**INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED'09**
24 - 27 AUGUST 2009, STANFORD UNIVERSITY, STANFORD, CA, USA

# MATCHING THE VOICE OF THE ENGINEER TO THE VOICE OF THE CUSTOMER: AN EVOLUTION OF QFD

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**ABSTRACT**
Previous research has noted the crucial need for engineers to understand the wants and needs of the customer if engineering enterprises are to remain commercially viable. Research has also demonstrated that this commercial sustainability is a vital component of "Designing for Sustainable Development", rendering an understanding of the customer even more important. Traditionally, QFD has played the role of translating this Voice of the Customer into something that engineers can understand at a point in the design process when the target is still somewhat vague – the "Fuzzy Front End" of design. Unfortunately, QFD has not become as widely accepted as might be thought.
This paper therefore looks at some of the problems inherent in QFD and proposes a new methodology to fit into the Fuzzy Front End – "Voice of the Engineer/Voice of the Customer" (VoE/VoC). The methodology goes beyond the pure analysis of QFD and the complexity that therefore ensues, to a method that is far simpler, yet has significant benefits. It describes the method using the example of a mousetrap and then presents two commercial case studies, carried on real products by Durham University. Finally, the paper concludes that the new methodology has the potential to render QFD a relic of the past.

*Keywords: QFD, Voice of the Customer, Voice of the Engineer, New Product Development, Sustainable Development*

## 1 INTRODUCTION

Recent work at the University of Liverpool [1], investigating Design for Sustainability, developed a series of Key Principles to help companies towards sustainability, the last and most important of which was that the ability of an organisation to sustain its own existence "relies on a true understanding of the consumer's wishes and demands and the consequent product functionality required" [1]. For the last 40 years, Quality Function Deployment (QFD) has been thought of as a highly useful design tool, attempting to provide this understanding of consumer wants (the "Voice of the Customer" - VoC) and trying to interpret that in the light of what engineering designers can/will achieve (the "Voice of the Engineer" - VoE). It is quoted as being able to "reduce the development time by 50% and start-up and engineering costs by 30%" [2]. However, whilst QFD is still used in some large companies, it has found minimal success in most for a number of reasons, not the least of which is its apparent complexity. Whilst it has failed to take hold, this has not diminished the need to attempt to match customers' needs with engineers' products. Further research has shown how products as simple as light bulbs can fail to meet the real needs of consumers and has demonstrated the use of Function Analysis to begin to bridge the gap between the Voice of the Customer and the Voice of the Engineer [3].

This paper continues the research by investigating the methodology of Quality Function Deployment. It considers the problems and issues surrounding the use of QFD, and then goes on to address these issues by looking at the basic intention. The paper describes a method developed at Durham University that takes QFD to a new level, reducing the complexity of its use and improving its output by matching the Voice of the Engineer to the Voice of the Customer in a way that is immediately comprehensible to engineer, marketing manager, finance director and manufacturer alike. It demonstrates the VoE/VoC method through the example of the mouse trap, highlighting its strengths and weaknesses with reference to classical QFD. Finally it presents case studies of the new approach as used for the benefit of local companies on their products.

## 2 QFD AND THE DESIGN PROCESS

The impetus for a New Product Design (NPD) may come from recognition of a market opening, the outdating of a previous design, a new technology "looking" for applications, or a strategic move to diversify. Whatever the catalyst, in its earliest stages the new design is largely unknown – not only is its likely form not yet clear, but its performance and capabilities have not yet been decided. The design processes referred to as "clarification of the task" and "creative design" by Pahl and Beitz [4] can be taken as being the part of the process that turns a vague idea into its first possible solutions, without necessarily saying what those solutions may look like. Koen et al [5], for example, suggest five key elements in their "Front End of Innovation" (FEI), namely Opportunity Identification, Opportunity Analysis, Idea Genesis, Idea Selection and Concept & Technology Development, this latter segment often being the first stage of a formal design process. Broadly speaking, such elements fall into one of three categories: research, creativity and analysis. All three of these categories are required to bridge successfully the gap between the NPD impetus and the launch of the formal design process. QFD has found itself a place in some companies, as a tool to help to fill this gap, often described as the "Fuzzy Front End" (FFE). Its key role is in interpreting the VoC and matching it to the technical requirements of the product. The history and development of QFD is well documented throughout the literature (see, for example, [2, 6]) and it is assumed by the author that the reader has a basic understanding of its structure and mechanisms.

Unfortunately, a number of problems have been associated with QFD and have prevented it from becoming as widespread as perhaps it could be.

1. QFD is widely believed to be a long and complicated process [2], demanding resources that may not be (believed to be) available.
2. Its (perceived) complexity implies that a QFD consultant should be brought in to discuss the QFD process and to carry it out and/or train staff, further increasing both expenditure and project timescale.
3. Most published case studies of QFD only use the House of Quality [7], vastly reducing the potential effectiveness of the methodology.
4. Difficulties in understanding and recording the "Voice of the Customer" [2] have reduced trust in QFD.
5. Recent concerns suggest that the methodology is inherently flawed in its reliance on the Voice of the Customer [6]. Arrow's Impossibility Theorem ([8], quoted in [6]) effectively implies that it is impossible to order consumer requirements to represent accurately a collective preference.
6. It is further suggested that the only way to avoid this issue is by increasing the complexity of the methodology through, for example, the use of fuzzy logic [9, 10].
7. The sequential nature of the methodology causes problems, firstly in that it goes against modern "concurrent engineering" thinking and secondly in that the Design "Hows" are generated directly from the customer "Wants", rather than being generated by the engineers and their understanding of the problem.
8. The output of the method is seen to be detailed, analytical evidence, rather than stimuli to the creative design process.
9. The decision making process throughout QFD is non-trivial and has therefore given rise to further complex additions [7].
10. The emphasis is typically on activities to achieve the House of Quality, rather than on the House itself.
11. Finally, QFD can be seen to focus primarily on analysis, where research and creativity are equally required to bridge the FFE gap successfully.

## 3 MATCHING THE VOICES

The method to be presented has come about over a period of years, through "Action Research" carried out by the University of Durham. Action Research can be defined as "a flexible spiral process which allows action (change, improvement) and research (understanding, knowledge) to be achieved at the same time. The understanding allows more informed change and at the same time is informed by that change" [11]. The work was therefore carried out in local companies on their products, generating real commercial benefit to the companies and, concurrently, investigating the problems inherent with QFD. The methodology was reduced and refined through numerous iterations within these companies into something that is simple to use, is time-efficient and addresses QFD's problems as identified above.

The end product of the new "VoE/VoC" methodology is a table very similar to that in QFD, although slightly simplified. The route to get there, however, is different. Two simultaneous paths are taken: the marketing department puts together the Voice of the Customer, in the manner typical of classical QFD, or using whatever resources it has available. At the same time, the engineering department develops a Function analysis (sometimes called a "FAST" diagram) of the product. Typically, much of the information already exists – marketing already have a feel for the customer and engineers already know what the product might be intended to achieve. The key is therefore to bring together these two distinct "voices" and to see what can be learnt from them.
To illustrate VoE/VoC we can consider a company manufacturing a mouse trap such as the traditional, wooden, spring-loaded trap, but wishing to develop a new, market-beating trap. The first phase is for marketing to pool their existing knowledge, and bring together any further required knowledge, to propose customer requirements for the new trap. This allows the importance of each requirement to the customer to be estimated on, for example, a scale of one to five, and an assessment to be made of the performance of the company's existing solution and its competitors' performance, as per Table 1 below.

*Table 1. Example of Voice of the Customer for a mouse trap*

| Requirement | Importance Rating | Customer Assessment | | |
|---|---|---|---|---|
| | | ▲ Company product | ■ Competitor A | ● Competitor B |
| Easy to place bait | 3 | 2 | 3 | 5 |
| Easy to set trap | 4 | 2 | 5 | 5 |
| Can see when it's done its job | 4 | 4 | 1 | 3 |
| Avoid touching dead mouse | 3 | 2 | 4 | 1 |
| | | | | |
| Kills swiftly | 5 | 4 | 1 | 1 |
| Humane | 5 | 2 | 4 | 1 |
| | | | | |
| You can rely on it | 4 | 2 | 4 | 3 |
| Mouse can't get bait and escape | 5 | 3 | 4 | 2 |
| Attracts mice well | 4 | 4 | 3 | 2 |
| Not too big | 1 | 4 | 3 | 4 |
| | | | | |
| Not too messy | 3 | 2 | 4 | 5 |
| Safe for my kids and pets | 5 | 1 | 2 | 3 |
| Doesn't keep trapping my fingers | 4 | 1 | 5 | 5 |
| | | | | |
| Cheap | 2 | 5 | 2 | 3 |

A good marketing department should already have most of this information to hand and, even where marketing is not so strong, some reasoned estimates can be made. If competitors' products are available or known, a competitive assessment can be made, rating the company's own product and the competition out of 5 for each of the customer requirements. Comparison between the two is then made by using the two equations:

*Strength (Weakness) = (Own - Best Competitor) x Customer Importance*

*Opportunity = (5 - Best Score) x Customer Importance*

These allow a simple and reasoned view of what the company's product is particularly good – or bad – at and where the opportunities exist within the marketplace.
Whilst marketing prepare this information, the engineering team put together a function analysis of the product. The purpose of a function analysis is to demonstrate the functions that a product must perform, without saying how it is to achieve them. Simple examples of such analyses – and the consequences of failure to consider them properly – can be found in [3]. For the mouse trap, the simplest level may look something like Figure 1. Again, the engineering team may already have this information, or will be able to put it together without much effort.

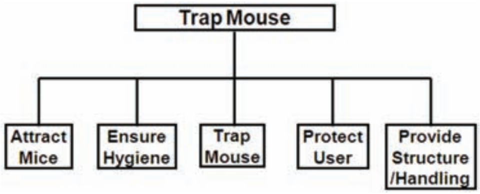


*Figure 1. Function Analysis for a mousetrap*

Contrary to classical QFD, where the VoE is developed as a result of the VoC, it is vitally important that the investigation into the Voice of the Customer and the Voice of the Engineer are carried out in separation, to identify clearly mismatches in understanding. As part of Akao's seminal book "Quality Functional Deployment" [12], Mitsuji presents QFD charts for the design and manufacture of prefabricated housing [13]. Takamura [14] then notes: "Generally speaking, satisfying the demands of the customer is the basis for developing a product that will be accepted and bought. However, this cannot be the basis for every aspect of product planning." He then goes on to point out that "neither the foundation nor the laying of the foundation was extracted as an important element" of the customer feedback – despite their obvious and crucial importance. By separating the Voice of the Customer from the Voice of the Engineer, this distinction is made. Function analysis quickly and easily picks up on the knowledge of the Engineer as to what a product must do (without giving specific solutions) which, in the case quoted would immediately have picked up on the necessity for the laying of solid foundations.

In the mousetrap example, there are two key points for the engineer to note: firstly, the customer expects the mouse to be dead and not to have to deal with a living animal; secondly, the customer wants that death to be humane. Taking these expectations into consideration requires a change in mindset by the engineer and thus begins to help to match his or her technical expectations to those of the customer.

The function analysis may now be amended simply to Figure 2, and then expanded if required by the engineering team to Figure 3, bearing in mind the Voice of the Customer.

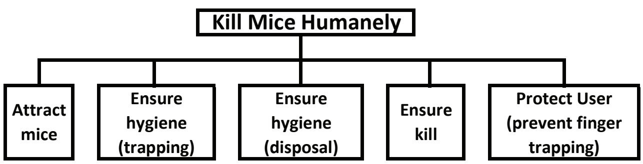


*Figure 2. Function Analysis for "humane mousetrap"*

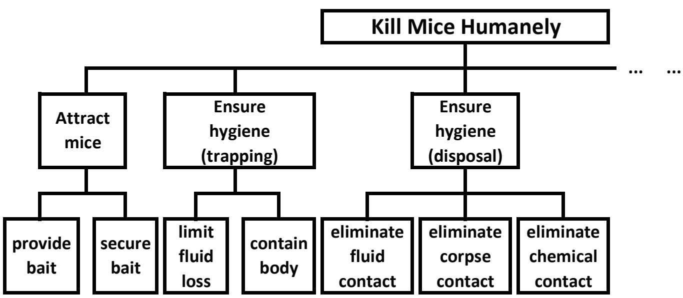


*Figure 3. Extended Function Analysis for "humane mousetrap"*

The data can now be entered into the VoE/VoC consolidation chart, as shown in Figure 4 – a slightly modified House of Quality. Crucially at this point, neither the data being entered, nor the specific results are of vital importance, although they can clearly be helpful. More important is the mindset of those entering the data, their understanding of the implications of the VoC against the functions provided by the VoE and the stimulation this brings into the creativity process. Indeed, in some circumstances, the chart can be missed altogether and designers can jump straight to generating creative solutions. An example of this is given in Section 5.

Returning to the chart, this is filled in as per classical QFD with VoC headings entered in the left hand column and the VoE functions entered into the top row. These are then linked to each other using the visual symbols provided to denote a strong link (9), medium link (3) or weak link (1). When each link is multiplied by the weighting of the customer importance, and summed down a column, the "Technical Importance Rank" (TIR) is obtained which shows the value of that function to the customer.

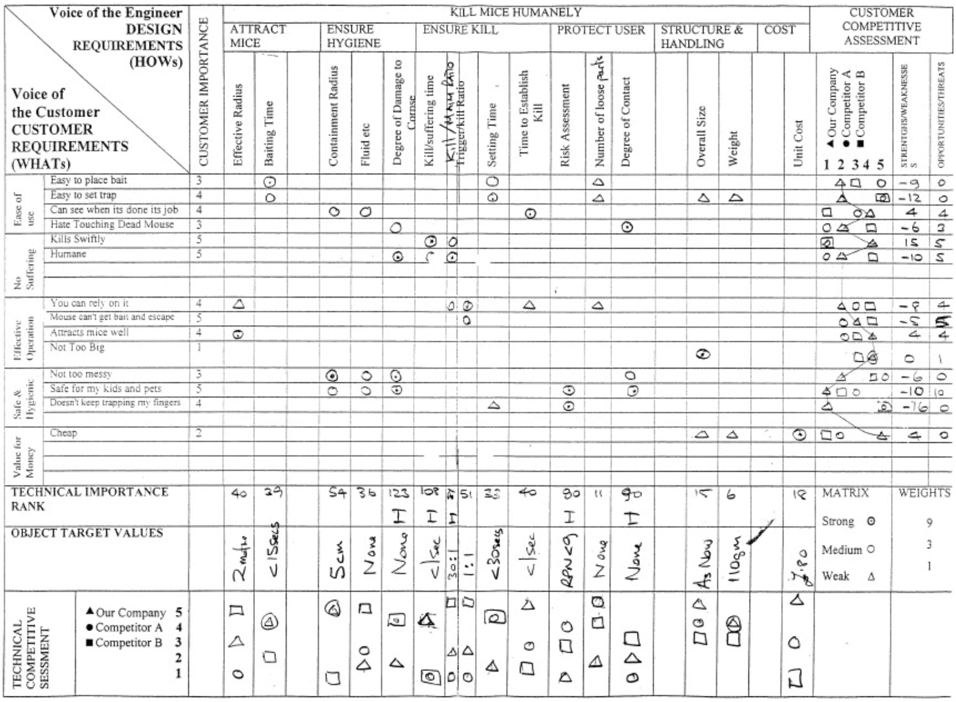


*Figure 4. Voice of the Customer/Voice of the Engineer consolidation chart*

A number of specific conclusions could be drawn from the results in Figure 4. Leaving aside any detailed analysis, which may indeed hinder the creative process that would follow its completion, the first point is to consider the Technical Importance Rank. This highlights (marked with "I") the functions that have proved to be the most important. The specific numbers are not necessarily of crucial importance, being subject to a number of potential weaknesses. However, their relative magnitudes are worth noting alongside "our company's" performance in the Technical Competitive Assessment beneath the TIR and Object Target Values lines. In this case, our existing solution (represented by the triangle) performs particularly badly compared to the competitors on "degree of damage to corpse" which is rated as the highest importance. On the other hand, it does significantly better than the competition in the kill/maim ratio.

Considering the "object target values" line, the provision of targets for technical functions has been cited as a difficulty, by Bouchereau [2] for example; where the functions have been generated independently of the VoC, however, such targets are now easily obtainable. Here, for example, "contain body" gives rise to the size of mouse (as opposed to the larger rat) that might be considered. The "eliminate" functions set a clear target of zero, whilst "provide bait" is binary, in that any solution either does or does not allow for the provision of bait.

Again, it is worth emphasising that the actual analytical results are probably not as important as the thought processes that a multifunctional team will go through in producing these results and the consequent benefits this will have in moving into the creative phase. For example, whilst completing the column "eliminate corpse contact", a number of solutions are likely to be generated simply because the design team are thinking about "eliminate corpse contact" in an exercise that does not attempt to force them into designing solutions. Whilst "intuition cannot be forced" [15] it can certainly be encouraged and the research inherent in this methodology is one means of providing the background information that will allow and encourage intuition.

| Parts \ Function | Attract mice | Ensure hygiene | Ensure kill | Protect user | Structure/ handling | Total |
|---|---|---|---|---|---|---|
| **Bases (2)** | | | | 2 | 8 | **10** |
| **Adhesive** | | | 40 | | | **40** |
| **Bait** | 10 | | | | | **10** |
| **Packing** | | | | 3 | 2 | **5** |
| **Assembly** | | | 1 | 2 | 0.5 | **3.5** |
| | | | | | | |
| **Function totals** | **10** | **0** | **41** | **7** | **10.5** | **68.5** |
| **Function %** | **15%** | **0%** | **60%** | **10%** | **15%** | |

*Figure 5. Function Cost Analysis (cost in pence) for "sticky pad" type mousetrap*

Concurrently with completion of the table, a simple but very worthwhile addition is that of Value Engineering or Value Analysis (VA). Whilst Ignacio et al [16] begin to bring VA into QFD, they use it as a decision support tool to help decide between alternative solutions. Da Silva et al [17] suggest using VA as part of the function analysis, but their approach appears only to add to the perceived complexity of the process. Of direct value is "Function Cost Analysis" (their "Resource Consumption Matrix"), a matrix which compares the components within an existing product (vertical axis) with the functions that the product must achieve (directly from the function analysis) on the horizontal axis. Knowing the cost of each component, the engineers take a judgement as to how much of that cost is used to satisfy each function. An example can be seen in Figure 5 which is based on a two-pack of simple "sticky pad" mousetraps (see http://www.jteaton.com/retail_rats.htm for an example). In this type of mousetrap, the mouse is attracted to bait which is situated on top of adhesive contained within a base; once there the mouse cannot escape the adhesive, thereby starving itself.

Engineering should once more already have the data and so the task of compiling it into this format is not onerous. The chart on its own generates benefits in understanding the cost of each component within the product, whether that cost is appropriate bearing in mind the function that it is achieving, whether a component serves any function or indeed whether a function is served by any component – in this case, no component is judged to "ensure hygiene". When considered alongside the consolidation chart, however, it reveals the cost of providing each function – particularly revealing when compared to the technical importance of that function. Needless to say, much can be learned from carrying this out not only on a company's own products, but also on their competitors' products.

## 4 COMPARISON TO QFD

Through the action research within local companies, this method for matching the Voice of the Engineer to the Voice of the Customer has evolved to address a number of the difficulties faced by classical QFD and outlined in Section 2. One specific change, which addresses several of the issues, is the change from the VoE being a result of the VoC, to the VoC and the VoE being developed independently and concurrently. As a result of this, and other changes, the following comments can be made, referring back to the points raised in Section 2.

1. QFD is widely believed to be a long and complicated process …

VoE/VoC relies on data already held by both marketing and engineering sections. Whilst collating the data may take a little time, it is not onerous. Completing the consolidation chart has the potential to take a period of time, but that should be prevented, with the emphasis instead placed on being necessary preparation for the creative phase.

2. Its (perceived) complexity implies that a QFD consultant …

There is no need for a consultant for training and use of the VoE/VoC methodology. Whilst it may be useful to have someone who has used it before to introduce and explain, this is not a pre-requisite.

Indeed, the Universities of Liverpool and Durham provide such experience for free in exchange for student case study material.

3. Most published case studies of QFD only use the House of Quality …

VoE/VoC takes the most useful components of the House of Quality, adding functional and value analysis. Whilst significant gains are available from the complete QFD methodology, sufficient benefit can be had from the VoE/VoC. This also helps in the addressing of point 2.

4. Difficulties in understanding and recording the "Voice of the Customer" …; and
5. Recent concerns suggest that the methodology is inherently flawed …

If the results of the method are purely analytical, as is the norm when QFD is used, this can only be the case. However, VoE/VoC takes the emphasis away from such a mathematical approach, looking instead for comparisons and trends that will be of use in the creative design phase. Whilst the results of the consolidation matrix are indeed numerical, the fact that one engineering function in Figure 5 has a TIR of 123 and another has a TIR of 108 only shows that both are important and should be addressed, rather than saying one function is actively more important than the other. Any more "suspect" results in gauging the VoC therefore have less of an impact on the process.

6. It is further suggested that the only way to avoid this issue is by increasing the complexity …

If complexity is off-putting to companies, increasing the complexity makes little sense. Not only does VoE/VoC avoid increasing complexity but it considerably reduces complexity.

7. The sequential nature of the methodology causes problems …

VoE/VoC allows concurrent preparation by marketing and engineering alike, readying both for the first formal project meeting and shortening the product development process. Once preparation is complete, both teams are au fait with the intentions behind the methodology and ready to consolidate their results, gaining maximum benefit from the now multi-disciplinary team. The presentation of both sets of results in parallel exposes gaps between VOC and VOE which can then be addressed.

8. The output of the method is seen to be detailed, analytical evidence …

This has been sufficiently addressed in previous answers.

9. The decision making process throughout QFD is non-trivial …; and
10. The emphasis is typically on activities to achieve the House of Quality …

The emphasis of VoE/VoC is on the comparisons and trends produced and on the creative phase to which the method naturally progresses.

11. Finally, QFD can be seen to focus primarily on analysis, where research, creativity and analysis are required to bridge the FFE gap successfully.

VoE/VoC encourages research, analysis and creativity, bridging the FFE gap and helping the search for the next "winning" product. Ideally, a Concept Generation Session will subsequently be carried out by those consolidating the chart; alternatively, the results can be presented to the relevant people at the start of the session.

The one weakness of the methodology (although, without which it would be completely meaningless) is its reliance on a genuine understanding of the consumer. It assumes correct modelling of customer desires, which may in fact not be the case. As mentioned in section 2, point 5, the literature suggests that customer desires cannot be turned into a collective preference. A more full discussion and investigation into this area of research is beyond the scope of the work presented here – indeed it is more in keeping with social and psychology research. It seems reasonable for the purposes of this paper, however, to suggest that companies do indeed make assumptions about consumer desires and preferences and are able to inform their engineers on the basis of these desires. Errors in the companies' understanding, irrespective of the problems represented by Arrow's Impossibility Theorem, will lead to numerical inaccuracies in any method used. The VoE/VoC methodology presented here, however, circumvents the problem by using the customer wishes to present trends and directions and to stimulate creativity, rather than as a foundation for the strict mathematical analysis typical of QFD and "improved" QFD methods.

## 5 CASE STUDIES

As mentioned earlier, the methodology is a result of action research by Durham University, carried out on real products in real companies. A number of case studies which formed part of the research will now be presented to demonstrate both the methodology and its benefits.

The first case study is a project for a company producing convector heaters. As part of an overall brief to reduce the costs of the convector heater, a full VoE/VoC analysis was carried out. The functionality of the product was analysed to be as in Figure 6.

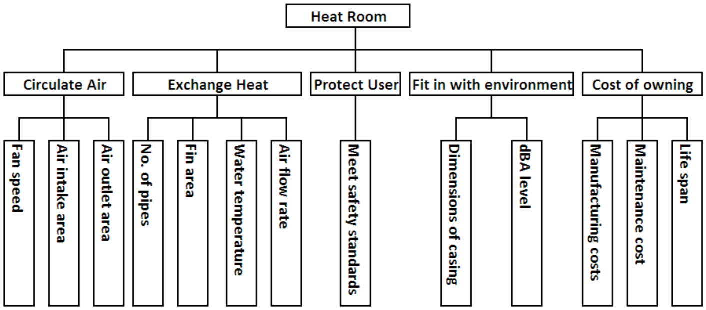


*Figure 6. Functional Analysis of Convector Heater.*

The marketing department, who believed themselves to have a good understanding of their customers, were provided with a list of customer requirements and rated the requirements on a scale of 0-5. They were then able to compare their own product's performance with that of a competitor's product and the resultant consolidation chart can be seen in Figure 7.

| | | **Circulate Air** | | | **Exchange Heat** | | | | **Protect User** | **Fit in with Environment** | | **Cost of Owning** | | | **Customer Competitive Assessment (Host company: X competitY)** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Customer Importance Rating** | Fan speed | Air intake area | Air outlet area | No. of pipes | Fin area | Water temperature | Air flow rate | Meet safety standards | Dimensions of casing | dBA level | Target manufacturing costs | Maintenance cost per annum | Life span | 1 | 2 | 3 | 4 | 5 | Strength (Weakness) | Opportunity (Threat) |
| Heating performance | **3.5** | A | B | B | B | A | A | A | | | | | | | | | | X | Y | -3.5 | 0 |
| Suitability for environment | **3.5** | | | | | | | | | B | B | | | | | | | | XY | 0 | 0 |
| Ease of installation | **3** | | | | | | | | | B | | | | | | | Y | X | | 3 | 3 |
| Ease of maintenance | **1.5** | | | | | | | | | | | | B | C | Y | | X | | | 3 | 3 |
| Long life span | **3** | C | | | | | | | | | | B | | A | | | XY | | | 0 | 6 |
| Low noise | **4.5** | A | | | | | | | | | A | C | | | | | XY | | | 0 | 9 |
| Pleasing aesthetics | **2** | | C | C | | | | | | C | | C | | | | | Y | X | | 2 | 2 |
| Ease of use | **2.5** | | | | | | | | | | | B | | | | | XY | | | 0 | 5 |
| Low running costs | **3.5** | A | | | | | B | C | | | | | | | | | XY | | | 0 | 7 |
| Summer function | **2** | | | | | | | | | | | B | C | C | | | XY | | | 0 | 4 |
| Different speed settings | **2** | B | C | C | | | | C | | | B | B | C | C | | | XY | | | 0 | 4 |
| Low cost of unit | **5** | | | | B | C | | | C | B | B | A | | B | | X | | Y | | -10 | 5 |
| Safety | **4.5** | | | | | | | | A | B | | | | | | | | | XY | 0 | 0 |
| **Technical Importance Rank** | | **113** | **15** | **15** | **26** | **37** | **42** | **37** | **46** | **50** | **72** | **80** | **8.5** | **48** | | | | | | | |
| **1st level TIR** | | **141.5** | | | **141** | | | | **46** | **122** | | **136** | | | | | | | | | |

| | | |
|---|---|---|
| Strong relationship: | **A** | 9 |
| Medium relationship: | **B** | 3 |
| Weak relationship | **C** | 1 |

*Figure 7. Consolidation Matrix for Convector Heater*

Notable within this matrix are the Strength and Opportunity columns: minor strengths exist in ease of installation and maintenance; on the other hand, the product performs particularly poorly in the unit cost. Equally, a number of significant opportunities exist with low noise, low running costs, long life span, ease of use and low unit cost (in descending order) all scoring five or over. Whilst the company clearly knew that unit cost was an issue, it being the overall subject of the study, the other four factors – all of which present similar or greater opportunities – were not necessarily widely know, particularly by the engineers.
The technical importance ranks for individual functions are combined, at the bottom of the matrix, into rankings for the first level functions which were then used in conjunction with value analysis of the product to provide Figure 8. Here, target costs are shown based on the relative ranking of the functions, whilst the actual percentage costs are also shown. The customer clearly puts considerable value on fitting the product into their own environment and yet the company spend is virtually zero in this area. The cost of owning, made up primarily of unit cost, unit life and energy usage, is similarly neglected. The key from this diagram is not necessarily the absolute value of each area of spending but the relative importance of each area to the consumer and how (and whether) that impacts on the company's designers/engineers. Without this simple analysis, the designers' own preconceptions would have influenced the redesign activity – probably excluding many of the factors brought out by the VoE/VoC methodology.

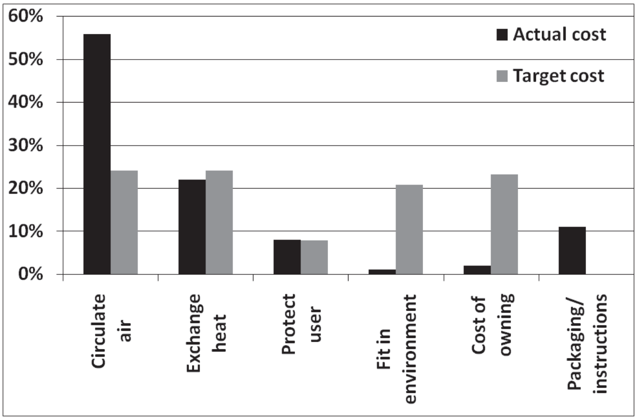


*Figure 8. Value analysis of the Convector Heater*

The next stage of the project was a series of studies of the product's problematic areas, as identified through the above analysis, which in turn resulted in a series of proposals to address them.
A second case study will now be presented, again from the action research carried out by Durham University, based on a lubrication system. The product in question had been recognized to be at least "mature" in the product life cycle and tending towards declining. The company had therefore made a decision that a New Product Development process should be carried out and looked to Durham University for help in understanding and implementing this process. The analysis included Voice of the Customer (based on Kano categorisations), Voice of the Engineer (including Value and Function Analyses), cross-voice comparisons (although no formal consolidation chart was produced – as suggested in Section 3) and idea generation.
The complete results of the VoE function analysis are too large to include here, but the first level – and key – functions are shown in Figure 10.

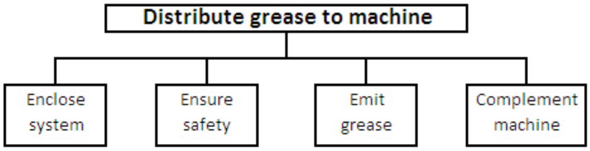


*Figure 10. Function analysis of the lubrication product*

The next part of the VoE analysis was a value analysis of the product and a competitor, the overall results of which are shown in Table 2. The breakdown of values by function is commercially sensitive; however the company's own product has five times more components than the competitor's, resulting in a total manufactured cost three times greater than the competitor.

*Table 2: Function cost analysis of the company's and a competitor's product*

| | Function | | | |
|---|---|---|---|---|
| Function as % of total cost: | Enclose system | Ensure safety | Emit grease | Complement machine |
| The company | 17 | 4 | 63 | 16 |
| A competitor | 14 | 0 | 64 | 22 |

Voice of the Customer analysis was limited by project time and company resources. An insight into the VoC was gained through interviews with the Managing Director and Sales and Strategy Manager – at least as perceived by the company. This was structured under 4 headings, dividing customer expectations into "expected", "high impact", "low impact" and "hidden" as shown in Figure 9.

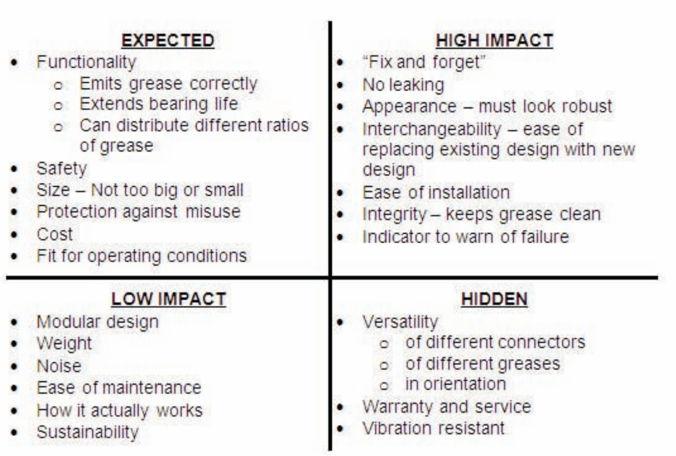


*Figure 9. Voice of the Customer analysis of the company/product*

Sufficient information had been gathered at this point that a consolidation chart was judged to be unnecessary. The customer required a robust, reliable system, workmanlike in appearance and with no leaks. On the other hand, the company's product was expensive, overcomplicated and did not match customer requirements as well as the competitors' product. This information was used to develop a list of functional requirements for a new product and the company moved into the concept generation phase.

## DISCUSSION

There are several relevant results of these analyses. Firstly, the methods used are simple to understand, easy to implement, rely primarily on existing knowledge and therefore lead very rapidly to the next stage of the design process. Secondly, the methods generated significant amounts of understanding above and beyond what the company already knew. For example, whilst the second company knew it was losing sales, it had not recognised the mismatch between the Voice of the Customer and the Voice of the Engineer. Thirdly, the methods required research, analysis and creativity – bridging the Fuzzy Front End gap. Fourthly, the results led directly to concept generation, allowing a number of potential new designs to be developed. The gathering of data during the research provided "germination" time for new ideas which were then implemented based on the newly gained knowledge of the analysis team. Finally, no detailed, complex analysis was necessary. Indeed, in the second case it was sufficient simply to collate and analyse the raw data, rather than consolidating it formally through the chart of Figure 4. The methodology can therefore be seen to be sufficiently flexible and non-onerous to fit in with the everyday requirements and pressures of company design teams.

## 6 CONCLUSIONS

The starting point of the research that led to this methodology was the acknowledgement that Designing for Sustainability requires a deep understanding of the needs of the customer. Whilst many companies may have this understanding within their marketing team, the translation into the world of the engineer is often missing. QFD is one means of providing that translation but whilst it has found success in some companies, that success has been limited by the complexity and other failings of the method, to the extent that it is widely acknowledged that most companies – whether SME or larger – do not use QFD.

The methodology presented in this paper relies on information that most companies should already have. By decoupling the VoC from the VoE, it minimises the preparation work required whilst allowing that preparation to be done concurrently, rather than sequentially. Furthermore, it reduces compound errors that occur through building the VoE on the VoC and brings in independent and extremely valuable input through the new VoE.

The VoE/VoC methodology contains the components required to bridge the fuzzy front end of the design process – research, analysis and creativity – whilst providing an ideal framework during which new ideas can germinate prior to the first formal design phase. It includes a consolidation chart to match formally the VoC and the VoE and to provide extra information such as identifying opportunities with respect to competitive products; this information is optional, however, as the case study demonstrated.

The method developed by this research has been shown through action research to enable companies to match their own understanding as engineers to the wants and desires of their customers – a step towards ensuring their own sustainability as a commercial enterprise. In doing so, it has the potential to render formal QFD a relic of the past

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