidisciplinary teams are empowered to take responsibility for bringing the new product or service to market.
4. The whole process is managed as a project.

5. The organisation has (and applies) defined procedures which enable the efforts of many different groups and individuals to be coordinated and focused on the task.
6. Good use is made of tools, techniques and models.

1. The Voice of the Customer

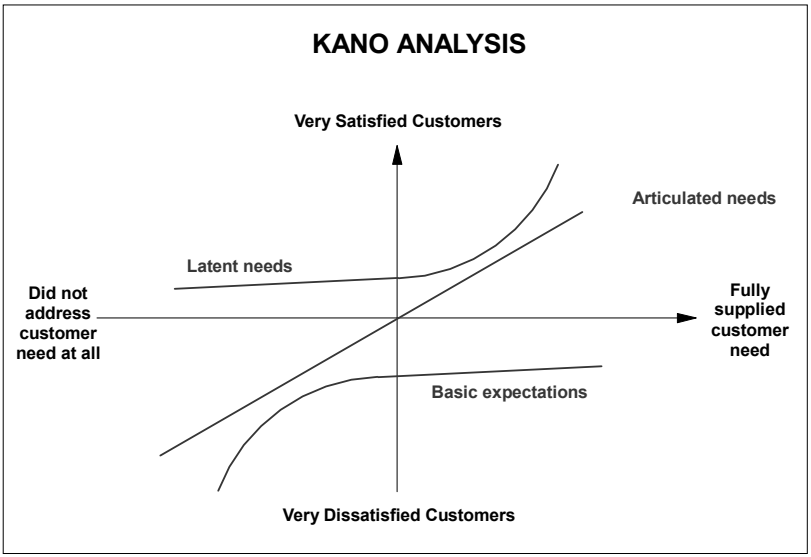
The principle here is that the process of design, development and introduction of new products and services is *informed* by customer needs. This does not mean that market leaders simply react to identified customer demands, but rather that they examine the benefits that a customer might gain from possessing one of their products or using their service. A leading power tool manufacturer is said to have told its staff that whilst the company made and sold drills, what their customers actually wanted were holes. It is important not to lose sight of the fact that any product or service offering is just one of an extensive, perhaps infinite, range of ways in which customers actual needs might be addressed.

Noriaki Kano (Dimanescu & Dwenger, 1996) identifies three levels at which excellent products respond to the voice of the customer:

- Products must first meet all their customers' *Basic Expectations* — things that must exist for a person even to consider buying a product.
- Secondly, they must meet the customers' *Articulated Needs* — things on a sliding, 'the more the better' scale of satisfaction (like miles per gallon) but without a pre-set value which determines satisfaction/dissatisfaction.
- Lastly, they fulfil some *Latent Needs*, sometimes called *Delighters* — unexpected features whose absence is not really noticed but whose presence evokes a delighted reaction: "Hey, that's good!"

The graphical illustration of Kano's principle, below, shows that customers can never be more than moderately satisfied with a product that only meets basic expectations (but will clearly be very dissatisfied with one that fails this initial criterion). The way to greater customer satisfaction is to supply articulated needs in greater measure than competitors' products, and/or to surprise customers with unexpected 'delighter' features which address

latent needs. Kano analysis consists of examining product ideas in these three dimensions, and acting on the knowledge gained.



Of course, delighters quickly become articulated needs, and then basic expectations; few product designs can remain unchanged for long periods without losing market share to more innovative competitors. The clear underlying theme is the necessity for understanding the customers' *needs*: knowing what the customer is trying to achieve and how the product or service will benefit its user.

Finding out what customers think is usually called market research. To be effective, this needs to be a dynamic process involving an interaction between customers, researchers, designers and managers (Barraba & Zaltman, 1991). Customers do not usually express their wishes in language which is immediately accessible to, or usable by, designers. There is an interpretative function to be performed here, but this carries with it the risk of distortion. Designers are best suited to solve problems, but they need to understand what the problem is, rather than simply being told what to develop (Inwood & Hammond, 1993).

A wide range of techniques is available to help company insiders understand customer needs, some of which are briefly mentioned below. Clearly, market research is a specialised function and expert advice should be sought before any decision is made.

Consumer idealized design (Ciccantelli & Magidson, 1993)	A small group is selected from a chosen market segment and asked to propose design features - not to be concerned with feasibility, only with desirability. The process is observed either through one-way glass or by video.
Debriefing	New buyers are asked about what led them to their purchase.
Diary studies	"People record all the episodes which are relevant to the target products, after which they are debriefed personally by representatives from the company" (Hartley, 1995).
Natural and controlled *experiments* and f*ield studies*	
Interviews [‡] *, questionnaires* and *telephone research*	Dimanescu & Dwenger (1996) recommend that the interview team "immediately debrief by recording as exactly as possible the actual words used by the customer", reporting that they have found that this technique "led to understanding the motivation underlying a customer's expression of a requirement ... led to discovering some significant latent needs".

[‡] Interestingly, extensive research by Griffin & Hauser (1993) suggests that one-to-one interviews are more cost effective than focus groups and that "20-30 interviews are necessary to identify 90-95% of customer needs". Two one-to-one interviews were "about as effective as one focus group" and four one-to-one interviews were "about as effective as two focus groups" They comment that "both one on one experiential interviews and focus groups seem to be effective in identifying needs, but the group synergies expected from focus groups do not seem to be present".

Focus Groups and *customer panels* ‡	
Metaphor elicitation (Zaltman & Coulter, 1995)	This technique involves recording stories told by customers about product-use scenarios and analysing the metaphors used.
Lead users Also called *innovators, trendsetters, early adopters* and *alphas*.	This approach involves selecting people who have needs and demands now which are likely to be more widespread in the future. "Lead users are users whose present strong needs will become general in the marketplace months or years in the future" (von Hippel, 1989). Product ideas can be thoroughly tested on the lead user and the design of the product will thereby anticipate the requirements of the growing market.
Contextual enquiry	This is an advanced form of direct observation in which key clients are observed over an extended period. Researchers note how they work and the role a particular product plays in that work environment. A variation on this technique is to video customers using (or unwrapping, setting up, configuring, etc.) the product to observe what caused them problems, what they had to look up in instruction manuals and so on, as well as recording any comments and observations. Several writers advocate direct contact between customers and engineers. Ulrich et al (1995) argue that "those who directly control the detail of the product, including the engineers and industrial designers, must interact with the customers and experience the use environment of the product". Dimanescu & Dwenger (1996) call this "customer watching".

Subjective cluster technique (Griffin & Hauser, 1993)	Customer needs are written on cards and customers are given packs of the cards and asked to sort them into piles, each pile representing similar needs and different in some way from the other piles. A single need from each pile, called an exemplar, is selected to represent the customer needs in the pile.

All these techniques have their own shortcomings, risks and disadvantages, and there is always the risk of alerting competitors when performing any kind of market or consumer testing. Ciccantelli & Magidson (1993) have reservations about the value of much customer-sourced information. They believe that most methods of involving customers in product design “tend to elicit mostly information about what they do not want, rather than startling new insights about what they really want or need”. In any case, as Hartley (1995) points out, "literal responses from customers are not our ultimate goal. Rather we want to understand the customer. We must use knowledge and insight, not data and information, to make our decisions. And knowledge does not come from numbers alone. It comes from being able to assume the perspective of the customer”.

2. Time to market

All things being equal (an important qualification) the faster a new product can be developed and put on sale the more profitable it is likely to be. This is largely because the life-span of modern products can be fairly short, with the effective end-date determined by external factors such as new developments, fashions and perspectives. This means that the earlier the product or service can be put 'on sale' the longer its revenue-earning life will be, although this presupposes that the revenues accruing will include an element of profit.

The profitability of advanced technology products is particularly sensitive to delays in overall development times (ie where development takes longer than allowed for in original budget estimates). Rienertsen (1994) studied the sensitivity of profit on computer printers over five years and concluded that:

Development costs ‡ over-running by 30% led to a	**2**%	reduction in lifetime profits
Reducing selling prices by 10% due to quality problems led to a	**15**%	reduction in lifetime profits
Shipping 6 months late led to a	**32**%	reduction in lifetime profits

Inwood & Hammond (1993) believe that this kind of pattern would apply to most markets which are subject to rapid change, although some markets seem less sensitive than others to these factors. In high-growth markets with short product life-cycles, six months' delay on launch could reduce profits by 33%, but this fell to 7% in slow-growth markets with long product life cycles (Rienertsen, 1994).

Speed, though, goes hand-in-hand with added risk. Streamlined, effective processes which waste no time or effort but still ensure rigorous controls, are essential. There is a delicate balance here: business plan procedures, investment analysis and detailed project control arrangements protect companies against waste and inappropriate investment, but tend towards delaying the launch of new products. The acceptance of some level of risk, with the certainty of occasional failures, is concomitant with achieving development speed.

3. Cross-functional teams and **4. Manage as a project.**

These two principles are usefully considered together, since the adoption of project management concepts and approaches often, perhaps normally, involves the assembly of a team of people from varied backgrounds. In the context of product and service development a key requirement is that the *project team* takes collective responsibility for delivering the required outcomes. This may need special and explicit organisational backing, since the team members will often retain their normal responsibilities in addition to their project roles. It is particularly important that they see themselves as project team members, with links to functional departments, rather than as functional representatives or delegates on the project team.

‡ Development costs should not be confused with ongoing product costs in this context. Rienertsen found, for example, that 9% extra product cost reduced profits by 45% in slow-growth markets and 22% in fast-growth markets.

There are difficulties involved in establishing cross-functional teams, which may not fit neatly into existing management structures or organisational cultures. The problems of working in 'matrix' structures are well documented (Gray, 1998, includes comment on this issue) and derive from individuals having two (or more) reporting lines, producing tensions which can only be effectively resolved at the organisational level. On the positive side, the establishment of a cross-functional project team enables product requirements to be identified to all participants simultaneously; any necessary clarification takes place immediately, and as many activities as possible can take place concurrently.

Team characteristics of openness, personal security for their members, free expression, questioning, intrinsic satisfactions, and participation in goal definition have been found to be positively associated with successful project outcomes (Gray, 2001) and these characteristics may be especially significant in product and service development, where qualities of creativity and innovation are supremely important.

Project management has its own extensive literature which will not be reviewed or summarised at any length here (see Gray, 1998, for a more comprehensive review). However, some points which are particularly relevant to product and service development need to be mentioned.

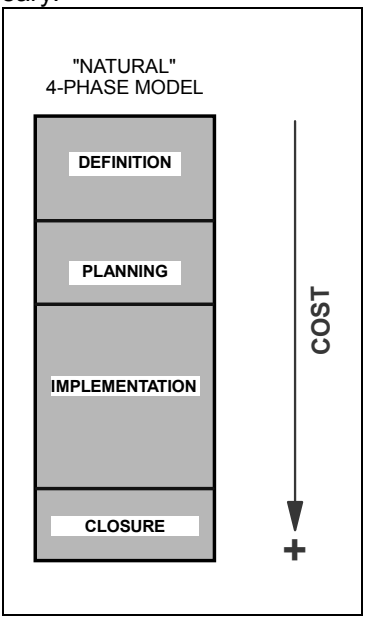
- For every project there should be a single, named individual who genuinely 'owns' the project for the company. This role, sometimes labelled 'client' or 'champion' is a difficult one, since it involves stewardship of the company's resources and therefore the exercise of control over the project team's activities ~ including, ultimately, the possibility of closing the project down ~ as well as advocacy on the project team's behalf.

- There should be only <u>one</u> project manager for each project, who reports to the Client. There should be no doubt that the Project Manager is in charge of the project, under the client's overall authority.

- To be in control of a project it is necessary for the team to have:
  1) a plan which tells them how things *should be*;
  2) a flow of information which tells them how things *are*;

3) the *power to change* things if necessary.

- All projects have natural phases. There are probably four of these 'natural' phases:
  - Definition, which begins with the initial concept, clearly states *what* is to be done, and may go through outline business case and authorisation stages;
  - Planning, in which detailed consideration is given to *how* the project objectives will be realised;
  - Implementation, in which the plans are carried out; and
  - Closure, in which the project's deliverables are handed-over to in-life management, and all loose ends are tied up.



These 'natural' phases are often sub-divided to meet the needs of specific projects and/or organisational processes

Each phase represents an escalation of cost. For this reason transition from one phase to the next should be formally authorised following a Phase Review. Reviews should be taken very seriously - projects develop a momentum of their own and may be relentlessly continued when they should be changed or even stopped. However, reviews need not be long or bureaucratic; if normal project controls are in place the answers to the questions raised at reviews should be known already.

The general disciplines of project management form the basis of a set of specific procedures for the management of product and service development work.

5. Defined procedures.

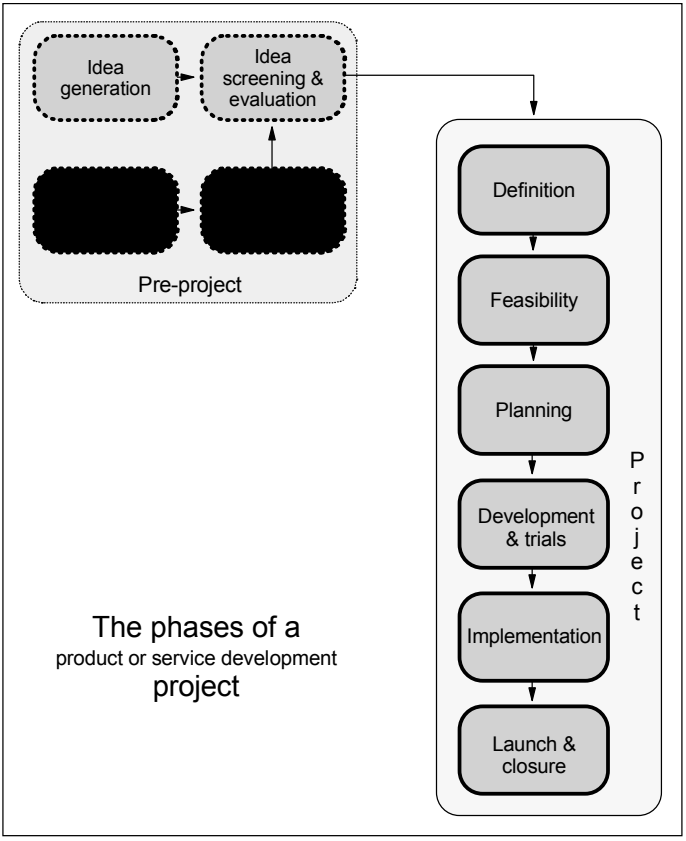
There is a consensus among writers on product innovation that formal, explicit processes correlate positively with project success. The dangers of excessive control, bureaucracy and over-cautious attitudes to risk are acknowledged, but the advantages of procedures that provide mutually understood frameworks for disparate activities seem to outweigh the drawbacks. In most cases, a proportion of the work will be 'contracted-out' by the project team to other, functional, departments or to external suppliers. These 'outsiders' will inevitably have their own ways of getting things done and may be unwilling or unable to change to meet the demands of a project team that may be providing a relatively small proportion of their overall workload. In these circumstances it is even more important that framework procedures are in place that allow maximum freedom within defined limits, whilst controlling interfaces and ensuring that nothing is overlooked.

Of course, excellent processes will make little or no contribution to productivity and competitiveness unless they are applied properly and consistently. Individuals and departments within an organisation may well have their own preferred approaches, and objectively these might even be superior in some way to the chosen organisational model. However, a consistent, organisation-wide model is the only realistic way of achieving the full coordination of activities which is key to successful product and service innovation. Only top management can ensure that the chosen process model is applied consistently across the organisation.

Various models are available, of which Kotler's (1986) eight-stage model seems to capture the essentials:

1. Idea generation
2. Idea screening
3. Concept development and testing
4. Market strategy
5. Business analysis
6. Product development
7. Market testing
8. Commercialisation

It would be tempting to regard Kottler's "stages" as a phase structure for a product or service development project, but the stages are not necessarily sequential; for example, stages 4 and 5 could be regarded as contextual/ environmental, and not consequent upon the earlier stages, which are product-related. However, a basic phase structure can be derived from Kottler's and other process models:



In this model ideas are captured from as wide a variety of sources as possible, and those that seem to have potential for profitable exploitation go forward as input to development projects. The decision of whether an idea merits further effort ~ and therefore resource costs ~ depends both on

its prima facie practicality and its strategic fit for the organisation. This in turn will be informed by 'business analysis'.

The project phases in the model illustrated above need some explanation.

- During the *Definition* phase the validated idea is evolved into a clear product description, and the project objectives and constraints are defined; technically a different activity from defining the product itself.

- In the *Feasibility* phase the practical implications of developing the product or service are critically examined. Costs are estimated and markets examined. This enables a business case for developing and marketing the product or service to be prepared which leads in turn to the allocation of budgets and other resources.

- In the *Planning* phase the detailed steps, or work packages, are defined that must be undertaken in order to achieve the desired or specified results.

- The *Development & trials* phase sees the product or service idea transformed into a 'working model' ~ or whatever logical equivalent applies to the particular case. The word *Trials* is plural because a variety of trials may be required, including:
  - bench tests (or again, a logical equivalent to this) to test whether the product or its individual components work as expected,
  - field trials to test whether the product satisfactorily performs the function it is intended to serve, and
  - market trials to test whether it appeals to potential buyers.

- In the *Implementation* phase physical products are put into production, the 'service surround' is developed, staff and agent training is undertaken, distribution agreements are activated and any other necessary practical steps are taken to prepare for the first sale.

- In the *Launch & closure* phase the product or service is made available to customers. Typically *Launch* is an instantaneous event: prior to the moment of launch the product or service exists but is not available to paying customers, afterwards it is.

Closure is the formal end of the development project and hand-over of responsibility to in-life management. In practice, many of the project team members may be involved in subsequent management of the product, but it is important to recognise that their roles have changed. It is helpful to mark this transition with some kind of 'rite of passage' so that the change is evident both to the individuals themselves and to others in the organisation. A formal project closure review is a worthwhile activity in its own right, and may also fulfil this secondary function.

Each phase represents an escalation of costs and should be formally authorised following a rigorous review of progress against objectives, plans for the next phase, and changes in the context or environment which might affect the desirability of continuing with the project.

6. Tools, techniques and models.

There is general agreement among practitioners about the value of applying tried and tested models, tools and techniques in the process of product and service development. Many of these are described in the literature and some examples will be briefly mentioned here.

- Kano Analysis

  Kano Analysis (see Dimanescu & Dwenger, 1996; also Vasilash, 1995) has already been described, above. It has particular value as a 'quality check' technique in evaluating the product's appeal to its target customers.

- Contextual Enquiry

  Contextual Enquiry and related techniques, also described earlier, can be explored in more detail in Dimanescu & Dwenger (1996); Hartley (1995); Holtzblatt & Beyer (1993); Inwood & Hammond (1993); Takeuchi & Nonaka (1986); Ulrich et al (1995) or Wheelwright & Clark (1992).

- Lead Users

  As well as providing direct voice of the customer information, as described above, *Lead Users* can be intimately involved in the design and development process. For more detail of the Lead User concept, see von Hippel (1982, 1986, 1989) or Hartley (1995)

- Taguchi Method

  The *Taguchi Method* (advocated by Dr Genichi Taguchi) is also called *Robust Design*. It argues that Quality in a product means the minimum loss which the product causes to society over its whole lifetime, so repair, replacement and eventual disposal all have to be costed in.

  Products are subject to varying conditions in use, some of which can be controlled but others are effectively uncontrollable. These uncontrollable variations are referred to as 'noise'. Products must be able to continue functioning despite these variations. *Robust design* sets out to make the product insensitive to 'noise' in use, which means "designing quality in" from the very beginning. The earlier in the design and manufacturing process low quality is eliminated, the less it will cost over the product's life-time. Taguchi method involves identifying all the relevant noise factors and deciding just how *tolerant* the product would need to be to each factor. The product is then designed from the outset to be able to cope with predetermined levels of variation in the working environment.

  For more information about Taguchi method (which has many applications apart from product and service design) see Peace (1993); Phadke (1989) or Taguchi (1986).

- S.P.I.N.

  SPIN is a generic technique, especially favoured by sales people. Its objective is to get the subject (in this case the actual or potential customer) to express an explicit need which can then be met by one or more design features in the new product or service. There are four stages:

  S The customer is asked about the **Situation**. Background information is established and an understanding gained of how it feels to be the customer in regard to the current situation.

  P The **Problems** ~ the difficulties or feelings of dissatisfaction that arise from the situation ~ are explored.

  I The **Implications** of the problems are elucidated. The potential consequences if the problems aren't addressed/resolved are defined.

  N The explicit **Needs** arising from the implications are applied to specific product design features which could help to resolve or prevent the problems.

- Pugh Concept Selection

  Concept Selection, developed by Professor Stuart Pugh, is a basically simple evaluation matrix system for selecting the best design option from a range of possibilities. The following notes and example have been adapted from Pugh (1981). The procedure is as follows:

  a. Establish a number of *possible solutions* to the design problem under consideration. These must be described at a similar level of detail
  b. Build a list of *design criteria* for evaluation, from the product requirements specification.
  c. Choose a *"datum"* (benchmark) against which the other concepts will be evaluated. This should be an existing design in the same

product area, if there is one, or else one of the concepts which seems at first sight to offer a good fit to the need.

d. Enter the concepts and the evaluation criteria on two axes of a *matrix*.

	Concept											
Criteria	1	2	3	4	5	6	7	8	9	10	11	12
Ease of achieving 105-125 DbA		S	–	+	–	+	+	–	–	–	–	+
Ease of achieving 2000-5000 hZ		S	S	+	S	S	+	S	–	–	–	+
Resistance to corrosion, erosion & water		–	–	S	–	–	S	–	+	–	–	S
Resistance to vibration, shock & acceleration	D	S	–	S	–	S	–	–	S	–	–	–
Resistance to temperature	A	S	–	S	–	–	–	S	S	–	–	S
Response time	T	S	–	+	–	–	–	–	S	–	–	–
Complexity: number of stages	U	–	+	S	+	+	–	–	–	+	+	–
Power consumption	M	–	–	+	–	–	+	–	–	–	–	+
Ease of maintenance		S	+	+	+	+	–	–	S	+	+	-
Weight		–	–	+	–	–	–	S	–	–	–	+
Size		–	–	–	–	–	–	–	–	–	–	–
Number of parts		S	S	+	S	S	–	–	+	–	–	–
Life in service		S	–	+	–	S	–	–	–	–	–	–
Manufacturing cost		–	S	–	+	+	–	–	S	–	–	–
Ease of installation		S	S	S	S	+	–	S	–	–	–	–
Shelf life		S	S	S	S	–	–	S	S	S	S	S
Σ +		0	2	8	3	5	3	0	2	2	2	4
Σ –		6	9	1	9	7	12	11	8	13	13	9
Σ S		10	5	7	4	4	1	5	6	1	1	3

This example refers to a car horn

e. *Compare* each concept with the datum, on each of the evaluation criteria. Score each as **+**, **–**, or **S**, according to whether the concept is better, worse, or the same as the datum against that criterion.

f. *Add up* the **+**'s, **–**'s, and **S**'s, to identify the most promising concepts. Re-run the exercise with any areas of special strength removed and see whether the same concepts still score high. Change the datum concept and go through the process again.

The concepts that survive a few iterations of the process are likely to be the good options for development.

- RACI

RACI is another generic technique used in the context of project management to clarify levels of responsibility.

Once activities (work packages or tasks) have been defined, four roles or levels of responsibility are identified for each activity:

R Who is *Responsible* ? ~ Who is it that actually performs the task?

A Who is ultimately *Accountable* ? ~ and has the power of veto?

C Who should be *Consulted* ? ~ before a decision is taken?

I Who needs to be *Informed* ? ~ so that they know what's going on?

RACI analyses are valuable in almost any project plan, and in many business-as-usual situations.

- Four Fields Mapping

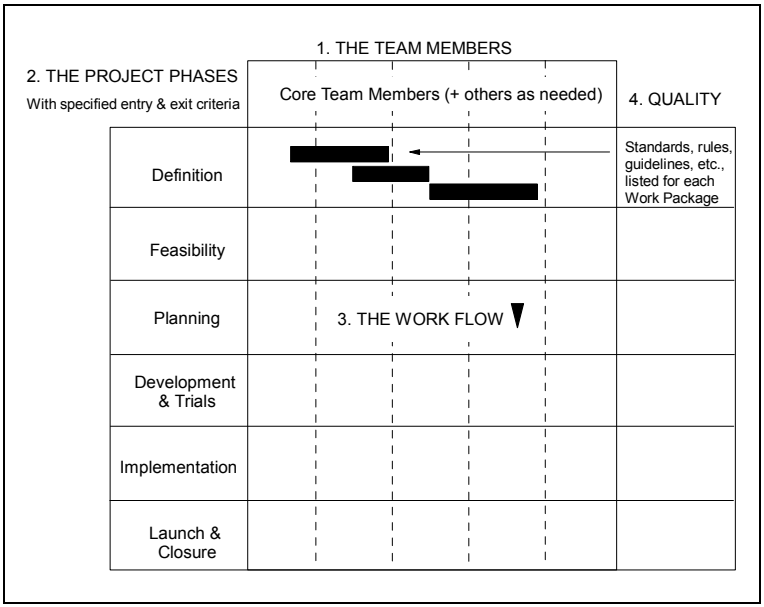
Four Fields Mapping (Dimanescu, 1992) is a project management tool which integrates four sets of information:

1. *Team* members, from their various functional areas;
2. The *phases* of a project, or work package;
3. The *work flow,* including tasks, decisions and events;
4. *Quality*, or the process, guidelines, regulations, standards, etc., within which the project is being implemented.

The work packages for each core team member (and others if appropriate) are entered on a matrix-type diagram, against a vertical axis of the project phases. Within this layout the work packages are placed in chronological order, with the linkages between them shown in as much detail as the team finds helpful. (Too much detail can make the diagram confusing, but each team member should know:

a) which work package provides the necessary *inputs* to his/her work package.

b) which work package is waiting for the *output* of his/her work package).



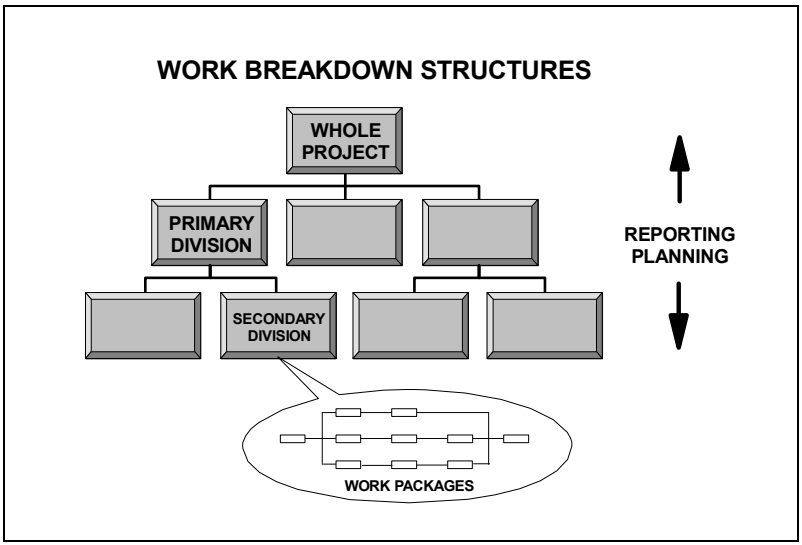
The fourth element of the 'map' is the quality standards, rules, guidelines, etc., that should apply to the work packages within each project phase. These are shown on the diagram.

Showing these factors on a single, integrated diagram draws attention to the linkages between the work of the various functional departments involved in the project and encourages cross-functional team working.

- Work Breakdown Structures

Work Breakdown Structures (WBS) are hierarchical breakdowns of all the work required to complete a project. Starting with a description of the whole project, subdivisions are made into meaningful sections, for example, specific kinds of work, or perhaps geographical sectors. Lockyer and Gordon (1996) suggest that: "Common ways are by division of the product into major components which are then split into sub-assemblies and so on down to components, by a functional breakdown or by cost centre code."

Further logical subdivisions may be made 'exploding' the WBS into increasingly detailed units. It is recommended that these subdivisions should be based on deliverables, rather than on the work, or tasks, needed to produce those deliverables. At the 'bottom' of the structure, work packages can be defined which specify tasks to be undertaken, together with relationships with other tasks and a variety of detailed information about timescales, deliverables, costs and resource needs.



The principle is exactly the same as an *organisation chart*, where Divisions are sub-divided into Departments, composed of Units or

Teams, composed of Individuals. The same idea leads to a *Bill of Materials*, where a complete product is composed of Major Assemblies, which are constructed from Sub-Assemblies, which are built-up from Components, which comprise various Parts. (Different terminology may sometimes be used for these 'levels of completeness')

The objective in building a WBS should be to appoint an 'owner' for each of its elements: a named individual who will take responsibility for the deliverables defined for that element *and all its sub-divisions*.

During the life of the project the WBS can be used as a model for reporting progress, since each of its elements represents a summary of all the work below it in the hierarchy.

- Quality Function Deployment

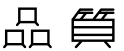
Quality Function Deployment (QFD) is possibly the most powerful tool available for use in product and service development. QFD is the subject of Part 2 of this paper.

PART 2

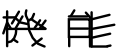
QUALITY FUNCTION DEPLOYMENT (QFD)

Introduction

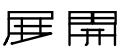
Quality Function Deployment (QFD) ~ often called the “House of Quality” because of the distinctive shape of the developed matrices ~ is a matrix analysis tool which brings design, production and customer-facing or marketing people together in a structured setting to make design decisions, based on voice of the customer information. The name is a direct translation from three Japanese expressions:



Hin Shitsu is translated '*Quality*', in the sense of a characteristic, a feature or an attribute.



Ki No is used to denote a *Function* within a company, such as Engineering, Accounts, or Personnel.



Ten Kai is translated as '*Deployment*', in the sense of allocation of resources to meet a particular purpose, as in military deployment.

QFD was first developed by Prof. Yoji Akao in Japan in the late 1960s as “a method for developing a design quality aimed at satisfying the consumer and then translating the consumers’ demands into design targets and major quality assurance points to be used throughout the production stage” (Akao, 1990). It was first applied in Japanese shipyards in the early 1970s and subsequently taken up in the United States in the mid 1980s. It is now in use across the industrial world. Modern applications of QFD extend the design decisions to include a product’s whole life-cycle, including environmental issues such as disposal.

QFD can represent a significant investment in preparation, training and implementation time which at first sight might appear incompatible with the aim of reducing time to market. However, significant savings in terms of reduced cost, reduced design and production time, and increased customer satisfaction are claimed to make this investment extremely cost-effective (Gray, 1996). In any case, QFD can be applied with varying levels of rigour and detail ~ Akao himself comments: “It is my wish that a company develop

its own approach to quality deployment suitable to its needs" ~ and a 'quick and dirty' application of the process has been found to be very effective as a team-building tool. There is, however, general agreement among practitioners that expert facilitation is helpful in achieving the best results.

Descriptions of QFD and guidance for its application can be found in varying levels of detail throughout the product and service development literature. The many sources used in the compilation of this overview will be cited at the end of this section and fully attributed in the Bibliography.

Inputs

The basic input of QFD ~ its raw material ~ is the *voice of the customer*. The development team need to know:

- who the customers for the product or service are;
- what they want the product or service to do for them;
- what benefits they are looking for;
- what level of performance they want.

This information has to come from customers. If these decisions are made by company people who believe they 'know what the customers want' (however much positional or expert power they may have) then much of the benefit of QFD will be lost.

Some QFD experts advocate bringing the actual words of customers into the QFD workshop, so that team members who would normally have little direct contact with the end users of products or services can get to hear the raw, unfiltered views of the people who, eventually, pay their salaries. Others believe that some translation and classification beforehand is legitimate and helpful. Whichever view is taken the objective must be to make the genuine views of customers available to the development team, in language and terminology which the team can use. This information must be collected and digested before the QFD process begins.

The *needs* that customers have are defined without making any assumptions about how those needs might be met. For example, it might be established (by listening to the voice of the customer) that there is a need for some means of taking a car's weight off its wheels, perhaps to

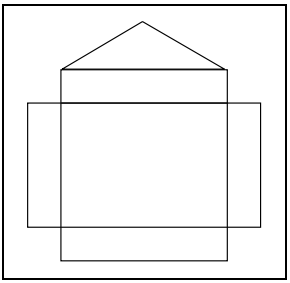
change a tyre. A company might decide to offer a traditional car jack, but there might be other ways of meeting the customers' need.

They needs are then grouped into logical 'families' for ease of handling. These families usually take a *primary - secondary - tertiary* form, where the primary groups are the needs customers have, the secondary groups are the kinds of benefits from a product that might address those needs, and the tertiary groups are more specific product requirements. For the example above the groupings might be as follows:

- *Primary*: A need to lift a car's wheels clear of the ground, easily and in virtually any situation.
- *Secondary:* The benefits required include ease of use, versatility, reliability, safety, little maintenance.
- *Tertiary:* Some of the design requirements are: portability, low user effort, user can remain standing, quick release, copes with wet or dry ground, usable on uneven ground, usable on all cars, cannot collapse, no extra tools needed, ...

Weightings need to be applied to all identified benefits to indicate their importance to customers. This will help when design decisions have to be made. Naturally, these weightings must be based on voice of the customer information.

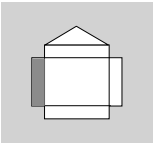
Once the inputs are assembled the QFD process itself can begin. This usually takes the form of one or more structured workshops, involving all the key players. The output of the workshop will be agreement of and commitment to a product design, which will be recorded in the form of a matrix with a distinctive shape, often called the 'house of quality'.

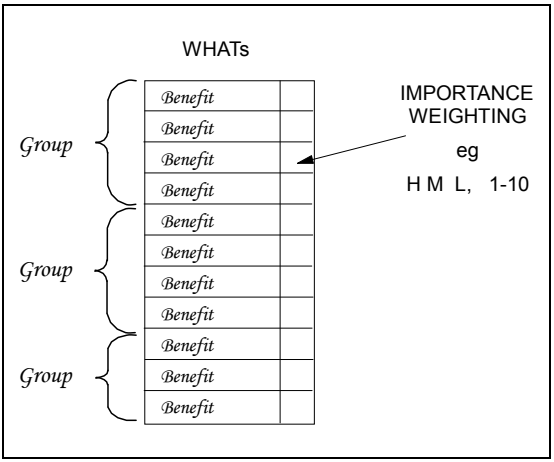


The various components of the matrix are constructed and assembled systematically in a series of stages.

QFD Step 1

The structured and weighted list of benefits, (known in the QFD jargon as the 'WHATs' ~ ie, *what* customers want from this product) is agreed and written-up as the left-hand side of the matrix.





These benefits will be of varying importance to customers and these weightings can be expressed alongside each item.

Part of the content of this section for the car jack mentioned earlier (omitting the importance weightings) might be:

Group	Benefit
ease of use	portability
	low user effort
	user can remain standing
	quick release
	no extra tools needed
versatility	copes with wet or dry ground
	usable on uneven ground
	usable on all cars
reliability	maintenance free
	works all the time
	does not jam in operation
safety	cannot collapse

QFD Step 2

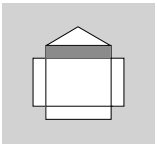
The next step is to consider the design features that can or could possibly be included (the term *product attributes* may be more accurate, because the discussion may well be at a level below that of recognisable features). These are termed the 'HOWs', because they represent the ways (plural) in which the company could (not *will*, at least at this stage) meet the customers' requirements. Each attribute should be potentially measurable (measurement targets will be entered later) to provide performance targets when the product comes to production.

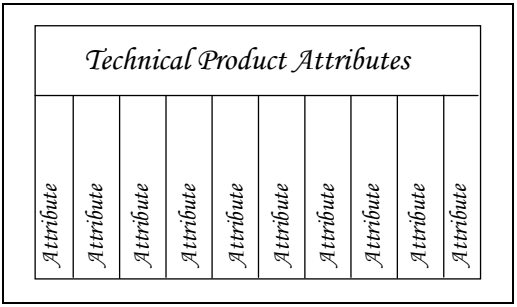
It is helpful to group the HOWs into primary - secondary - tertiary families, in much the same way as the WHATs were grouped. Examples of the kinds of attributes to appear in this section for a tangible product might include:

- Materials to be used
- Operating principles
- Types of mechanism
- Methods of assembly
- Packaging/presentation
- Size, shape, weight
- Lifting force required

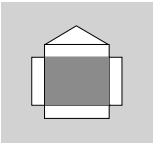
Similar principles would apply for an intangible product or service.

Written-up, the HOWs occupy the top central part of the matrix, and appear in this form:



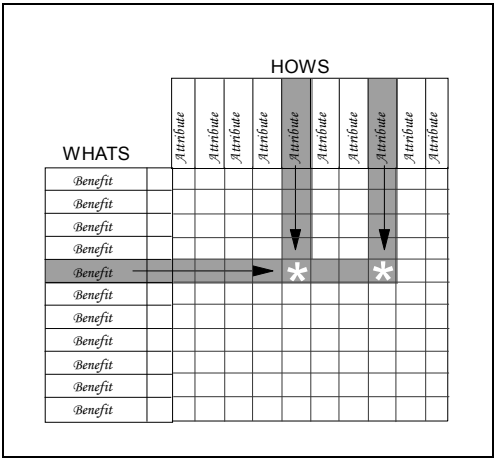


QFD Step 3

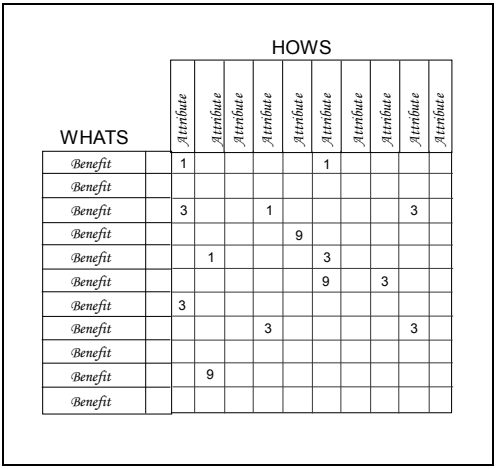


The two basic elements of the matrix, the WHATs and the HOWs, are now in place. The next task is to track their relationships. This is done in the main body of the matrix.

For each 'WHAT' one or more 'HOWs' are identified that would provide the desired benefit.

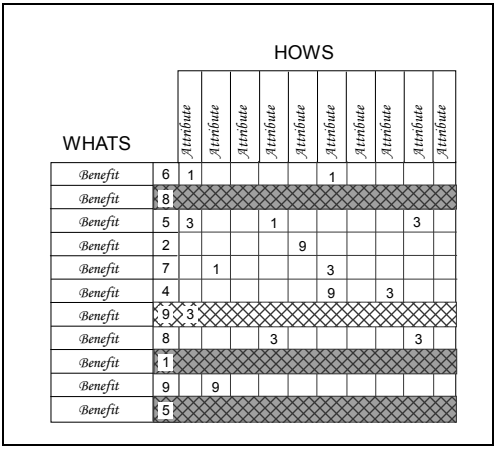


The strength of the fit is assessed: eg, a product feature that provides a customer benefit completely and without qualification should be scored high. One that only partially provides the desired benefit should be scored medium, and one that makes only a small contribution should be scored low. If there is no relationship between the required benefit and the product feature then no entry at all is made in the matrix.



An ordinal ranking of 1, 3, 9 for weak, strong and very strong relationships is recommended here, but care must be taken when using numerical ratings in this way as the strength of relationships is usually at best informed guesswork. Mathematical calculations performed on estimated base data can result in figures with a convincing appearance of accuracy, but this appearance may be spurious.

This process is likely to show that there are some customer-desired benefits (WHATs) which are not being provided by any of the HOWs, and others that are only partially provided. This is an opportunity for the team to discuss the issues *as a team*, capitalising on the very real asset of having technical, operations and customer-facing people all together to address the problems.

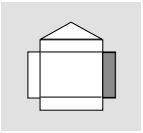


One question the team will certainly be asking when they look at a WHAT that is not being fully provided is “how much does it matter?” Good voice of the customer information can help to answer this through the importance ratings assigned to the WHATs:

Another outcome is that there may be product features ('HOWs') for which there does not seem to be any customer requirement. The team may conclude that the feature is not wanted and should be omitted. There is a possibility, though, that the feature is a potential 'delighter' - something no customer has thought of but which will surprise and delight them when they see it. At the very least there should be serious discussion about any unconnected 'HOWs'.

It may also help in this decision process to know how relevant competitor products are perceived by customers. The proposal is compared with competitors’ products or services, using authentic customer information, not internal opinion.

Information about this is collected and placed in an extension of the matrix on the right-hand side:



WHATS		L	M	H
Benefit	6		**U**	B
Benefit	8	B	A	C
Benefit	5			**U**
Benefit	2	**U**		B
Benefit	7		C	**U**
Benefit	4		**U**	
Benefit	9	**U**	B	
Benefit	8	C	**U**	
Benefit	1	A		B
Benefit	9			**U**
Benefit	5			B

CUSTOMERS' PERCEIVED PERFORMANCE RATING

U = US
A = BLOGGS & Co
B = SMITH plc
C = JONES Assocs

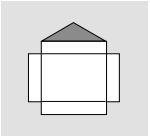
The central part of the matrix is now complete. It provides information from which the team, working together, can assess how well the product proposal will meet customers' needs, and how well it matches up to competitors' offerings.

HOWS

WHATS		Attribute	Attribute	Attribute	Attribute	Attribute	Attribute	Attribute	Attribute	Attribute	Attribute	L	M	H
Benefit	6	1					1						**U**	B
Benefit	8											B	A	C
Benefit	5	3			1					3				**U**
Benefit	2					9						**U**		B
Benefit	7		1				3						C	**U**
Benefit	4						9		3				**U**	
Benefit	9	3										**U**	B	
Benefit	8				3					3		C	**U**	
Benefit	1											A		B
Benefit	9		9											**U**
Benefit	5													B

Clearly, the possibility arises at this stage that the proposal may be damaged or weakened by a mismatch between WHATs and HOWs, or that competitors have a better product (in customers' eyes) which cannot economically be matched. This could result in a decision to cut losses by ending the development project at this point. This is, in fact, a major benefit of QFD; it can help to focus effort on profitable activity and away from potential loss-making initiatives.

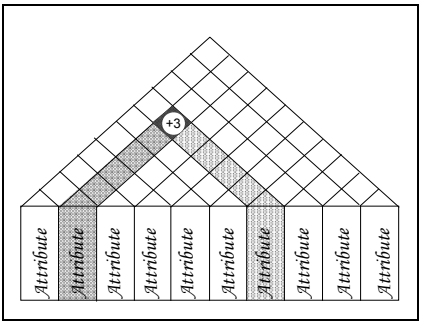
QFD Step 4



The team now turns its attention to making choices between the various ways of providing customer-desired benefits; choosing the HOWs to provide the WHATs. The QFD matrix allows relationships between HOWs to be analysed, using the interaction matrix (the triangular 'roof' of the 'house of quality').

Each HOW is examined to determine whether relationships exist with other HOWs. These might take the form of conflicts, where one HOW is incompatible with another, or support, where one HOW is enhanced by association with another.

These relationships, and their strengths are recorded by entering positive or negative numbers in the matrix, using the same 1, 3, 9 scores as in the main body of the matrix.

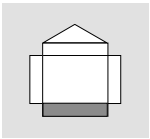


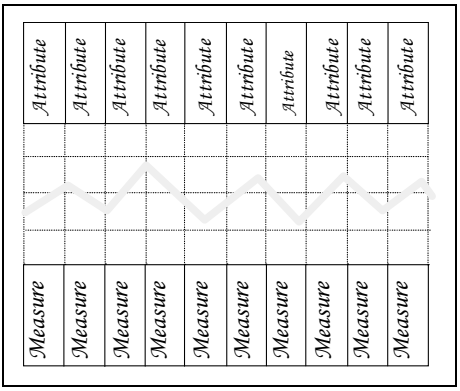
Choices will sometimes need to be made between HOWs. The factors contributing to a sound choice will be varied, and will probably include technical, commercial, and marketing elements. For this reason discussion and decision-making should involve the whole team. This is a major strength of the QFD approach.

QFD Step 5

More information will be needed in order to implement the detailed technical design and manufacture, if applicable. The next stage is to define quality targets, or measures, for each of the HOWs that are to be incorporated into the new product or service.

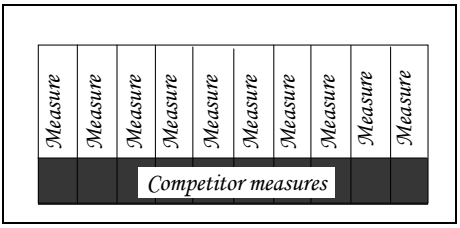
This information is entered in the area at the base of the matrix, and is often referred to as the 'HOW MUCH' element of QFD.



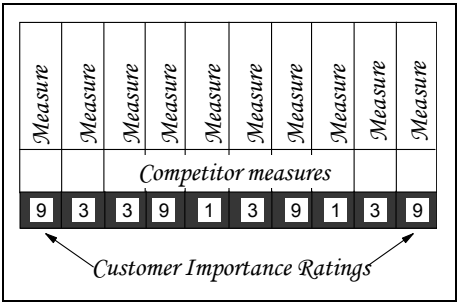


In defining quality measures it is clearly worthwhile to consider the question: “how much is needed?” In a few cases the answer to this question will be determined by purely technical considerations, but customer requirements will always have a degree of influence, and may be the only thing that really matters. It must also be remembered that there is always a cost implication of additional quality, so a relevant question is "how much will customers pay for?"

Any available information about the measured performance of each feature ('HOW') in competitors’ products may be entered in an additional section below the 'HOW MUCH' area.



Since the relative importance of each 'HOW' will directly influence the final product design, a further section can be added indicating the importance to the customer of each item, using the same numerical annotation already used elsewhere in the chart.



These two additional levels of information may be valuable to the team, but necessarily add complexity. It is a matter of judgement whether their usefulness justifies their inclusion.

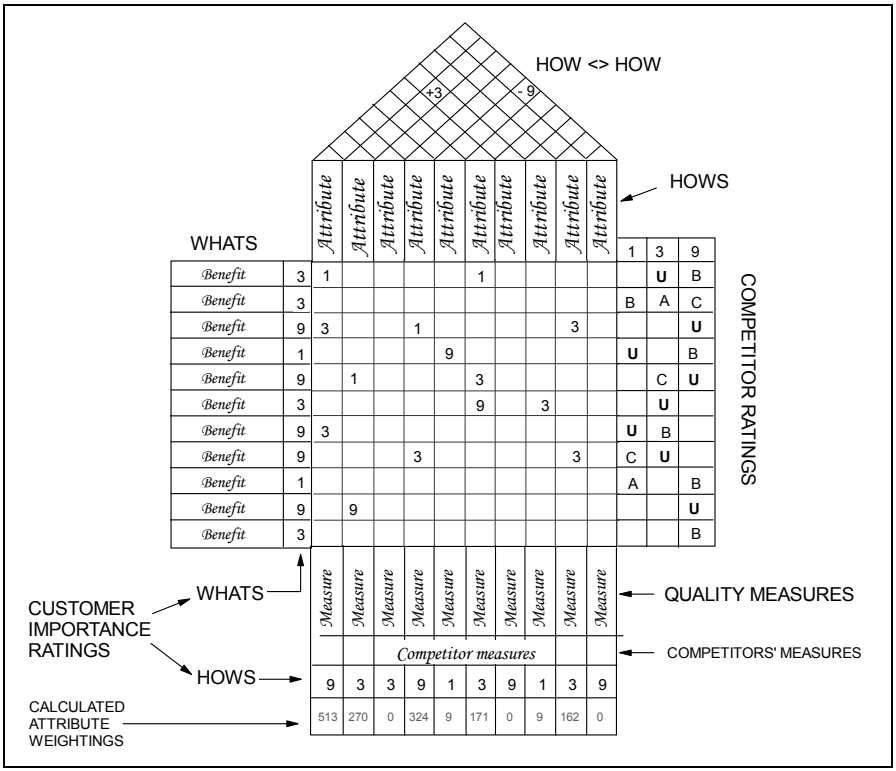
The basic QFD matrix is now complete. The team has now assembled most of the information it needs to describe in some detail the product it intends to bring to market. It knows:

- WHAT benefits customers want to derive from the product;
- The relative importance to customers of each of those benefits;
- HOW those benefits (and perhaps some other benefits that customers haven't thought of) are to be provided in terms of the product attributes that will be incorporated into the product;
- The relative importance to customers of each of those product attributes;
- HOW MUCH (ie, quality targets or measures) of each product attribute it will build in to the product;
- Competitors' performance in a number of respects, to provide useful benchmarks.

This information, collectively arrived at and committed to by team members from the different functional departments, will be sufficient for many products and services and many development teams. It is often convenient to add a further panel below the matrix in which to show calculated attribute weightings. These are arrived at by taking the score indicating how well a HOW satisfies a WHAT and multiplying it by the customer importance

rating of the WHAT. All the figures arrived at in this way are totalled at the foot of each HOW column and the result multiplied by the customer importance rating of the HOW. This gives an overall value rating to each HOW, as a basis for discussion. As usual when performing mathematics on essentially qualitative data, it is advisable to use these figures only as indicators.

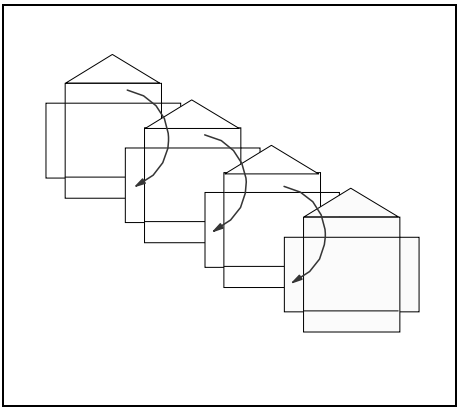
Completed QFD Matrix



Using the data from the QFD 'House of Quality' as input, the team can now formulate a project plan to carry through the implementation and launch the product or service.

In some cases a greater level of detail will be needed than a simple, once-through, application of the QFD House of Quality. The QFD methodology lends itself to iterative applications, in order to get closer to a detailed design which can be implemented throughout the manufacturing and supply processes. In fact, this was a feature of the original design by Prof. Akao in the 1960s. Each iteration results in more tightly-defined, highly-specified HOWs, with their associated quality targets or measures.

This is achieved by taking the HOWs from the first matrix, and treating them as WHATs for the second, and so on, until the required level of detail is reached.



Clearly, this represents a considerable investment of time and resource, and it would be sensible to make an assessment of the benefits likely to be gained from the process before committing to it.

Summary

The use of QFD seems to bring benefits beyond those of analysis and classification which are intrinsic in the technique. It captures or promotes many of the elements of good practice and in that sense can be seen as a microcosm of the product or service development process. For many organisations, the dialogue between members of the multi-disciplinary team which is a major feature of QFD may prove to be its most valuable function.

Sources used in compiling this account of QFD were: Akao (1990); Dimanescu & Dwenger (1996); Eureka (1986); Hauser (1993); Griffin & Hauser (1993); Hauser & Clausing (1988); Inwood & Hammond (1993); Marsh (1991); Rosenau & Moran (1993); Sivaloganathan et al (1995); Sullivan (1986); Wheelwright & Clark (1992).

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Andrew Judge MSc is a Product Manager in a UK telecommunications company with a range of product and portfolio management responsibilities. His role encompasses the launch of new products and services, management of an existing product portfolio and setting portfolio strategies and plans. In a previous role he was responsible for the design of the organisation's product management processes and best practice. In this role he managed an education programme and an accreditation scheme for the company's managers.

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