VOL. 9, NO. 7, JULY 2014 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences


www.arpnjournals.com

A COFFEE MACHINE DESIGN PROJECT THROUGH INNOVATIVE METHODS: QFD, VALUE ANALYSIS AND DESIGN FOR ASSEMBLY

Leonardo Frizziero
Department of Industrial Engineering, Alma Mater Studiorum University of Bologna, Viale Risorgimento, Bologna, Italy
E-Mail: leonardo.frizziero@unibo.it

ABSTRACT

This work is a sample of designing a simple object, just like a coffee machine, using innovative methodologies as Quality Function Deployment, Value Analysis and Design for Assembly. These are three methods which serve to improve quality during the process of design; they are part of the famous designing technique which is named Concurrent Engineering. The first one, QFD, is structuring all the information which come along with each design project; the second one, Value Analysis, is about the evaluation of all the costs that our project implicates; the last one, Design for Assembly, is a methodology oriented to direct the design process towards the exemplification of all the components' shapes: in this way, we can obtain a product easy to be assembled.

Keywords: coffee machine, innovative methodologies, QFD, value analysis, design for assembly.

INTRODUCTION

The aim of the present paper is to adopt innovative designing method, just like Quality Function Deployment (QFD), Value Analysis (VA) and Design for Assembly (DfA) to design an innovative coffee machine.
These are three methods, among several ones [1-5], which serve to improve quality during the process of design; they are part of the famous designing technique which is named Concurrent Engineering. The first one, QFD, is structuring all the information which come along with each design project; the second one, Value Analysis, is about the evaluation of all the costs that our project implicates; the last one, Design for Assembly, is a methodology oriented to direct the design process towards the exemplification of all the components' shapes: in this way, we can obtain a product easy to be assembled.
To employ methods cited, we built a specific project structure with QFD, in order to start with a design concept of a simple mechanical device just like a coffee machine.
During the work we applied concepts about cost analysis, using VA, and how design for assembly (DfA), in order to integrate all the three methodologies to carry out an innovative and complete project concept. [6-9]

The three methodologies employed: QFD, VA, DfA

QFD - quality function deployment

Quality Function Deployment (QFD) was developed to bring this personal interface to modern manufacturing and business alike. In today's industrial society, where the growing distance between producers and users is a concern, QFD links the needs of the customer (end user) with design, development, engineering, manufacturing, and service functions. It helps organizations seek out both spoken and unspoken needs, translate these into actions and designs, and focus various business functions toward achieving this common goal. QFD empowers organizations to exceed normal expectations and provide a level of unanticipated excitement that generates value.

QFD is:

a) Understanding Customer Requirements;
b) Quality Systems Thinking + Psychology + Knowledge/Epistemology ;
c) Maximizing Positive Quality That Adds Value;
d) Comprehensive Quality System for Customer Satisfaction;
e) Strategy to Stay Ahead of the Game.

Background

Quality professionals refer to QFD by many names, including matrix product planning, decision matrices, and customer-driven engineering. Whatever you call it, QFD is a focused methodology for carefully listening to the voice of the customer and then effectively responding to those needs and expectations.

First developed in Japan in the late 1960s as a form of cause-and-effect analysis, QFD was brought to the United States in the early 1980s. It gained its early popularity as a result of numerous successes in the automotive industry [10].

METHODOLOGY

In QFD, quality is a measure of customer satisfaction with a product or a service. QFD is a structured method that uses the seven management and planning tools to identify and prioritize customers' expectations quickly and effectively.

Beginning with the initial matrix, commonly termed the house of quality, depicted in Figure-1, the QFD methodology focuses on the most important product or service attributes or qualities. These are composed of customer wows, wants, and musts. (See the Kano model of customer perception versus customer reality.)

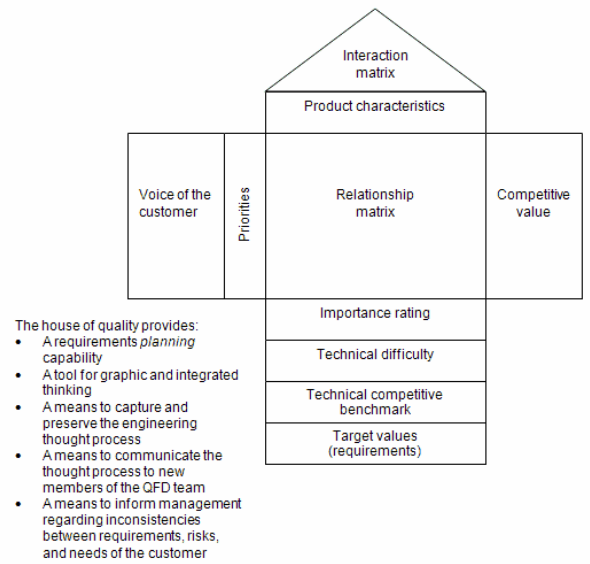

Figure-1. House of quality.

Thus, QFD is the deployment of customer-driven qualities to the responsible functions of an organization.

Many QFD practitioners claim that using QFD has enabled them to reduce their product and service development cycle times by as much as 75 percent with equally impressive improvements in measured customer satisfaction.

Quality Function Deployment is a method which analyzes products environment, customer needs and can explain some parameters to reach a higher level of quality of our product. It starts with an analysis of customers, then with some matrixes (interrelation, relation and so on) can explain what parameters need to be deployed to obtain the right device. It can be strengthened by fuzzy logic in the decision-making process [11-14].

In the present work, QFD analyzes the following parameters (you will see their deduction at the end of the work):

- Solidity
- Functionality
- Simplicity to use
- Maintainability and clearly
- Resistance (to wetness and heat)
- Easiness to handling
- Good design
- Ergonomics
- Performances
- Stability
- Economics of purchasing
- Eco-compatibility

We can see that the above parameters are quality ones, not at all technical ones. This is the reason why this method is developed to obtain an improvement of quality in our device.

VA - value analysis

Value Analysis is often done by systematically following a multi-stage job plan. Larry Miles' original system was a six-step procedure which he called the "value analysis job plan." Others have varied the job plan to fit their constraints. Depending on the application, there may be four, five, six, or more stages. One modern version has the following eight steps:

- Preparation
- Information
- Analysis
- Creation
- Evaluation
- Development
- Presentation
- Follow-up

Four basic steps in the job plan are:

a) **Information gathering:** This asks what the requirements are for the object. Function analysis, an important technique in value engineering, is usually done in this initial stage. It tries to determine what functions or performance characteristics are important. It asks questions like; what does the object do? What must it do? What should it do? What could it do? What must it not do?

b) **Alternative generation (creation):** In this stage value engineers ask; what are the various alternative ways of meeting requirements? What else will perform the desired function?

c) **Evaluation:** In this stage all the alternatives are assessed by evaluating how well they meet the required functions and how great the cost savings will be.

d) **Presentation:** In the final stage, the best alternative will be chosen and presented to the client for final decision. [15].

Background

Value analysis design (VA) or value engineering (VE) is a systematic method to improve the "value" of goods or products and services by using an examination of function. Value, as defined, is the ratio of function to cost. Value can therefore be increased by either improving the function or reducing the cost. It is a primary tenet of value engineering that basic functions be preserved and not be reduced as a consequence of pursuing value improvements.

Methodology

The Value Analysis is the more effective instrument for the management of the Value. Value (Index of Value) V (value) is the relationship between the W usefulness (worth) minimal estimated price that it is disposed to pay in order to obtain the function in examination, in a determined place and in determined circumstances and environmental conditions them, and the total production cost or of the member who develops function same C (cost).

In synthesis the Analysis of the Value is an operating methodological instrument that concurs to catch up objects of the Quality (excellence) to you, placing maximum attention on the functions and the relation to your indices of value.

DfA-design for assembly

DFA is the method to design the products in order to facilitate assembly.

It is concerned only with reducing product assembly cost:

- minimizes number of assembly operations,
- individual parts tend to be more complex in design.

Background

Simplify the design and reduce the number of parts because for each part, there is an opportunity for a defective part and an assembly error. The probability of a perfect product goes down exponentially as the number of parts increases. As the number of parts goes up, the total cost of fabricating and assembling the product goes up.

Automation becomes more difficult and more expensive when more parts are handled and processed. Costs related to purchasing, stocking, and servicing also go down as the number of parts are reduced. Inventory and work -in-process levels will go down with fewer parts. As the product structure and required operations are simplified, fewer fabrication and assembly steps are required, manufacturing processes can be integrated and lead times further reduced. The designer should go through the assembly part by part and evaluate whether the part can be eliminated, combined with another part, or the function can be performed in another way [8].

Methodology

Design for assembly (DFA) is a process by which products are designed with ease of assembly in mind. If a product contains fewer parts it will take less time to assemble, thereby reducing assembly costs. In addition, if the parts are provided with features which make it easier to grasp, move, orient and insert them, this will also reduce assembly time and assembly costs. The reduction of the number of parts in an assembly has the added benefit of generally reducing the total cost of parts in the assembly. This is usually where the major cost benefits of the application of design for assembly occur [16].

The embodiment: a coffee machine design

"To plan activity is not one only scientific-technique, but also humanistic. In the planning the synthesis between two cultures is come true because object or process thought from the man that it is not conceived and produced for other men, from the humbler tool to the more sophisticated system does not exist. ".Taking to cue these most important concepts and having with the present abstract to face the design process of a coffee maker for homely use (the object of which the three planners did not possess in phase of start up no acquaintance, if that one does not work them), the three planners has thought opportune to realize a short search that more deeply dealt how many all the thematic ones tied to the coffee: the nature of the product, its characteristics, its property, the means and the methods in order to work it and for creating it, several the instruments and blot some to them, already existing, in order to prepare it.

THE COFFE MACHINES

They are composed from a covering, saying auto body and from a group coffee, than in its turn it is constituted from the following technical members: a pump that serves to generate pressure in the hydraulic circuit, a heat exchanger where the water comes heated and maintained to the ideal temperature by means of a control system temperature and room of extraction where once deposited the coffee happens the “percolation”, that is the passage of a fluid through pierced means; in the case in issue the warm water represents the fluid and the coffee the pierced means. Between the main ones you for the control of the distributed volume are put to you, for the vapor distribution, the milling and the dosage of the powder in the case of I use of coffee in grains. In the continuation photos some examples are brought back here of blot some from coffee in commerce; the different can be noticed approach to the planning of the same ones: that one of Sapper is passed from minimalisti plans (as an example) to plans a lot elaborates (sees the machine to you Bomb) (Figure-2):

Figure-2. Kinds of commercial coffee machines.

In a generalized manner, the result of the analyses of the market and the first selection of the relative ideas to a product (job in great part carried out in the previous understood one it) does not contain all the information necessary in order to give beginning to the phase of true and own planning. It must, then, to this point to start a second phase of collection and of selection of they give to you that it goes under the name of explanation of the task. The explanation of the task is one of the most important aspects of the modern methodologies of planning. The problem must more completely be defined and clearly possible so that the correction in it is made successive they are limited.

One first review of the plan contemplates one series of questions apt to catch up this aim:

a) documentation of the atmosphere (6 questions)
b) organization of one synthesis of
c) requirements appraisal of the importance of the requirements (matrixes)

d) formulation of the specific technique
e) sketches of the product
f) designs CAD of product
g) rendering of the product.

The 6 questions serve to immediately characterize those characteristics that the object to plan necessarily must possess. They are:

a) Who: Who uses the product?
b) Thing: Which it is the use of the product?
c) Where: Where it is used?
d) When: When it comes used?
e) Because: Why it is used?
f) Like: How it comes used?

In our specific case, we have:

a) Who uses the coffee maker?
b) Which is the use of the coffee maker? The coffee maker comes used in order to make the coffee, possibly good!
c) Where it comes used the machine of the coffee?
d) When and how many times come used?
e) Why is it used? The coffee is used for being able to drink.
f) How is it used? The coffee is drunk expressed.

From the carried out analysis over, we have characterized therefore following requirement that our product must possess:

a) Solidity and robustness
b) Functionality
c) Simplicity of use
d) Maintainability and clearly
e) Resistance to wetness and heat
f) Ease of handling
g) Good design
h) Ergonomics
i) Performance
j) Stability
k) Economics of purchase
l) Eco - compatibility

The matrix system

In order to estimate the relative importance of defined requirement over, the interrelation matrix is used. The interrelation matrix is one instrument in order to evidence the relations motives of dependency e/p of relative importance between various requirement or concepts; the instrument serves in order to define priority and to establish optimal sequences of actions.

Effects (lines); Causes (columns)	1	2	3	4	5	6	7	8	9	10	11	12	
1. Solidity		1	1	1	3	9	3	1	1	9	3	1	33
2. Simplicity	1		0	3	9	0	0	0	3	0	9	1	26
3. Functionality (good coffee)	0	1		0	0	9	0	9	0	0	3	0	22
4. Maintenance	1	3	0		9	3	1	1	9	0	1	0	28
5. Dampness and heat resistance	1	9	0	9		0	3	0	9	0	3	0	34
6. Handiness	3	0	9	3	0		1	9	0	3	1	0	29
7. Design	3	0	3	1	0	1		9	0	3	9	1	30
8. Ergonomics	3	0	1	1	0	9	3		0	3	3	0	23
9. Velocity	0	3	1	0	9	0	0	0		0	9	3	15
10. Stability	9	3	1	1	1	3	1	3	1		1	0	24
11. Economy	3	9	1	3	1	1	9	3	3	1		1	44
12. Eco-Compatibility	1	1	0	0	1	0	1	0	1	3	1		9
TOT.	25	30	17	22	33	35	22	35	27	22	43	7	

Figure-3. Interrelation matrix, 1st use.

They give you income in an interrelation matrix often are constituted from the groups of analogous requirement. The development of the method is articulated in the following points: - to formulate the matrix of requirement, bringing back in the lines and the columns of one matrix the same voices; - to determine the relations of cause and effect or relative importance; - to estimate the relations motives or the relations of importance between the various voices.

Matrix of Relative Importance

	1	2	3	4	5	6	7	8	9	10	11	12	
1. Solidity	1	1	2	1	1	1	1	1	0	1	1	0	
2. Simplicity	1	1	2	1	2	1	2	1	2	2	2	1	
3. Functionality (good coffee)	0	0	1	0	1	0	0	0	0	0	1	0	
4. Maintenance	1	1	2	1	2	0	0	1	1	1	1	1	
5. Dampness and heat resistance	1	0	1	0	1	0	0	1	1	1	1	0	
6. Handiness	1	1	2	2	2	1	2	1	2	2	2	2	
7. Design	1	0	2	2	2	0	1	0	1	1	1	1	
8. Ergonomics	1	1	2	1	1	1	2	1	1	1	1	1	
9. Velocity	2	0	2	1	1	0	1	1	1	1	1	1	
10. Stability	1	0	2	1	1	0	1	1	1	1	1	0	
11. Economy	1	0	1	1	1	0	1	1	1	1	1	0	
12. Eco-Compatibility	2	1	2	1	2	0	1	1	1	2	2	1	
Votes	13	6	21	12	17	4	12	0	12	14	15	8	144
Weight (%)	9%	4%	15%	8%	12%	3%	8%	0%	8%	10%	11%	5%	100%

This matrix shows that the most relative important requirements are: ***Functionality***, ***Resistance*** and ***Good Design***.

Figure-4. Interrelation matrix, 2nd use.

According to employment of the matrix of used interrelation it is that one for giving an appraisal of relative importance variable "the independent ones" once discriminated. For an analysis of the relative importance, conventional ballots are used: 1 if the line element has the same importance of the element column; 0 if the line element has greater importance of the element column; 2 if the line element has smaller importance of the element column. With this instrument, the values more elevate you of the sums for line indicate variable the more important between those "independent ones".

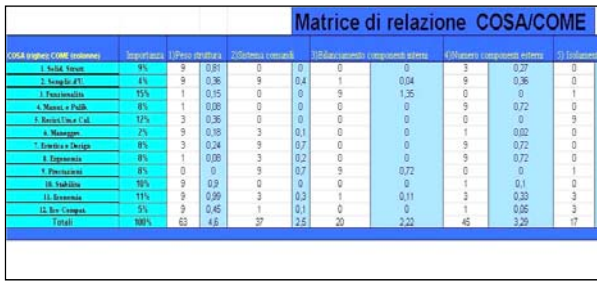

Figure-5. Matrix of relation (WHAT/HOW).

With the Matrix of Relation the needs are compared, that is the HOW (wish to you), with the parameters characterize to you from the planner, that is LIKE (like satisfying the need). In the more general case, the line HOW represents requirement to satisfy while AS of column they represent the parameters or the actions to place in action in order to satisfy line requirement. They give you of line can be gained, as an example, from the concepts it summarizes and places to you in order of importance from the interrelation diagrams.

As before specific it can be already asserted that the machine must have:

a) to low weight [17, 18]
b) good shape and colors adapt to you
c) boiler not cumbersome, but fast = > coil boiler
d) good materials, compatible with the alimony.

Basis on the quality requirements derived from the analysis through QFD, we can summarize the results in Figure-6:

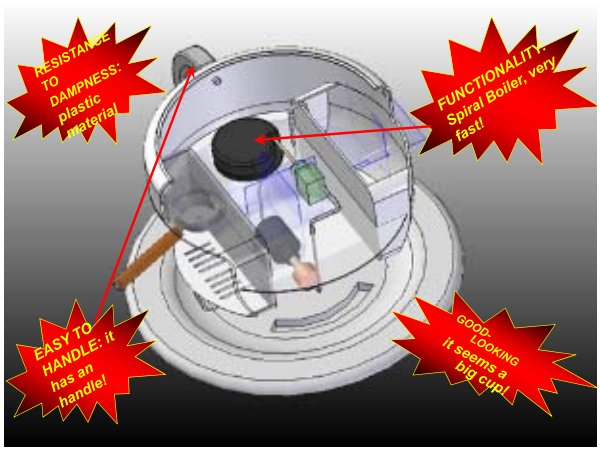

Figure-6. Coffee machine designed from functionality.

The final pictures

The work is going to be completed through the definition of the manufacturing 2D drawings and the following 3D:

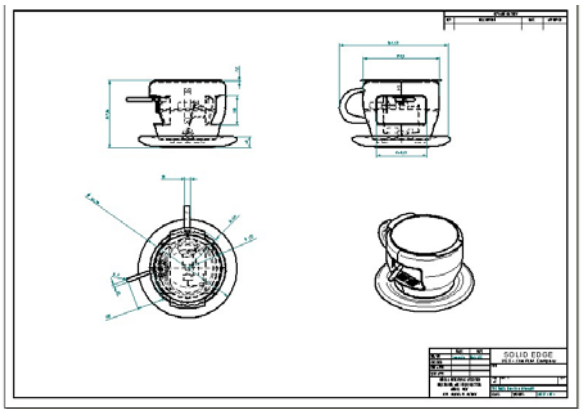

Figure-7, 8. 2D and 3D drawings of coffee machine.

Figure-9. Rendering of coffee machine.

CONCLUSIONS

We found that QFD methodology shows how it is important structuring information to design, VA how the costs are important to design and DfA how production influences design.

Through an ordered information flow, we can arrive at the final product faster and following the right requirements of clients.

This is a methodology to reach quality during the design process, not later.

Quality is a feature to design, not a process to apply at the finite product.

REFERENCES

[1] L. Piancastelli, L. Frizziero, N.E. Daidzic and I. Rocchi. 2013. Analysis of automotive diesel conversions with KERS for future aerospace applications. International Journal of Heat and Technology. ISSN 0392-8764. 31(1): 143-154.

[2] L. Piancastelli, L. Frizziero and I. Rocchi. 2012. An innovative method to speed up the finite element analysis of critical engine components. International Journal of Heat and Technology. ISSN 0392-8764. 30(2): 127-132.

[3] L. Piancastelli, L. Frizziero and I. Rocchi. 2012. Feasible optimum design of a turbocompound Diesel Brayton cycle for diesel-turbo-fan aircraft propulsion. International Journal of Heat and Technology, ISSN 0392-8764. 30(2): 121-126.

[4] Freddi A. 2002. Imparare a progettare, Pitagora, Bologna [in Italian].

[5] Shingley J.E., Mische C.E. and Budynas R.G. 2005. Progetto e costruzione di machine. McGraw-Hill, MILANO.

[6] http://homepages.cae.wisc.edu/~me349/lecture_notes/detailed_dfa.pdf.

[7] Antony R.N., Hawkins D.F., Macri D.M. and Merchant K.A. 2001. Sistemi di Controllo, analisi economiche per le decisioni aziendali. McGraw-Hill, MILANO, [in Italian].

[8] ASQ-https://asq.org/learn-about-quality/qfd-quality-function-deployment/overview/overview.html.

[9] L. Piancastelli, L. Frizziero, E. Morganti and A. Canaparo. 2012. Fuzzy control system for aircraft diesel engines edizioni ETS. International Journal of Heat and Technology. ISSN 0392-8764. 30(1): 131-135.

[10] L. Piancastelli, L. Frizziero and E. Pezzuti. 2014. Aircraft diesel engines controlled by fuzzy logic. Asian Research Publishing Network (ARPN). Journal of Engineering and Applied Sciences. ISSN 1819-6608. 9(1): 30-34, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[11] http://en.wikipedia.org/wiki/Value_engineering.

[12] http://en.wikipedia.org/wiki/Design_for_assembly.

[13] L. Piancastelli, L. Frizziero, G. Zanuccoli, N.E. Daidzic and I. Rocchi. 2013. A comparison between CFRP and 2195-FSW for aircraft structural designs. International Journal of Heat and Technology. ISSN 0392-8764. 31(1): 17-24.

[14] L. Frizziero and I. Rocchi. 2013. New finite element analysis approach. Pushpa Publishing House, Far East Journal of Electronics and Communications. ISSN: 0973-7006. 11(2): 85-100, Allahabad, India.

[15] L. Piancastelli, L. Frizziero, E. Pezzuti, "Kers applications to aerospace diesel propulsion", Asian Research Publishing Network (ARPN), "Journal of Engineering and Applied Sciences", ISSN 1819-6608, Volume 9, Issue 5, pp. 807-818, 2014, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[16] L. Piancastelli, L. Frizziero, "How to adopt innovative design in a sportscar factory", Asian Research Publishing Network (ARPN), "Journal of Engineering and Applied Sciences", ISSN 1819-6608, Volume 9, Issue 6, pp. 859-870, 2014, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[17] L. Frizziero, F. R. Curbastro, "Innovative methodologies in mechanical design: QFD vs TRIZ to develop an innovative pressure control system", Asian Research Publishing Network (ARPN), "Journal of Engineering and Applied Sciences", ISSN 1819-6608, Volume 9, Issue 6, pp. 966-970, 2014, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[18] L. Piancastelli, L. Frizziero, G. Donnici, "A highly constrained geometric problem: The inside-outhuman-based approach for the automotive vehicles design", Asian Research Publishing Network (ARPN), "Journal of Engineering and Applied Sciences", ISSN 1819-6608, Volume 9, Issue 6, pp. 901-906, 2014, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[19] L. Piancastelli, L. Frizziero, E. Pezzuti, "Aircraft diesel engines controlled by fuzzy logic", Asian Research Publishing Network (ARPN), "Journal of Engineering and Applied Sciences", ISSN 1819-6608, Volume 9, Issue 1, pp. 30-34, 2014, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.