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APPLICATION OF QUALITY FUNCTION DEPLOYMENT

IN THE PRODUCTION OF FLEXIBLE PACKAGING MATERIAL

By

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ABSTRACT

APPLICATION OF QUALITY FUNCTION DEPLOYMENT IN THE PRODUCTION OF FLEXIBLE PACKAGING

by

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The Quality Function Deployment (Q.F.D.) model was described and the flexible packaging industry was characterized and an application of Q.F.D. in the flexible packaging industry was considered. For this application, a detailed study of the package user requirements was outlined and several documents were proposed which give a framework for the process of developing Q.F.D. in a convertor company. Several recommendations were made for the use of Q.F.D. in packaging. The advantages and the benefits of the model were outlined.

To Elbio Rubino my father and best friend.

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TABLE OF CONTENTS

LIST OF FIGURES

I. INTRODUCTION

The objective of this work is to define a method by which quality can be designed into the product. Once the concept is defined, a model will be proposed and an application in the packaging area specific to the production of flexible packages will be considered.

It is important to keep in mind that after a model is developed theoretically, the process of implementation is very costly and time-consuming. Therefore it is critical to develop models which provide a reliable degree of assurance of good results.

The first step is to consider and understand the needs of the specific industry and as a consequence to define in detail the goals, considering the company management policies. Once the objectives of quality are established, a commitment will result.

In this work the Quality Function Deployment (Q.F.D.) model will be considered. This method is a new approach to quality design and it has been shown to be very successful in all those industries in which it has been used.

One of its characteristics is its versatility; it can be adapted to many different situations. Q.F.D. has been used in very diverse fields; for example, the automotive and digital equipment fields, and the result has been very positive.

Q.F.D. as a model provides the means to analyze quality through the understanding of the product. It is a model that will break down the product into its elemental components, parts and functions, improve them and finally integrate them into the product itself. Two key features of the model are that quality will be designed into the product and customer views will play a major role in the process. These characteristics, in fact, give strength to the model.

This work will first describe the Q.F.D. model, and the Flexible Package Industry. Further it will suggest what steps need to be followed for the implementation of the model in the specific case of flexible packaging material. Finally a series of documents will be developed which will help as a guide for the organization and execution of the model.

II. LITERATURE REVIEW

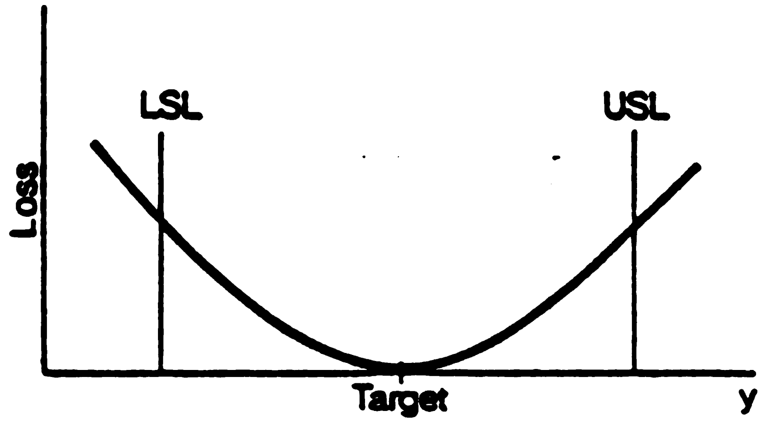
A. QUALITY DESIGN DEFINITION

Quality is a means by which a product will fulfill customer needs. There are many expectations placed on quality and most of them are not well defined. It is important to understand the quality concept to visualize its possible uses. Quality must be designed into the product and then it must be controlled during the production process. These are two aspects of quality which are different but they interrelate and one influences the other.

The main aspect which will be discussed in this work is quality design. The process of designing and implementing quality requires the cooperation of all people in the company. This type of involvement will include the President, Directors, middle managerial staff, line workers, salesmen and also affiliated companies. This approach to quality which requires the collaboration, cooperation and participation of all workers in all different departments and areas is defined as Company Wide Quality Control (C.W.Q.C.) or total quality control (Ishikawa 1985, Sullivan May 1986).

Ishikawa emphasizes how education plays an important role in dealing with quality. His approach requires that all persons involved understand what quality is and eventually apply and encourage quality control in their own area. It is important to provide quality control courses which are well defined for each area or department since "quality control begins and ends with education" (Ishikawa 1985:pp. 91). He stated that a defective product will not only be inconvenient to the consumer but also will affect the company since it will waste raw material and energy and will diminish the company's image. This waste is also a loss for society.

According to Genichi Taguchi (Byrne and Taguchi, 1987), "the quality of a product is the minimum loss imparted by the product to the society from the time the product is shipped." This loss will relate to the product that reaches the consumer. The loss includes consumer dissatisfaction, added warranty cost to the producer, and loss due to a company having a bad reputation and losing market share. Loss can even take place in products that fall within specification, because loss increases as variability takes place within the expected specified values. Taguchi developed a loss function and found that a quadratic function describes loss in several cases. The loss increases as the product deviates from the target value as shown in figure 1. To reduce the loss the product must be produced with minimal variation (Barker, 1986).



$$L = k\,(Y-T)^2$$

where:

L = loss in dollars

k = cost coefficient

Y = value of quality characteristic

T = target value

Figure 1: Taguchi's Loss Function (Byrne and Taguchi 1987: 20).

The key element for achieving high quality and low cost is parameter design. Parameter design is based on classifying the variables that influence a product's performance into two categories: design parameters and source of noise.

Design parameters are also described as controllable factors. Sources of noise could be described as uncontrollable factors; in general, these are responsible for causing a product quality characteristic to deviate from its target value. There are three types of noise:

i) inner noise: this includes variability intrinsic in the manufacturing process, for example aging of machinery.

ii) outer noise: these are external conditions, such as temperature and humidity, which influence or affect product performance.

iii) between product noise: this is associated with manufacturing imperfection.

To control these factors is very costly and sometimes very difficult, or even impossible, to do. Therefore it is important to select controllable factors which make the product process less sensitive to change. Instead of finding and eliminating causes of variation, since the causes are often noise factors, the impact of the cause should be removed or at least reduced. The goal is to improve quality by reducing impact of noise factors and thus, eventually, to reduce cost.

Parameter design is a tool to reduce noise factors and reduce cost, by recognizing controllable factors and treating them separately from each other. The key element is to discover interaction between parameters and noise factors. There is no need to completely identify the noise factor, as long as the noise factor is changed or reduced in a balanced way through different trials (Byrne and Taguchi 1987, and Kackar 1985). This approach emphasizes the significance of Quality Design. Quality Function Deployment (Q.F.D.) provides a method to apply quality design to a product.

B. QUALITY FUNCTION DEPLOYMENT

In 1972, Kobe Shipyard of Mitsubishi Industries Ltd., introduced the idea of Q.F.D. In Japanese the word deployment means extension or broadening of activities. The Q.F.D. means that the production of quality is a concern and a responsibility of all areas and persons in the corporation. Some specific cases of deployment before 1977 were described in Mizuno and Akao's book, Quality Function Deployment- An Approach to Company-Wide Quality Control, which has been used as a work guide by many Japanese companies (Kogure and Akao, 1983). The first U.S. study case was in 1986 and since then, Q.F.D. has been growing rapidly. The big three automotive companies are beginning to use Q.F.D. and other, non-automotive users such as AT&T Bell

Laboratories, Omark Industries, Digital Equipment, and Procter and Gamble, are implementing this method (Fortuna, 1988).

According to Yoji Akao (King, 1987), Q.F.D.: "In many of the cases reported, the use of Quality Deployment has cut in half the problems at the beginning stages, and shortened development time by one-half to one-third, all the while assuring users' satisfaction and increasing sales". Q.F.D. "expands" the time it takes to define the product, but the total design process is "shortened" by focusing on priorities, and it improves documentation during the process (King 1987, Sullivan 1987)

Q.F.D. is a procedure that helps to design product and services based on customer demands and requires the involvement of all members. Several charts and documents help to analyze the objective and outline the concept of concern. Q.F.D. design is a process by which quality is optimized. There is not a specific method or formula for the implementation of Q.F.D. The Q.F.D. model needs to be adapted to the specific product or service. It is also important to notice that Q.F.D. will have a different approach for different products in the same company. There are some general tools and stages that will be described later on in this work that will help in the implementation of Q.F.D. (King 1987, Kukla 1986).

C. QUALITY FUNCTION DEPLOYMENT TOOLS

To be able to deal with Q.F.D. it is important to consider tools which will help to gather and process information. These tools will be significant for the development of the product. These tools will determine and orient a path through which the problem will be considered and significant issues concerning the product design will be outlined. There is a set of "seven new tools" (King 1987, Cohen 1988, Box and Bisgaard 1987) which are:

1) Affinity Diagram
2) Tree Diagram
3) Matrix Diagram
4) Interrelationship Digraph
5) Matrix Data Analysis
6) Program Decision Process Chart
7) Arrow Diagram

These tools help to analyze data and eventually are used in building up a relationship between ideas and attributes. These tools organize and structure information in a way that can be understood and the interrelationship perceived by all the persons from different departments, or areas. For implementation of Q.F.D., these tool are very important and require some attention (King 1987, Cohen 1988). The best detailed description of the seven new tools will be found in King. The following is a brief description of these tools:

1. Affinity Diagram:

"This tool will help to build an overall hierarchical structure of ideas" (Cohen, 1988). Information such as ideas, opinions, and issues are collected and analyzed to determine certain relationships between all the different ideas. To understand its application some of the steps are as follows:

Step 1: In Q.F.D. the ideas will come from the reaction or comments of the customer. At this point what is important is to determine general ideas of the requirements and these will be the basic elements or blocks.

Step 2: The ideas collected in Step 1 are grouped trying to find some relation among them. This is just a grouping of concepts or ideas or simple suggestions.

Step 3: In the process, it is better that several persons from different areas participate (at least 6 members should be present).

Step 4: In each group of ideas from Step 2, a successive hierarchy of ideas will be formed where different levels of significance will be determined.

A practical way to implement the Affinity Diagram consists of writing each idea on a separate card. The cards are then arranged and moved to cluster those cards or ideas which seem to relate and in this way a general concept is obtained. Then these concepts are arranged in some order or rank. This information is then written down on paper defining and establishing a line of relationship within each group of ideas or concepts.

This tool is used when the problem to be solved is complex and there is some time available to deal with it. This tool is very useful when ideas are not well defined, when they are unstructured and not clear.

2. Tree Diagram:

The Tree Diagram also deals with organizing and ranking ideas. This tool uses the Affinity Diagram and tries to structure the information using a more analytical and technical approach. In other words, it will complete and analyze the Affinity Diagram and a more logical and structured information scheme will be obtained. This tool is used when the objectives of achievement need to be completely understood; it is used also when the implementation of those objectives needs to be known in relation to a specific methodology.

To be able to understand the use of this tool the following steps describe its implementation:

Step 1: Definition and description of the goal or problem, which could come from the Affinity Diagram.

Step 2: Then all the tasks, methods, causes should be generated which will relate to the main goal previously agreed upon.

Step 3: A code system will be created and the ideas developed in Step 2 will be evaluated.

Step 4: A construction of the Tree Diagram consists of mapping and relating all ideas to the central goal.

3. Matrix Diagram:

This tool will help to evaluate the correlation of ideas among each other. A set of ideas or items are placed on a horizontal axis and another different group of concepts on the vertical axis. Each interaction will define a specific relation that needs to be evaluated for the relationship between concepts.

This tool helps to visualize and relate different characteristics, tasks, and functions in a logical connection, giving a clear and graphical display of the concepts. There are different types of matrices which could be used depending on the nature of the problem to be analyzed. The most common arrays are:

L-shaped Matrix: this is the basic one where column and row are used to determine the interaction between two sets of ideas.

T-shaped Matrix: this type will combine two L-shaped matrices. This matrix system will analyze two sets of ideas versus a third set.

Y-shaped Matrix: this type of matrix also helps to analyze or compare three sets of ideas or items among each other.

X-shaped Matrix: this is not very commonly used. It will analyze the interaction of four sets of items.

C-shaped Matrix: it is possible with this matrix to visually represent the interrelation of three sets of items by connecting the three sets among each other at one common point.

The implementation of this tool will be carried out according to the following steps:

Step 1: The definition of the different sets of ideas that need to be considered.

Step 2: Once the ideas are defined the proper matrix type should be selected.

Step 3: The drawing of the matrix and the determination of the relationships.

Step 4: A set of symbols needs to be considered which will identify the degree of the relation among the different sets of items that are being studied.

4. Interrelationship Digraph:

This tool will relate or link a central problem with ideas or items and provide a visual means to accomplish the solution to the obstacle under consideration. Once a problem is defined, the ideas need to be organized, and the Interrelationship Digraph will provide a very creative pattern to solve the problem. An idea begins in a central concept which will generate other ideas, from which eventually a final outline in a specific pattern will result. This tool will allow study of multivariable problems and the different factor relationships.

5. Matrix Data Analysis:

This tool will use the information from the Matrix Diagram and rearrange it in a way which could identify and show the weight of the different variables.

<u>6. Process Decision Program Chart (PDPC):</u>

Bob King defined PDPC as a tool which "maps out every conceivable event and contingency that can occur when moving from a problem statement to possible solutions. This tool is used to plan each possible chain of events that need to occur when the problem or goal is an unfamiliar one."
This tool was developed for use when the environment is unknown or imperfect. Under such conditions, evaluation must precede implementation. In 1950, Dr. Deming suggested the diagram during a meeting at the Japanese Union of Scientists and Engineers, J.U.S.E. (King, 1987):

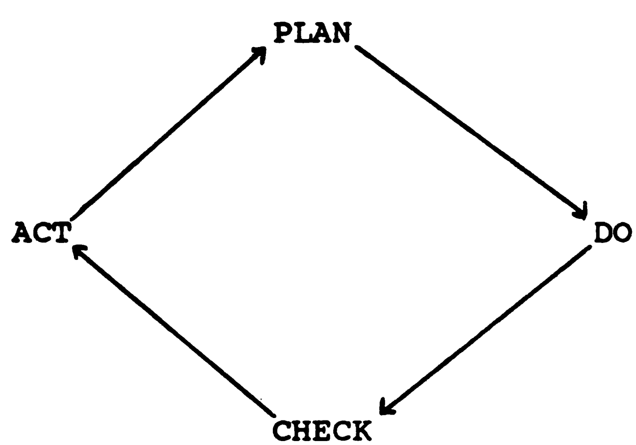


Figure 2: Deming Cycle or Shewart Cycle

(King 1988: Appendix A-2)

"We <u>Plan</u> what we want to accomplish over a period of time and what we are going to do to get there.

We <u>Do</u> something that furthers the goals and strategies developed in number 1.

We <u>Check</u> the results of our actions to make sure that there is a close fit between what we hoped to accomplish and what was actually achieved.

We <u>Act</u> by making the changes that are needed in order to more closely achieve the initial goals or develop procedures to assure continuance of those plans that were successful." (King 1988 Appendix A-2)

There are a few steps which could help the implementation of this tool:

Step 1: A detailed study of the total Tree Diagram must be done.

Step 2: Each branch of the Tree Diagram must be questioned for possible problems that could take place.

Step 3: Enumerate possible actions to be taken throughout the branch of the Tree Diagram and connect them.

Step 4: The whole system should be considered with the inclusion made, with old and new paths.

This study should be made only in those branches in which modification will be made.

7 Arrow Diagram:

This tool helps to organize the task in a proper schedule and helps to control the process. It is used when the objective or task is known and the duration of each step is familiar.

The implementation consists of:

Step 1: All the steps of the project are known and their durations are also known. Those steps are listed.

Step 2: Each stage is considered and the relation between each one is defined and the path is established.

Step 3: After the path is outlined, the nodes are identified which are the beginning and the end of a task.

Step 4: The duration of each task is considered.

Step 5: By considering Steps 3 and 4, the beginning and ending time of each node is established.

Step 6: The critical paths are individualized.

Step 7: Finally the beginning and the end of the project is determined.

This tool is closely related to the Pert Diagram method.

D. QUALITY FUNCTION DEPLOYMENT DESCRIPTION

Q.F.D. provides a series of documents that can be used as a guide for the work and also a way to record all information in a meaningful way. The Q.F.D. will focus on the product or service as the main objective of the project and supply the means by which all different areas such as Research and Development, Marketing, Finance, Production etc., interact in a smooth and effective way. Q.F.D. coordinates the efforts of all persons involved in the project .

There is not a standard procedure by which Q.F.D. should be implemented but there are four phases described by B. King which will help to outline the procedure:

1) The organizing phase: In this phase the product or service that is going to be improved is identified, as well as the persons and departments that are going to participate in the project.

2) The descriptive phase: The product or the service is viewed from different perspectives. In this phase the following items will be considered:
   i) Customer Demand
   ii) Substitute Quality Characteristics: these are the elements that the producer will control in order to

fulfill the customer demands.

iii) Functions: what the product does or the product's action.

iv) Mechanism: this is the first level of detail or subgroup in the Q.F.D. outline.

v) Components: second level of detail in the Q.F.D. study.

vi) New concept: new ideas about the product or the components of such a product or service.

vii) Product Failure Mode: study the product or service to determine how and why it fails.

viii) Component Failure Mode: consider the failure of components of the product as in vii.

3) The break-through phase: This phase is the elaboration stage where the different items mentioned in the descriptive phase are combined in a matrix and the interrelations are evaluated. Several matrices will be produced depending on the objectives which were set.

4) The implementation phase: The design process is different for each product or service depending on the company structure and on the product or service considered. With this in mind it is possible to define certain steps to be followed:

i) Product Planning: this requires identification of the product, the need for improvement, and the company policy with respect to the specific product improvement. Inputs are necessary from several departments such as marketing, sales, engineering, research and development, production and quality control. The competitors' products will be studied as well. The information is analyzed, usually under matrix data analysis. The results of this study will show how the product is perceived by the customer, how it stands versus its competitors, and what type of improvement will be necessary.

ii) Individual Product Planning: various aspects of the product will be compared among each other by using the Matrix analysis and specific items of improvement will be identified. This system allows a view of the product from different dimensions. At the end of this study a complete set of improvements that need to be included in the product will be identified.

iii) Product Design: at this point of the implementation there are three stages. The first stage is the product development, which includes the development of both the product and the manufacturing process; the second stage is the Prototype; and finally the third stage is the Testing and Evaluation.

E. AN APPROACH TO QUALITY FUNCTION DEPLOYMENT

It is important to have a complete commitment of all persons in the company to the implementation of Q.F.D. It also requires specific training in the use of the tools and in the understanding of the Q.F.D. concept. It is important to emphasize that Q.F.D. is not only a method but also a philosophy. The company that decides to use Q.F.D. must provide for some time for training and the assimilation of the new concept and ideas.

The "House of Quality" diagram is one approach to construct Q.F.D. The House of Quality is "a kind of conceptual map that provides the means for interfunctional planning and communication" (Hauser and Clauseing 1988; Kenny, Khan and Mayer 1988). It is a specialized matrix that enhance the preparation of the Q.F.D. analysis. The House of Quality as Hauser and Clauseing described it will allow all people from different departments and having different responsibilities to interact in pursuit of a common goal. It is an excellent example of use of the matrix approach and it can serve as a guide to design other matrices.

The outline of the House of Quality which follows will help to understand this Q.F.D. approach. Referring to Figure 3 the House of Quality consists of:

1) Collecting the word of the customer. The information will be analyzed by using the Affinity or the Tree Diagram. From this a list of the customer demands will be clearly identified.

2) Filling in the Planning Matrix (see figure 3) will be as follows:

i) on the left side of the central matrix the Customer Needs will be listed.

ii) on the right side of the central matrix the Planning Matrix will be outlined. This matrix will determine the importance of the customer needs and a value will be assigned which will represent its significance. This matrix will include information concerning an evaluation of the competitors' product. Also it will consider how the product is doing presently with respect to each customer requirement. A "sales point" will reflect how significant or powerful is the requirement for sales purposes, so a value will be assigned. A "ratio of improvement" will be evaluated; this is how the product needs to improve with respect to each requirement. After all the information and values are obtained, a final value will be obtained by which the raw weight of each requirement will be obtained by combining all the information outlined in this matrix.

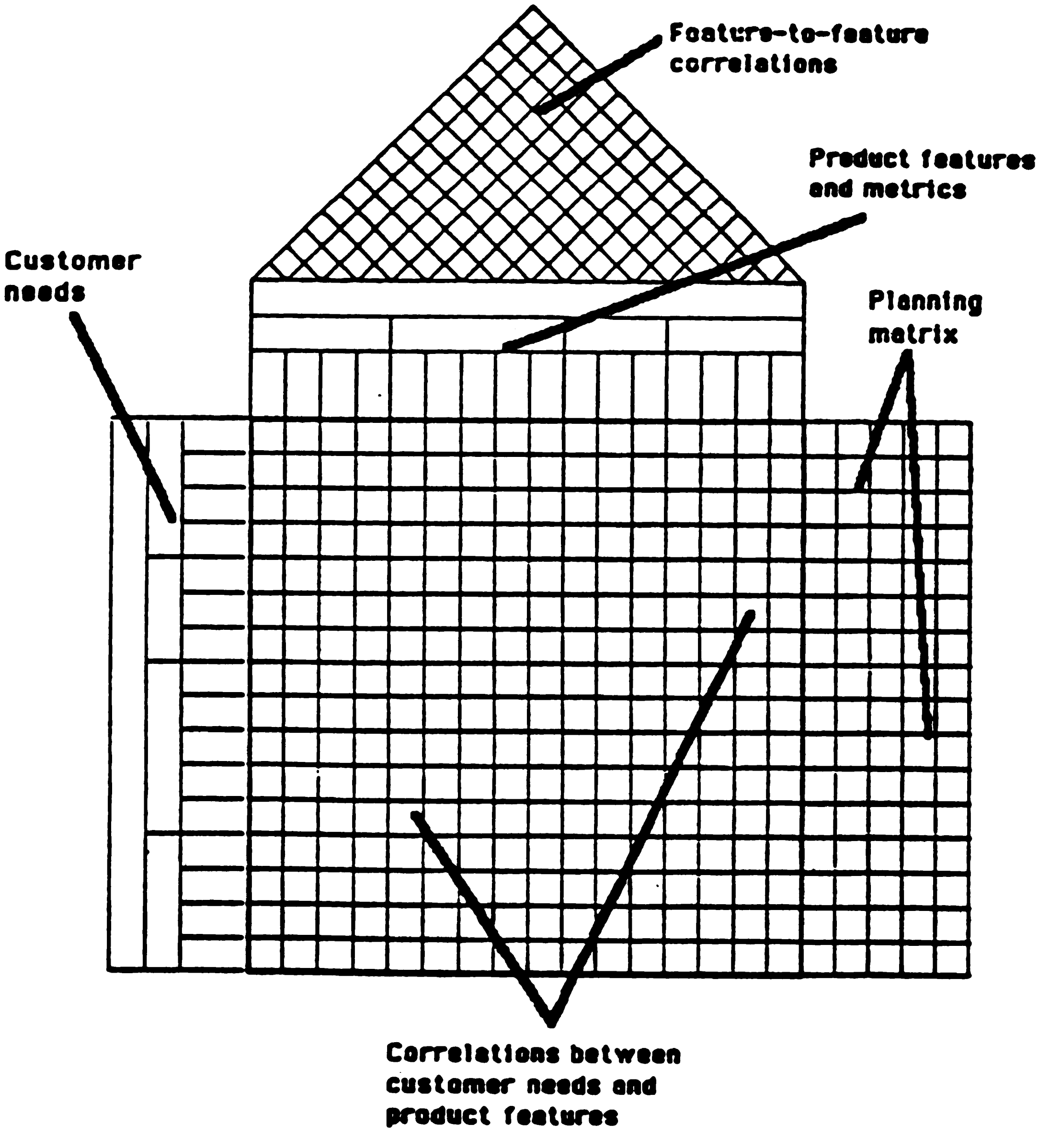


Figure 3: "House of Quality" (Hauser and Clausing, May-June 1988:202)

iii) At the top of the House of Quality the Product Feature Matrix is developed. This information comes from the study of the product itself, its function and parts, all features that constitute the product. This information can be developed by the use of the Affinity and the Tree Diagram tools.

iv) The roof of the House of Quality consists of the Feature to Feature Correlation. This matrix describes the correlations of the parts or functions to each other. A set of symbols will be developed to determine the interaction. The information obtained from this part of the House will determine what type of feature or function needs attention from the different development groups. In other words it will establish the need for communication among the different development groups.

v) The Correlation Between Customer Needs and Product Features. First the interaction between the feature or the function and the specific customer interaction will be identified. Such interaction will be considered, and the correlation will be defined. A set of symbols will be developed by which a possible, moderate, strong or no correlation will be determined. A value will be assigned to each correlation symbol. Then the raw weight of each customer requirement obtained in the Planning Matrix is multiplied by the correlation value found in the Correlation between Customer Need and Product Feature Matrix. This procedure will determine the influence of each feature or function in meeting each specific customer demand. Then all the cell values of each column are added. At the bottom of the House the number obtained ranks the importance of each feature in meeting customer needs by raw weight.

The "House of Quality" was used as the basis for designs of the matrix that form the analytical tools for the application to packaging. Even though the House of Quality will not appear in precisely the form shown above, the study of the House of Quality and its conceptual basis led to the method and documents that were used.

F. SIGNIFICANCE OF QUALITY FUNCTION DEPLOYMENT

The implementation of Q.F.D. in a company requires a lot of effort in the planning procedure at the beginning of the project but eventually the results of this effort will have many advantages in terms of product quality and cost saving. Q.F.D. requires some coordination procedure and training for implementation.

The results of the application of Q.F.D. in the automotive industry have been very significant. For example, Q.F.D. was used by Toyota. From January 1977 until April 1984, Toyota introduced four new vehicles. In 1977 Toyota began to use Q.F.D. It required four years of training and preparation. The consequence of the use is shown in figure 4 . "Toyota reported a 20% reduction in start-up costs on the launch of a new van in October 1979; a 38% reduction at November 1982; and a cumulative 61% reduction at April 1984. During this period, the product development cycle (time to the market) was reduced by one third with a corresponding improvement in quality because of a reduction in the number of engineering changes." (L.P. Sullivan, June 1986:50).

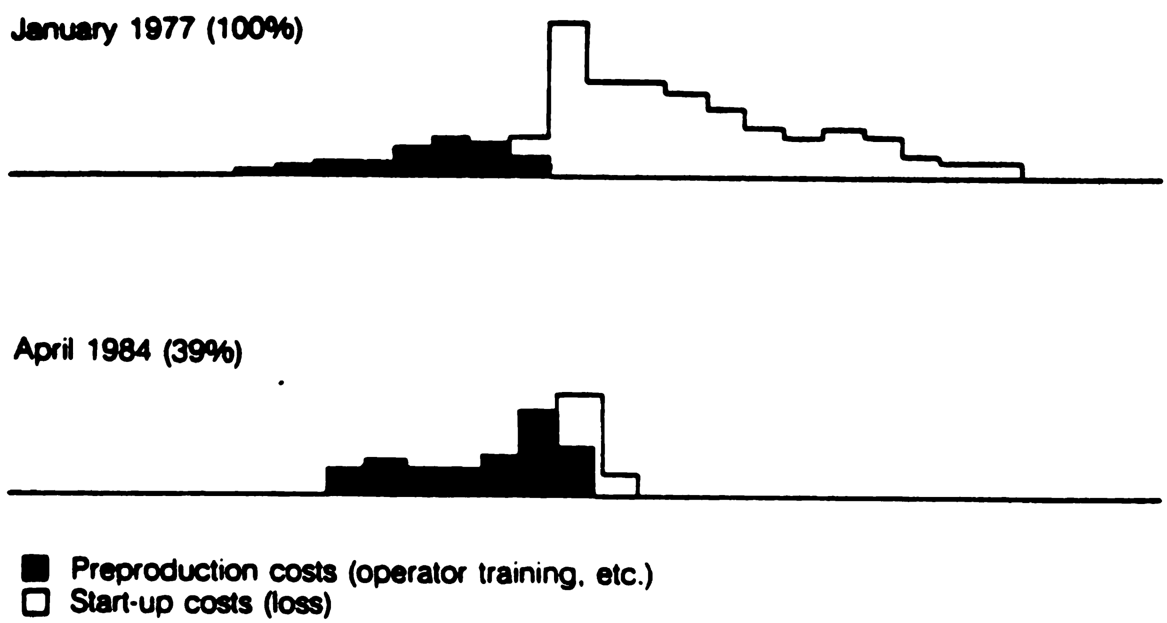


Figure 4: Start-up cost and preproduction costs of Toyota autobody before and after Q.F.D. (Sullivan, June 1986: 50)

Quality Function Deployment has been mainly applied and studied in the automotive industry, and now the idea is beginning to spread to other industries.
This work will try to use the principles already outlined for the application of Q.F.D. in the packaging area. Since this method has been proven to be very successful in all the fields to which it has been applied up to now, it seems likely that the adaptation of this method to packaging will provide significant benefits.

III. APPLICATION OF Q.F.D. IN A CONVERTOR COMPANY

A. Q.F.D. IN PACKAGING

For the application of Q.F.D. in packaging, a flexible package will be considered; specifically a laminated flexible package. Even though only one type of packaging industry is under consideration, this work is an attempt to extend the use of Q.F.D. into the whole area of packaging.

In the use of Q.F.D., it is important to understand and carefully analyze all aspects of the system and the nature of the company. It is also very important to define the product or service where the Q.F.D. is going to be applied. The information concerning the market and the strategy of the company toward the product or service, needs to be known. Therefore, a description of the type of industry, the inter-dependence between the convertor and his customer, the type of production, and the significance of quality will be discussed for the flexible packaging industry, since all these aspects will significantly contribute to the Q.F.D. model.

B. DESCRIPTION OF FLEXIBLE PACKAGING INDUSTRY

This industry is very dynamic. A convertor usually receives raw material such as film or resins (like pellets) from a supplier and converts these into laminate or film which will also be printed. This packaging material will be used by a user such as a food or pharmaceutical company to pack their respective products, and a consumer will finally use the total of product and package. The package material in this example will be used in the user's company in Form-Fill-Seal (F.F.S.) machinery. To understand the process, the following diagram shows the sequence proposed:

SUPPLIER	Provides resins, inks, adhesive, foil, solvents.
↓	
CONVERTOR	Extrudes film, laminates, prints, coats.
↓	
USER	Packages product on form fill seal machines.
↓	
CONSUMER	Public. Depends on user, convertor and supplier to provide a fresh, wholesome product, properly identified at an acceptable price.

Figure 5: Diagram of the flow of packaging material from supplier to consumer.

The convertor could produce a single layer or multilayer laminate structure. The convertor will have to deal with different types of packaging material depending on the product which will be packed and also on the user's facilities. The convertor needs to adapt all these factors, so the production is not constant; it will vary with the nature of the packaging material which is required for the specific use.

The manufacturing process in a flexible packaging company is very complex, because many steps must be done when a printed flexible package material is produced. All the steps are done in sequence and a very important interrelation exists among all of them. Because the machinery is becoming very highly automated, a proper adjustment of any step in the process requires several trials, which means time and raw material are expended. These represent high cost for the convertor and eventually for the user. The setting of the equipment depends greatly on the quality of the raw material, the skill of the technical persons and operators, and also the proper planning of the product and the production process. An interruption in the production process because of defects or variation from target specification implies high cost and material waste. Therefore, for efficient production, a convertor must consider constant training of their personnel and careful and detailed product development. These two aspects will interrelate, one affecting the other, and as a consequence, Q.F.D. could play an important role in organizing and designing the product, process and services at the convertor.

There are three key issues which need some attention for understanding the convertor framework:

1) User's requirements
2) Understanding and processing of information from supplier and user
3) How the user and supplier will constrain and influence the convertor production process

1. User's Requirements

The user under consideration is another company which has specific requirements from the consumer. The user's requirements have in this case more than one source. These sources include consumer expectation, package material performance at the user's facilities, package and product interaction, product characteristics and cost.

When considering the consumer's expectation, the user needs to find out what the consumer wants from the package, such as an easy-opening or reclosing. While the user can recognize the specific needs or requirements of the consumer, it is the user and the convertor together who must find the proper solutions to those consumer expectations. When considering good machine performance such as good sealing or cutting process, the packaging material need to adapt to the user's machinery for an efficient production process. (Evenson, 1987)

The product such as food or drug that will be packed must be carefully studied. The product will dictate requirements the package needs to fulfill such as moisture or aroma barrier, in order to maintain the product's quality for a specific period (Evenson 1987).

Cost plays an important role in packaging requirements. This aspect will also determine what type of package could be available, to fulfill the user's marketing and sales strategy.

2. Understanding and processing information from supplier as it affects user's requirements

The information from the user must be carefully studied, but also the convertor needs have information from the raw material supplier which will also help to fulfill users' requirements. The convertor needs to know the composition of available raw materials and their conformance to specification. This information is critical and needs to be completely understood and available in an accessible format. All this information needs to be integrated into the packaging material design, since the convertor must adapt to the user's expectation. The information must be detailed and available to the convertor. A constant study of the manufacturing process should be maintained.

A system which could absorb new inputs coming from the above mentioned studies, should be structured so that the convertor can constantly and efficiently adapt to user needs and expectations.

3. How the user and supplier will constrain and influence the convertor

The convertor will produce package materials for different users and also for different types of products to be packed, such as food and drugs. These two classes of products have different requirements for shelf life, for example. Each package material will have different characteristics and will also have a specific production process. There are many parameters of the package material which will vary depending on the user requirements and also on the nature of the product to be packed. These involve for example, material composition which can be laminated structure or single film structure. A lamination can consist of plastic, aluminum foil, or paper in varying combinations. The laminating process will change depending on the materials considered. The printing process will also depend on the design required and the materials to be printed. The inks to be used will depend on the printing process used and also on the material which will be applied. These few considerations are some from a long list of things that the convertor must take into account for each package material. The variables are critical to the finished package material performance, and each package material will have its own specification list.

The convertor needs to be versatile and able to adapt to the user requirements quickly and efficiently. The convertor must be aware of the supplier resources since these will dictate in many ways what type of package materials are available. The convertor must work closely with the supplier to develop materials that fulfill the user needs and expectations. Therefore the convertor must be aware of and understand the supplier's technology and together they will obtain suitable materials.

All these aspects show how dynamic is the flexible packaging industry. There is an extensive load of information that needs to be properly processed. Therefore a system should exist that could absorb all information and provide an efficient outcome in the package material development process. It is not enough just to have the information available; it is also important to be able to use it efficiently.

Even if the flexible package is produced to specification, if the package material is not well designed it could have negative consequences for the user and for the consumer because the specification is wrong. Sometimes a bad design is not detected immediately. For example if a package material lacks barrier properties so that it fails to maintain the product's freshness for the preestablished time, then the product could spoil before it arrives at the consumer. However, this would not be detected until long after production of the package material. This could be very dangerous for consumer safety and also for the user's image. Another type of problem occurs when the package material produced according to specification will not perform well at the user facilities. This will cause delay in the production and also package material waste. Again, a bad design is not detected until long after the material has been produced.

These are two examples of consequences of a poor package material design which will result in loss for the convertor, the user and eventually the consumer. A proper design is critical in obtaining a package material that meets all requirements. The convertor, the supplier, and the user need to participate in the development of the package material design. Therefore a methodology should be considered that processes the information from all the different areas and industries involved. The Q.F.D. method provides this approach to quality design. Through Q.F.D. quality can be designed into the product and the packaging material production will be done under specific and well-designed specification, with pre-established variations of acceptable size. Information will be prioritized and focused on specific items and product development will account for the user and consumer requirements. The package material and the production process will be optimized by improving quality and cost through the participation and collaboration of all companies and areas involved in the quality design. This follows the main principle of Company Wide Quality Control (C.W.Q.C.), and Q.F.D. is a consequence of this principle.

C. APPLICATION OF Q.F.D. TO THE FLEXIBLE PACKAGING INDUSTRY

The application of Q.F.D. implies that all persons at the convertor, the supplier and the user are aware of the Q.F.D.

concept and philosophy. This requires that each person in each area be familiar with and completely understand and participate in the development of the Q.F.D. method. At this point top management must define and promote this idea and they should motivate and encourage all people at different levels to collaborate and participate in this approach. This attitude is the key element in the implementation of Q.F.D.

1. Convertor processes information from the user

To obtain information from the user and eventually process such information, several meetings between the convertor and user must take place. The convertor needs to learn and understand about the product which will be packed and also about the user facilities and machinery.

This information should be gathered from various sources, including:

1) The user Marketing department, which will provide information about consumer expectation concerning the finished product; this will include printing design, package function, cost, distribution system and distribution time.

2) User Research and Development department, which will give information about the product's chemical and physical constitution and possible vulnerability.

3) User's Production department, will give information about packaging machinery and company facilities. This information is very important since good package material performance at the user's facilities will depend very much on the material's chemical characteristics and on the converting process. Hence, to be able to account for the packaging material performance in the quality design, the convertor must understand the user's F.F.S. machinery.

For this flow of information from the user to the convertor and vice-versa, it is necessary to generate a good understanding and a sense of trust between the user and the convertor. Since much of the information is very confidential, trust and collaboration are key issues in the convertor and user relationship.

The meetings between user and convertor should be held in a structured way. For these meetings to be efficient, information should be obtained and documents elaborated for the outline of all relevant and significant facts prior to each meeting. The Q.F.D. provides the tools for the processing of information such as the Affinity Diagram or the Tree Diagram method. The Q.F.D. matrix to be used will provide the means for considering all possible and important outcomes, and will define the dynamics of the projects.

Several meetings will take place throughout the development of the Q.F.D. projects. The meetings should have a maximum of 6 to 8 persons attending. The persons that will comprise the different working groups at the various stages of the project will be from both the convertor and the user companies. The constitution of the working group will depend on which type of information is needed to accomplish the specific Q.F.D. task. The persons that usually will be involved in any committee, will be personnel from among the following departments depending on specific committee and task:

1) Convertor: Production
   Research and Development
   Engineering
   Purchasing
   Quality Control

2) User: Marketing
   Production
   Quality Control
   Research and Development
   Engineering

Also a person from the convertor will monitor and coordinate all the meetings and guide the discussions. This person must have an extensive knowledge about the Q.F.D. dynamics and must be familiar with all the Q.F.D. tools.

The convertor finance department should advise the project committee about cost considerations whenever needed, but regular membership in the working group is not necessary

<u>2. Convertor processes information from the supplier</u>

The supplier of raw material, also plays a key role in the quality design of packaging material. The supplier possesses information about raw material, such as resins, film adhesives, inks, etc., which will be very important for the generation of the quality design. The supplier's knowledge of the chemical composition, characteristics, and physical properties of the different components of the packaging material will be very valuable information which the convertor needs to be aware of and process during the product development.

The information should be gathered and processed by the supplier and the convertor together. The convertor should let the supplier know the requirements and together they develop the quality for each raw material. Since the convertor requirements will be a function of the user needs, this procedure must be coordinated by the convertor.

Referring specifically to the relation between the convertor and the supplier, the information should be gathered through several meetings where individuals from the convertor and supplier companies are present. The following persons must participate in order to gather the information:

1) from the convertor:
   * Research and development department will let the supplier know about the convertor's technical needs.
   * Production department
   * Engineering department, will give to the supplier the information concerning convertor's facilities
   * Quality Control department will design a proper system of quality control in consultation with all affected departments

2) from the supplier:
   * Research and Development department
   * Production department
   * Quality Control department

The convertor's Purchasing department should receive and acknowledge all the information processed. Also the Finance department from both companies should advise on the cost aspect.

D. SPECIFIC APPLICATION OF Q.F.D. TO A FLEXIBLE PACKAGING MATERIAL

Even though Q.F.D. should be developed by the convertor together with both the user and the supplier, only the convertor and the user analysis will be considered in this study.

In this application of the Q.F.D., a procedure will be designed as follows:

i) identification of user's requirements

ii) several documents will be produced where all relevant data will be considered.

iii) the documents will be used to outline the implementation of the Q.F.D. method.

The elaboration of each document will serve as a guide for the application of Q.F.D. to the package material. The objective will be to translate the voice of the user into specific quality characteristics that the finished product must meet, and eventually to reduce costs.

To illustrate the Q.F.D. approach, a package material for a chocolate candy bar will be used. The package material will be a laminated structure of two layers, a printed aluminum foil and a polymer plastic, which will be produced in rolls by the convertor and which the user will operate in F.F.S. machines.

To develop the Q.F.D. model for application in the production of flexible packaging material, the "seven new tools" (Literature Review page 9) and the concepts used in the "House of Quality" (Literature Review p. 21) and the concepts developed in the work of "Quality Function Deployment" (Sullivan, June 1986), will be applied.

1. Accounting for user's requirements

The design of the package will cover three main aspects:

* Product and package interaction
* Package appearance
* Package material performance at user's facilities

A list of questions is developed for each point which will help in the analysis of the demands and further in the discussion of relevant information (Barrash 1987, Anthony 1988).

For product and package interaction, the questions suggested for studying this area are:

* What kind of product is going to be packed?
* What are the main product components which will be critical in the product composition?

* What is the expected distribution time until the product arrives at the consumer?
* What are the environmental conditions, such as relative humidity and temperature,to which the product will be exposed during distribution?
* What type of distribution system is going to be used?

For the appearance of the package, the following questions will help in the definition of the user requirements:

* What type of design or graphics and how many colors will the printed package have?
* How elaborate is the design, and what degree of print definition is required in order to display the message ?

For good performance of the package material in the user's packaging process, it is important to understand the user's machinery. The following questions propose an approach for considering this aspect:

* What type of F.F.S. machine is going to be used to package the product?
* What type of sealing method will the F.F.S. employ?
* What type of storage conditions does the user have for storing the package material before it is used?
* How long approximately is the packaging material stored at the user facilities before being used?

These sets of questions will help to provide a means to understand and define the user's needs. This information is one of the most critical parts of the analysis because this will be the basis for developing the Q.F.D. This information will be analyzed by using the Affinity Diagram and the Tree Diagram method (Literature Review p.10-12) . The questions suggested are exemplary. A full application of Q.F.D. would generate many more questions in each category.

A set of eight documents will be described. The first document will serve to identify the user's requirements for the candy bar package material. These requirements will be deployed and correlated to quality characteristics and component properties through the following six documents. The eighth document will identify a quality control plan for critical material component properties.

Document 1, User Requirements, will be generated in a table form (shown in figure 6, page 46). The first column will contain the primary level of requirements which are very general. The second will be filled with the secondary level of requirements which will be more specific. Finally the last column will be filled with the tertiary level of requirements, which is an even more specific list of demands on which all the study will be based.

level 1	level 2	level3
compatibility of food product	mantain flavor	no loss of aroma or flavor
		no change in flavor or aroma
	keep food product fresh	no oxidation
		no moisture loss or gain
		no change in food product composition
material performance	machine performance	material does not tear at F.F.S. machine
		material does not deform at F.F.S. machine
		good sealing
		material run fast and well at F.F.S. machine
	lamination	no solvent smell
		no delamination
appearence	printing	colors don't fade
		good precision
		good color

Figure 6: Document 1, User Requirements

Once the list of requirements is obtained, the next step is to evaluate each of them. The evaluation must be done by the participation of the user together with the convertor. This evaluation will generate Document 2, Rating of User Requirements, (shown in figure 7, page 49). This document will process the following information:

* How important is each requirement for the user, or how critical is each requirement in terms of the finished product?
* How is each user's requirement fulfilled by at least two packaging materials produced by the convertor's competitors?
* What is the user expectation for each requirement?

By answering these questions, the requirements will not only be identified but also they will be weighted in terms of their significance with respect to the product, user and eventually consumer expectation.

To complete Document 2 the following information needs to be gathered:

Step 1:The Level 3 requirements from Document 1 are entered in column 1 of Document 2.

Step 2:A numerical scale is chosen, for example 1 to 5.

The user will evaluate each requirement from Document 1 using such a scale, and in this way a rating of importance for each requirement will be established. The requirement that is very significant for the user will be rated with a 5, and the least important will be rated with 1. The rating is entered in column 2, as "requirement importance" for each requirement.

Step 3: In this Step, the convertor must evaluate it's own packaging product and the competitors material. The convertor's technical and marketing people will be involved in this work. Specific tests will be run on the convertor's own and competitors' packaging material under the same conditions. Then a final evaluation will result which will determine how each package material from each source performs. A scale of 1 to 5 will be used. A material with a very good performance for a specific requirement will rank 5 and those with poor performance will rank 1. These entries will be made in columns 3 "convertor today", 4 "competitor 1" and 5 "competitor 2" respectively.

Step 4: After step 2 and 3 are completed, the user and the convertor need to determine which requirements need

1 list of user's requirements from Document 1	2 requirement importance	3 convertor today	4 competitor 1	5 competitor 2	6 objectives	7 sales importance	8 degree of change	9 degree of priority	10 relative priority
no loss of aroma or flavor									
no change of aroma or flavor									
no oxidation									
no moisture loss or gain									
no change in food product composition									
material does not tear at F.F.S. machine									
material does not deform at F.F.S. machine									
good sealing									
material run fast and well at F.F.S. machine									
no solvent smell									
no delamination									
colors don't fade									
good precision									
good color									

Figure 7: Document 2, Rating of User's Requirements

to be improved. This improvement will be a function of the requirement importance and how well the company is fulfilling the requirement. A scale of 1 to 5 will be used. Those requirements for which performance needs to be improved will be assigned a 5; those requirements that do not need change will be rated as 1. The entries will be placed in column 6, headed "objectives".

Step 5: The convertor and the user will consider which requirements are critical in defining saleability. For example, the package appearance will make the package very attractive and will make the finished product more saleable. This time a scale of 1 to 3 will be used which will describe the following situation:

3 high contributor to saleability

2 moderate contributor to saleability

1 does not contribute to saleability

These values will be entered in column 7, headed "sales importance".

Step 6: The "degree of change" column 8 is completed. This value will result by dividing the value of "objective" (column 6) by "convertor today" (column 3). This will establish a ratio for change. This ratio will be used for calculation in step 7.

Step 7: The "degree of priority" column 9. This value will be obtained by the multiplication of "requirement importance" (column 2) by the "degree of change" (column 8) by the "sales importance" (column 7). In this way the degree of priority for each requirement will be determined.

Step 8: In column 10 "relative priority" is considered. This value will represent how much each requirement is weighted with respect to the others. The value will result from adding all numbers in column 9 and then calculating the percentage for each requirement, with respect to the sum of priority values in column 9.

2. Correlation between quality characteristics and user's requirements

Quality characteristics are measurable items that the convertor will control in order to meet user's demands. The quality characteristics need to be identified and further need to be correlated to a specific user's demands. It is important not only to determine the possibility of correlation but also the degree of correlation between a specific quality characteristic and the user requirement.

Document 3, Correlation of User Requirements with Material Quality Characteristic, will show these correlation. The example of the candy bar packaging material would generate a document like the one shown in figure 8, page 53. This document will be a matrix where the quality characteristics will be established along the top horizontal axis and the user requirements from Document 1 and 2 will be set along the vertical axis. The matrix is a series of cells which will be filled with symbols which define the degree of correlation.

For the elaboration of Document 3 there are 6 steps :

Step 1:All the quality characteristics that the convertor must evaluate will be listed. These quality characteristics must be able to be measured. For the candy bar packaging material, the following quality characteristics can be listed:

* packaging material permeability to moisture
* packaging material permeability to oxygen
* percentage crystalinity
* polymer molecular weight distribution
* polymer molecular weight

list of user's requirements from Document 1	relative priority from document 2	Quality characteristics: permeability to H_2O	permeability to O_2	crystallinity %	polymer M.W.D.	polymer M.W.	solvent retention	tensile strength	elongation	tear strength	lamination strength	corona treatment	roll size	ink dryness	TOTAL ABSOLUTE WEIGHT
no loss of aroma or flavor															
no change of aroma or flavor															
no oxidation															
no moisture loss or gain															
no change in food product composition															
material does not tear at F.F.S. machine															
material does not deform at F.F.S. machine															
good sealing															
material run fast and well at F.F.S. machine															
no solvent smell															
no delamination															
colors don't fade															
good precision															
good color															
ABSOLUTE WEIGHT OF QUALITY CHARACTERISTIC															
RELATIVE WEIGHT OF QUALITY CHARACTERISTIC															

Figure 8: Document 3, Correlation of User Requirement with Material Quality Characteristics

* solvent retention
* tensile strength
* elongation
* tear strength
* lamination strength
* corona treatment
* roll size
* ink dryness

Step 2: A matrix will be established where on the top horizontal axis the quality characteristics will be written. At the left of the matrix, the first column will contain the list of requirements from Document 1. Column 2 will contain the value of "relative priority" obtained from column 10 of Document 2.

Step 3: Once the matrix is outlined and Step 2 is completed, the matrix must be completed. To do this it is necessary to determine how each quality characteristic influences the requirement. Each user's requirement will be considered and the degree of correlation with respect to each quality characteristic will be established. A scale will be used which includes the following symbols and values:

I little correlation with a value of 1

II moderate correlation with a value of 2

III strong correlation with a value of 3

Step 4: The procedure to fill out the matrix is as follow:

* each cell will be divided in two by a diagonal line,
* in the bottom half of the cell the symbol which identifies the degree of correlation, as described in step 3, will be written,
* in the top half of each cell a value will be obtained by multiplying the "relative priority" of each requirement from document 2 by the correlation value. (This relative priority has been transferred from document 2 to the second column of this document.

Step 5:The values of every cell in each quality characteristic column will be added. This sum will be placed at the bottom of every column, in the row label "absolute weight". In figure 8, it is the next to the last row.

Step 6:In the last row, below the "absolute weight" row, the "relative weight" for each quality characteristic will be determined. First, all the "absolute weights" will be added and "total absolute value" will be obtained. Then the percentage for each "absolute weight" will be obtained by dividing each "absolute value" by the "total absolute value" and finally multiplying by 100. This value will be entered for each quality characteristic in the last row labeled "relative weight of quality characteristic".

This document will give information about the correlation between each quality characteristics and each requirement and also will give an evaluation the importance of each quality characteristic in meeting the user's requirements.

3. Identification of significant Quality Characteristics

Document 4, Selection of Critical Quality Characteristics Significant to User's Requirements will allow recognition of those quality characteristics that need to be focused upon in order to fulfill the user's demands. To understand this document, figure 9 page 58 will help to visualize its format as applied to the candy bar packaging material.

The steps to elaborate this document are as follow:

Step 1: a matrix pattern will be used.

Step 2: each row will be filled with different information as follows:

row 1: all the quality characteristics from Document 3 will be written as column headings,

row 2: the value of the test result for each quality characteristic from convertor,

row 3: the "relative weight" from the last row of Document 3 will be entered,

row 4: will identify with a check mark those quality characteristics for which we need to change. The higher the relative weight the more there is need for change . Intermediate values of "relative weight" need a careful consideration but possibly no change is needed.The decision will be based upon the values of the "relative weight" and a strategy determined by the committee. The strategy includes the cost impact, the nature of the project and available facilities. It is not based upon the value of relative weight alone.

row 5:the value of test result for each quality characteristic from competitor 1, obtained through the testing of the competitor 1

		Quality characteristics												
		permeability to H_2O	permeability to O_2	crystallinity %	polymer M W D.	polymer M W.	solvent retention	tensile strength	elongation	tear strength	lamination strength	corona treatment	roll size	ink dryness
2	present convertor's values													
3	relative weight of each quality characteristc (Document 3)													
4	identification of significant quality characteristic by a check mark													
5	competitor 1 values for each quality characteristic													
6	competitor 2 values for each quality characteristic													
7	target value for each quality characteristic													

Figure 9: Document 4, Selection of Critical Quality Characteristics Significant to User's Requirements

packaging material.

row 6:the value of test result for each quality characteristic from competitor 2.

row 7:by processing the information from row 1 and 2, on those quality characteristics that need to be changed, as identified in row 4, a target value will be estimated considering mainly the "relative weight" of the quality characteristic and also considering the test result values of the competitors' material.

In the preparation of this document, persons from the convertor's quality control, research and development, marketing and engineering departments should participate.

4. Identification of the Components and Component Characteristics and their relation with Quality Characteristics

Document 5, Selection of Package Components and Assignment of Component Characteristics to Critical Quality Characteristics, will establish the relationship between the quality characteristics and the components of the packaging material. First, the components and component characteristics of the packaging material will be developed.

Then the critical quality characteristics obtained in Document 4 will be considered and their influence on the different packaging components will be established.

An illustration of Document 5 is shown in figure 10 on page 61. Using the candy bar packaging material example will help to understand the purpose and the dynamic of this document. To generate this document, five steps must be followed:

Step 1: First, the components of the packaging material need to be defined. In the case of the candy bar packaging material the components identified are:

* film layer
* total package material
* adhesive
* print
* roll

Step 2: The component characteristics will be recognized. The component characteristics are those which describe the properties of the component with respect to the total package material.

		Critical Quality Characteristics (from Document 4)								
components	components characteristics									
film	sealable									
	compatibility									
total package material	barrier									
	performance in F.F.S. machine									
adhesive	lamination									
	no solvent retention									
print	precision									
roll	good fit in F.F.S. machine									

Figure 10: Document 5, Selection of Package Components and Assignment of Component Characteristics to Critical Quality Characteristics

COMPONENTS	COMPONENT CHARACTERISTIC
* film layer	- sealable (inside layer) - compatibility with candy bar
* total package material	- barrier properties - performance on F.F.S. machine
* adhesive	- maintain lamination - doesn't retain solvent
* print	-precision
* roll	- fit well in F.F.S. machine

Step 3: Once the components and the component characteristics are identified, a matrix will be prepared as follows:

row 1: in the top row, the critical quality characteristics obtained in Document 4 will be written as headings.

column 1: the components already described will be listed.

column 2: the component characteristics will be listed.

Step 4: The matrix will be a series of cells. An evaluation system will be used to record the degree of correlation between the component characteristics and the critical quality characteristics. A set of symbols will be used in the following manner :

I = little correlation

II = some correlation

III = strong correlation

This correlation will determine which components need to be considered and which critical quality characteristics must be accounted for in order to fulfill the user's requirements. This document should be elaborated by persons from the convertor's quality control, research and development and marketing departments.

This document will be mainly concerned with the degree of correlation between the quality characteristics and the component characteristics. It is not necessary to numerically evaluate such correlation because what is important is to see how each component characteristic affect the quality characteristic which in the previous documents were weighted and numerically evaluated.

<u>5) Deployment of components</u>

In the previous document, the components and the component characteristics were related to the critical quality characteristics. Now it is necessary to identify the critical components' properties that will make it possible to fulfill the requirements established by the user. This study needs to be done very carefully and a detailed consideration of the package material will be required. People from the production, quality control, engineering, research and development departments should participate in this work. This is a critical part which necessitates good group coordination and collaboration from all the areas involved.

To develop Document 6, Deployment of Components and Component Characteristics into Critical Component Properties, (figure 11,page 65) the following steps will help to guide the procedure:

column 1: includes the list of components described in Document 5

column 2: consists of the list of component characteristics also obtained in Document 5

column 3: is a list of certain critical component properties that will directly affect the desired target value of the final product critical quality characteristics, (such critical quality characteristics were related to the components characteristics in Document 5).

components	component characteristics	critical component properties
film	sealable	melting point (polymer)
		melt flow index
		crystallinity %
	compatibility	polymer chemical constitution
		glass transition temperature
package	barrier	crystallinity %
		thickness
		polymer chemical constitution
	performance in F.F.S. machine	tensile strength
		elongation
		puncture resistance
adhesive	lamination	delamination
		amount of adhesive
	no solvent retention	adhesive viscosity
		boiling point (solvent)
print	precision	ink viscosity
		ink deposition
		solvent proportion
roll	good fit in F.F.S. machine	Roll size
		tension at rolling

Figure 11: Document 6, Deployment of Components and Component Characteristics into Critical Component Properties

Then these critical component properties will be further deployed to determine the production planning and control process. To process the information in Document 6 on the relationship among components, component characteristics and critical component properties, the Tree Diagram and the Process Decision Program Chart (P.D.P.C.) tools (Literature Review p. 12 and 15) could be used.

6. Analyzing the production process and determining the control system

Once the component characteristics are related to the critical component properties, it is necessary to relate these to the production process and determine the means to control and evaluate them. In Document 7, Designation of Process Control Point and Check Site for Critical Component Properties of Raw Material and Processes, the critical component properties will be considered and related to the raw material and processes that need to be controlled.

The illustration for this document is shown in figure 12 page 68. For this document to be elaborated requires a deep knowledge of the convertor process and facilities. In the construction of this document, personnel from the convertor's engineering, quality control, production and research and development departments should participate.

To complete this document requires one step as follows:

row 1: All the critical component properties (from Document 6) will be listed as column headings.

left columns: In the first two columns at the extreme left of the matrix, "raw material" and "process" will be listed.

right columns: At the extreme right side of the matrix, two columns will be distinguished:

"control point": this column will establish which part of the process or raw material needs to be controlled

"check site": identifies where measurements for the control points will take place

central matrix grid: a number of cells will result in which are identified ,by using a check mark, the relations between the critical component properties and the process or raw material.

Once the central matrix grid is filled, a check mark will

raw material	process	critical component properties	control points	check site
film				
	lamination			
	printing			
	rolling			

Figure 12: Document 7, Designation of Process Control Points and Check Sites for Critical Component Properties of Raw Material and Processes

determine how each critical component property affects the process or the raw material. Then a "control point" will be identified by recognizing how the part of the process or item of the raw material will be controlled, and the "check site" will identified where such control will take place. The name of this control point or check site is entered in the appropriate column on the right side of the matrix.

Document 7 will give information by which the critical component properties will be related through the component characteristics from document 6 to the process itself, and subsequently a control system can be developed as the next document is created.

7. Control system and process control.

After the process has been studied using the seven documents described, a control system must be developed. From Document 8, Statistical Process Control Plan for Critical Component Properties of Raw Material and Processes, the control system operating instruction can be obtained.

An example of this document as shown in figure 13 page 71 will help to understand the ideas included in this procedure. This document is the last one and the following steps will be used:

column 1: from Document 7, the "raw material" will be listed

column 2: also from Document 7, the "process" will listed

column 3: the "control points" are also brought from Document 7

column 4: the "check sites" are brought from Document 7.

column 5: the "control method" will be defined for each control point, such as $\bar{\bar{X}}$ or R charts. This will be determined as a function of the control point and how significant is the correlation between component characteristic and the quality characteristic (Document 5). It is also a function of the importance of the quality characteristic itself as determined in Document 4.

column 6: sample size will be described depending on the kind of control point and control method.

raw material	process	control point	check sites	control method	sample size	frequency
film		refer to supplier				
	lamination					
	printing					
	rolling					

Figure 13: Document 8, Statistical Process Control Plan for Critical Component Properties of Raw Material and Processes.

column 7: the frequency of the test will be established for each "control point", depending on the specific evaluation under consideration

The information contained in this document will be used for the elaboration of the control system operating instructions.

It should be noted that the control method, the sample size and the frequency of test will be influenced by the type of facilities and machinery in which production is taking place. The convertor needs to determine the accuracy and repeatability of his machinery and what type of adjustment and variation the equipment is able to handle. It is very important to have all detailed information available and ready to be used for the elaboration of this document. The participation of the engineering, production, quality control and research and development departments is a key factor in the completion of this final document. To further elucidate the technique developed here, a hypothetical case is proposed. This case illustrates with specific numerical examples how the information flows from document to document.

E. PRACTICAL EXAMPLE OF APPLICATION OF Q.F.D.

The following documents were filled out with hypothetical data, in order to demonstrate the dynamic of the Q.F.D. The numbers were arbitrarily chosen, usually at the extreme of the normal ranges, to illustrate the operation of the model. To make this example more clear and accessible only one user's requirement was considered, and this requirement was successively deployed until the eight documents were obtained.

The package under consideration is a laminate structure of aluminum foil and polyethylene. The aluminum foil layer is going to be printed by flexography, in three colors. The package material is sold to the user in roll form and is used in a F.F.S. machine. The product to be packed is a chocolate candy bar.

The purpose of the study is to improve the quality of the existing package material, for a longer shelf life. The project will be undertaken by the convertor's technical departments, mainly Research and Development, Quality Control, Production and Engineering; and the user's Marketing, Quality Control and Research and Development departments. Several meetings should take place in which the convertor and the user exchange information

It will be necessary to refer to the description of each document in the body of the thesis . It is suggested to copy these example documents in order to read them side by side with the instructions. The documents are as follows:

Document 1: Compatibility of food with the package as a general requirement was considered and deployed into three levels (shown in figure 14, page 75)

Document 2: The evaluation for the requirement importance (shown in figure 15, page 76) is hypothetical, as are the numbers in column 3, 4, 5 and 7. These are numbers which would be assigned by the committee according to the instructions given for the document.

The values in column 6 "objectives" were estimated based upon considering the "requirement importance", and how well the company is meeting the requirement.

The values in column 8, "degree of change" were obtained by dividing the values of "objective" (column 6) by "convertor today" (column 3).

The values of column 9 "degree of priority" result from the multiplication of the following values:

level 1	level 2	level 3
compatibility of food product with package material	maintain flavor	no loss of aroma or flavor
		no change of aroma or flavor
	keep food product fresh	no oxidation
		no moisture loss or gain
		no change in food product composition

Figure 14: Document 1, Numerical Example

list of user's requirements from Document 1 (level 3)	2 requirement importance	3 convertor today	4 competitor 1	5 competitor 2	6 objectives	7 sales importance	8 degree of change	9 degree of priority	10 relative priority
no loss of aroma or flavor	4	4	3	4	4	3	1	12	21
no change of aroma or flavor	5	3	5	4	5	2	1.63	16.3	29
no oxidation	3	4	5	4	4	2	1	6	11
no moisture loss or gain	3	2	4	3	3	1	1.5	4.5	8
no change in food product composition	5	4	5	4	5	3	1.2	18	32

Figure 15: Document 2 , Numerical Eexample

requirement importance X degree of change X sales importance

(column 2) (column 8) (column 7)

The values of "relative priority" for column 10 are obtained by dividing the degree of priority for each requirement (column 9) by the sum of priorities in column 9 and multiplying by 100 %.

<u>Document 3</u>: The correlation of user's requirement with the quality characteristics was determined, and each quality characteristic was evaluated as a function of the "relative priority" of the requirement. (shown in figure 16, page 78):

The list of requirements and the "relative priority" of each requirement from Document 2 was carried to the first two columns of the matrix.

The set of quality characteristics were related to the user requirements chosen and were set in the top row of the matrix.

In the lower portion of each cell a symbol such as I or II or III was chosen according to the degree of correlation between each user's requirement and each quality characteristic.

Each symbol placed at the bottom of the cell has a value of 1, 2, or 3. These values were multiplied by the "relative

		QUALITY CHARACTERISTICS						
list of user's requirements from Document 1 (level 3)	relative priority from Document 2 (column 10)	permeability to H_2O	permeability to O_2	crystallinity %	polymer M.W.D.	polymer M.W.	solvent retention	total absolute weight
no loss of aroma or flavor	21	42 II	63 III	63 III	21 I	21 I		
no change of aroma or flavor	29						87 III	
no oxidation	11	11 I	33 III					
no moisture loss or gain	8	24 III		16 II	8 I	8 I		
no change in food product composition	32	96 III	96 III				96 III	
absolute weight of quality characteristic		173	192	79	29	29	183	685
relative weight of quality characteristic		25	29	11	4	4	27	-

Figure 16: Document 3, Numerical Example

priority" value at the left of the matrix, and the product obtained was written in the upper portion of each cell.

For each quality characteristic all the values in the upper right corner of the cells were added and the sum written in the row titled "absolute weight of quality characteristic". All the values of the "absolute weight of quality characteristic" were added and this sum written at the far right end of the "absolute weight of quality characteristic" under the column heading "total absolute weight".

Finally the "relative weight of quality characteristic" was obtained by finding the percentage of each "absolute weight of quality characteristic" with respect to the "total absolute weight"

Document 4: A target value for each critical quality characteristic was estimated (shown in figure 17, page 80). The "polymer M.W." and the "polymer M.W.D." quality characteristic were not considered because they have a very low "relative weight of quality characteristic". The target values chosen reflect, strategy, technical judgement, cost, and technical feasibility. Note that the committee determined that solvent retention needed to be reduced below that of any of the three convertors.

1		QUALITY CHARACTERISTICS					
		permeability to H_2O (grs./m^2 day At)	permeability to O_2 (cc./m^2 day At.)	crystallinity %	polymer M.W.D.	polymer M.W.	solvent retention
2	present convertor's values for each quality characteristic	25	10	40	10.6	131,900	30
3	relative weight of each quality characteristic from Document 3	25	29	11	4	4	27
4	identification by check mark, the significant quality characteristic						
5	competitor 1 values for each quality characteristic	21	8	60	10.7	131,000	20
6	competitor 2 values for each quality characteristic	15	12	55	10.5	129,900	25
7	target values for each quality characteristic	15	8	55			10

Figure 17: Document 4, Numerical Example

Document 5: The correlation between critical quality characteristics and component characteristics was recorded using the set of symbols:

I = little correlation

II = some correlation

III = strong correlation

The numerical values for these symbols is not needed and none is assigned. This document is shown in figure 18, page 82.

Note that the polymer M.W. and polymer M.W.D. quality characteristics are not carried from Document 4 into Document 5, because they were not considered critical in Document 4.

All three components (film, total package material, and adhesive) influence compatibility, so they and their component characteristics must be listed in this Document 5.

Once this correlation is defined those components and component characteristics which have "some" or "strong" correlation with quality characteristics will be further deployed into critical component properties in Document 6. Every component characteristic showed correlation with at least one critical quality characteristic and so all five component characteristics were carried forward to Document 6.

Document 6: The component and component characteristics were deployed further into critical component properties. The

components	component characteristics	CRITICAL QUALITY CHARACTERISTICS: permeability to H_2O	permeability to O_2	crystallinity %			solvent retention
film	sealable	I	I	III			I
	compatibility	II	II	III			III
tota package material	barrier	III	III	III			I
adhesive	lamination	II	II	I			III
	no solvent retention	I	I	I			III

Figure 18: Document 5, Numerical Example

control of these critical component properties will make it possible to satisfy the critical quality characteristics which are essential for meeting the user's requirement. Document 6 is shown in figure 19 page 84.

<u>Document 7</u>: The critical components properties were related to processes and raw material and further to part of the control system (shown in figure 20, page 85). The check marks show the type of control test to be used for each of the critical component properties.

<u>Document 8</u>: This document (shown in figure 21, page 86) will complete the control system and from this document the operational instruction for the control system will be obtained.

components	component characteristics	critical component properties
film	sealable	melt flow index of the polymer
		melting point of the polymer
		crystallinity %
	compatibility	polymer chemical constitution
		glass transition temperature (Tg)
total package material	barrier	crystalinity of polymer %
		thickness
		polymer chemical constitution
adhesive	lamination	delamination
		amount of adhesive
	no solvent retention	adhesive viscosity
		solvent boiling point

Figure 19: Document 6, Numerical Example

raw material	process	CRITICAL COMPONENT PROPERTIES (Document 6)										control points	check points
		melt flow index polymer	melting point polymer	crystallinity % polymer	polymer chemical const.	glass transition temp.	thickness	delamination	amount of adhesive	adhesive viscosity	solvent boiling point		
film		✓	✓	✓	✓	✓						chemistry	Melt Flow Index. D.S.C. I.R.
							✓					physical	micrometer
adhesive										✓		physical	viscosity
aluminum								✓				physical	micrometer
	lamination									✓		adhesive viscosity	machine viscosimet.
								✓				lamination strength	Instron
											✓	tempera-ture	solvent extration
									✓			adhesive amount	machine dosis

Figure 20: Document 7, Numerical Example

raw material	process	control point	check site	control method	sample size	frequency
film		chemistry	Melt. Flow Index D.S.C. I.R.	← Refer to supplier →		
		physical	micrometer			
adhesive		physical	viscosity			
aluminum		physical	micrometer			
	lamination	adhesive viscosity	machine viscosimeter	Check sheet	20 ml	½ hour
		lamination strength	Instron	$\bar{X}$-R chart	std. strips	1 hour
		temperature	solvent extraction	$\bar{X}$-R chart	100%	½ hour
		adhesive amount	machine dosis	$\bar{X}$-R chart	100%	¼ hour

Figure 21: Document 8, Numerical Example

F. PRACTICAL AND ORGANIZATIONAL CONSIDERATION FOR Q.F.D. APPLICATION

All the documents described could be contemplated as one big chart, which was broken into eight different documents to be able to deal with this project of quality design more easily. The project has only one objective; to design quality into the product. Also the project maintains a constant unity of structure since each document depends upon the previous one in order to be completed. At the end of Document 8, it is important to realize that the user demands will be reflected in the control of the production process through the quality control system, which was the main objective of the project.

There are some recommendations for the application of the Q.F.D.:

* The time invested in developing this method could be considered too extensive. To avoid this, or to speed up the application of the Q.F.D., it could be useful to have all persons involved in the project trained in the method. All the persons should be aware of the mechanisms and tools to be implemented. A plan of action should be outlined.

* It will be helpful in the development of each document to

assign groups of persons with specific tasks and then process all information from the different subgroups for the creation of that document. The subgroups could be all working at the same time and a coordinator for each document will be organizing and supervising all information, as well as feeding data to each subgroup for further work.

* A Document Coordinator for each document, will be chosen and, depending on the nature of the document, this person will have either a technical or a marketing background. Also a General Coordinator will be chosen,who must have a deep understanding and knowledge of the dynamics of the Q.F.D. method. The General Coordinator will be the link between the different groups and will organize the final information from document to document. The General Coordinator will be the connection between technical, marketing and financial departments and also with the user's company. The General Coordinator will provide and select relevant information to be processed. This person needs to have both technical and management background. The firm must officially recognize this role and give it a specific place in the organization structure.

* User's requirements must be carefully selected. A very large list of user's demands could enlarge the project to such a degree that it will consume too much time and be very

ineffective; on the other hand, if the user's requirements are not totally considered, some overlooked requirements could be missed which were relevant to the quality design (Cohen, 1988).

IV. CONCLUSION

Because packaging is in constant change, it is continually adapting to new technology. Customer demands and expectations are critical. The Q.F.D. model provides a procedure to analyze information and incorporate it in an effective way into the product. Q.F.D. takes into account the user and the consumer views and also provides a design mechanism for making full use of all available technical, marketing and financial expertise to obtain controlled, innovative solutions to complex production problems.

The implementation and understanding of the model requires time and some investment in terms of training of the persons who are going to participate in the project, but eventually this will pay off once the model is properly applied. It is important to carefully study each step of the model, so a high level of commitment is required from all participants. A good analysis of the customer needs as well as the user company facilities and machinery is required in order to make possible the development of the Q.F.D.

The main advantage of the model is that a product will be obtained with a quality adapted to the specific needs or demands of the customer. The product will have the quality that is expected, not below or above that which is required, by identifying only those significant parts or features that are fundamental for product performance at all levels. As a consequence, the product obtained will be of good quality and produced at optimum cost.

Although Q.F.D.is a very new method for developing quality, it has been very successful in all those industries which have adopted it. The virtue of the model is its originality and the simplicity of the procedure. Further study and development of the model will make Q.F.D. a powerful tool in quality control for packaging.

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