

Building Conceptual Models in QFD

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Abstract: The aim of this article is two folds. Firstly, it presents a seven steps procedure for elaborating QFD Conceptual Models in product development. Two examples illustrate how this procedure can be utilized: one is in a manufacturing process with property transformation and, another one is with form transformation. Secondly, the article presents a set of factors that influence the choice of tables, matrices, and their arrangement in the construction of conceptual model: type of product, type of fabrication process, and stages of development cycle in which QFD is being applied. The seven steps procedure and the set of factors constitute the contribution of this article.

Key Words: product development, QFD, quality deployment, conceptual model, cause-effect.

摘要: 本文主要有两个目的。第一个是阐述在生产开发中构建 QFD 概念模型的七个步骤，在论述的时候举了两个例子将如何运用这个过程具体化：一个是在生产过程中的实物转换，另一个则是形式转换过程。第二个，文章概括了在概念模型中影响点和矩阵以及对它们管理的一系列因素：产品的种类，构建过程的类别以及在展开过程中 QFD 应用的阶段。这七个步骤和一系列的影响因素便是本文的主要意图所在。

关键字: 产品开发，QFD，质量展开，概念模型，因果关系

1. Introduction

QFD method was formulated by professor Akao and professor Mizuno by the end of 60's (Akao, 1990). Since then, many conceptual and methodological elements have been added by professor Akao himself and by other important Japanese researchers engaged in Japanese way of TQC and QFD. This has resulted in a comprehensive model of QFD and a compendium of alternative forms of application. QFD is subdivided into: (1) Quality Deployment (QD), where the focus is on the deployment of information necessary for achieving the quality of a new product; (2) Quality Function Deployment, restrict sense (QFD_r), where the focus is on the deployment of work necessary for assuring quality (Cheng and Melo Filho, 2007). The operational units of QD are: tables, matrices, conceptual models, and standards. Among these units, the importance of conceptual model should be highlighted, because it is the representation of the cause-effect

“architecture” needed for achieving the quality of a new product. It is through the construction of conceptual model that one comes to identify the tables and the matrices that are needed and, also, it is through the information brought out, step by step, by the conceptual model that the standards are elaborated before the production begins.

The Conceptual Model we refer to was initially represented by Cause-Effect Diagram, or Fish Bone (Akao, 1996). Along the evolution of QFD, one can observe the existence of, at least, three versions of conceptual models: the four matrices of American Supplier Institute (1989), the matrix of matrices of Bob King (1989), and the matrices of Comprehensive QFD. The latter one was developed in Japan within the context of TQC (Japanese style), and there have been efforts in increasing its usage throughout the world, specially stimulated by QFD Institute of the United States (Cheng and Melo Filho, 2007).

Conceptual Model in QFD can be defined as a graphic form for representing cause-effect relationships of required quality, or other effects, with cause factors that contribute to the formation of the product. It makes explicit these relationships and facilitates their visualization by the development team. However, studies have shown that QFD applications have largely been restricted to the first matrix – the quality matrix (Carnevalli and Miguel, 2007). In addition, in reports where the deployment goes beyond the first matrix, there is no description of how the conceptual model was obtained. Based on our experiences in QFD applications during the last two decades in Brazil, we structured a seven steps procedure for elaborating conceptual model in Japanese style Comprehensive QFD. We present examples of how this procedure can be used in two types of manufacturing processes: one with property transformation and another one with form transformation. In the second part of the article, we present a set of factors that should be analyzed because of their influence on the construction of conceptual models.

2. Building a Conceptual Model (in Comprehensive QFD)

To develop a product according to established performance targets, it is necessary to detail the project in a way that all factors that contribute to the attainment of the final product are projected. These factors are called contributing factors and can be divided into two groups. The first group is made up by factors related to the detailed project of the product, such as, demanded quality, quality characteristics of final product, functions, mechanisms, components, intermediary products, raw materials, among others. The second group is made up by factors related to the project of manufacturing process, such as processes, assembly operations, control parameters of equipments, among others. These two factor groups constitute the definition of the whole product development process, from raw material to end product. During the detailed

definition of the project for product and process, QFD Conceptual Model helps in the organization of contributing factors in a structured way, establishing cause-effect relationship with market needs as the starting point.

2.1. A seven steps procedure for building conceptual models

The procedure for building conceptual models we propose here is made up of seven steps: (1) to analyze the objectives of the QFD project; (2) to define the deployments in the dimensions of quality, cost, technology, and reliability; (3) to visit production line or to draw up a possible flow of process when there has not yet a line; (4) to group up items, such as, raw material and processes, in sets; (5) to define cause-effect relationships from client to raw material, in tables; (6) to define the sequence of matrices in the model; and, (7) to draw the conceptual model and to represent extractions (elements to elements) and conversions (numbers to numbers of prioritization). In order to illustrate this seven steps procedure, we will present two examples of its application. The first one was in a process industry and the second one was in a product assembly industry.

2.2 Example I: building a conceptual model for a product in a process industry

Step 1 – The objective of this project was “to develop a new product that meets the demands of a new client”.

Step 2 – The development team decided that a more elaborated conceptual model was needed, because it was important to establish all the contributing factors necessary for the development of the new product. Initially, it decided to deploy the Positive Quality (for more details on the relationship Objectives vs. Conceptual Model, see the guide for intervention in Cheng, 2003).

Step 3 – The team built the production flow in inverted direction, beginning with client satisfaction as the desired effect (see Figure 1). The team also defined the headings for the symbols to be used during the next steps. The arrow “Influence Relationship” is used to represent effect-cause relationship between groups of items that are outside the production flow, or that do not respect the inverted direction of the flow. For instance, in Figure 1, the group “client satisfaction” is outside the production flow, nevertheless, it is affected by the end product.

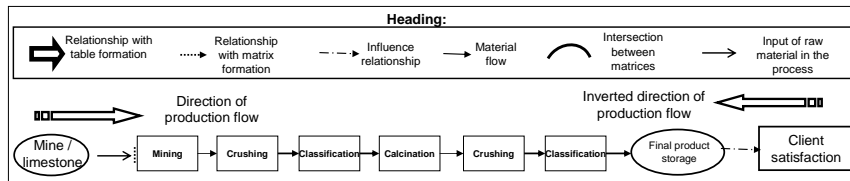


Figure 1 – The production flow with “client satisfaction” as the desired final effect.
Source: Cheng and Melo Filho, 2007.

Step 4 – The team defined the main group of items, and linked to it a table of QD deployment (see Figure 2). It also defined that, apart from the production processes, it will be necessary to define process control parameters (a table of deployment of processes control parameters). In the example shown in Figure 2, the team decided that it was not important to define quality characteristics of intermediary products, because the main alterations of the product occur during two processes: in the definition of raw material and when the product is in process, where the major alterations occur.

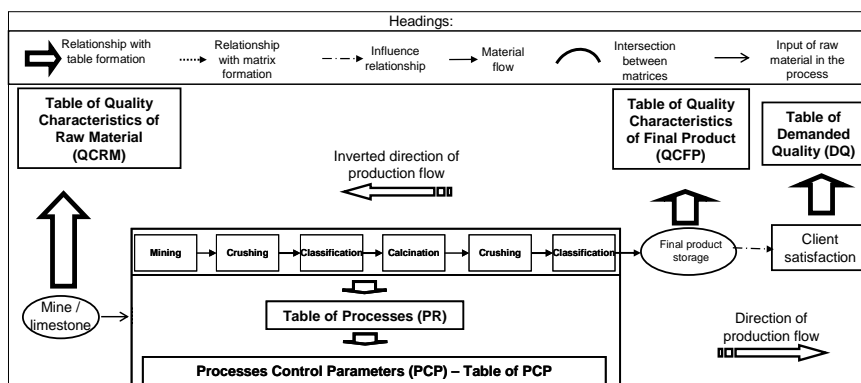


Figure 2 – The definition of tables related to contributing factors.
Source: Cheng and Melo Filho, 2007.

Step 5 – For the definition of matrices, the team carried out an effect-cause analysis beginning from the table of demanded quality, i.e., in inverted direction of the flow. The logic was (see Figure 3): to attend to the Demanded Quality (DQ) (effect), it is necessary that the product possesses certain quality characteristics of the final product (QCFP) (cause); thus, the first matrix should be DQ x QCFP. In order to attain QCFP (effect), it is necessary to have able manufacturing processes (PR) (cause); here we have another matrix, QCFP x PR. In order to achieve able manufacturing processes (effect), it is necessary to have control parameters (PCP) (cause) which should be adjusted in specific ranges; and, this forms another matrix, PR x PCP. The PCP (effect) should be established in a way that is able to modify the quality characteristics of raw materials (QCRM) (cause), and the QCRM (cause) should be established in a way that enables the PCP to alter them in accordance to the goals defined for the final product; this brings us to another matrix, PCP x QCRM. In this project, there would also be a direct

relationship between QCRM and QCFP, because QCFP (effect) are also affected directly by QCRM (cause); this relationship is represented by the arrow that links raw material to final product in Figure 3, and the matrix is QCRM x QCFP.

Step 6 – To establish the sequence of matrices in the conceptual model, the team followed the logic presented above and defined, in inverted direction of production flow, the intersections between matrices (see Figure 4). For instance, the matrices QCFP x DQ and QCFP x PR have an intersection with the QCFP: $DQ \times QCFP \cap QCRM \times PR$ or $[DQ \times (QCFP) \times PR]$.

Step 7 – Finally, the team constructed the conceptual model according to the effect-cause relationship defined previously. It also defined the processes of extraction and conversion that should be carried out in the matrices (see Figure 5).

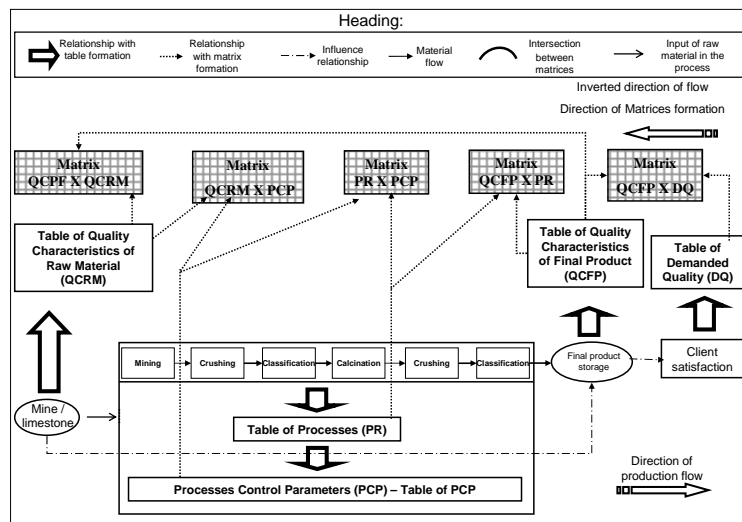


Figure 3 - The definition of matrices.
Source: Cheng and Melo Filho, 2007.

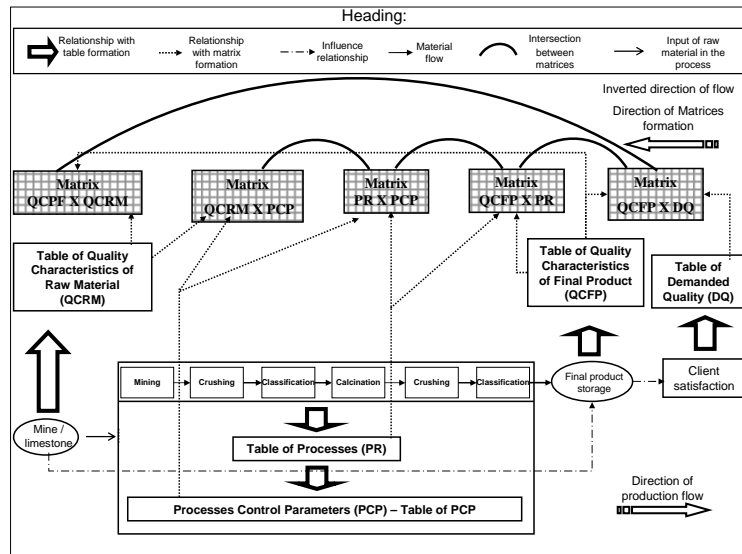


Figure 4 – The definition of matrices intersections.
Source: Cheng and Melo Filho, 2007.

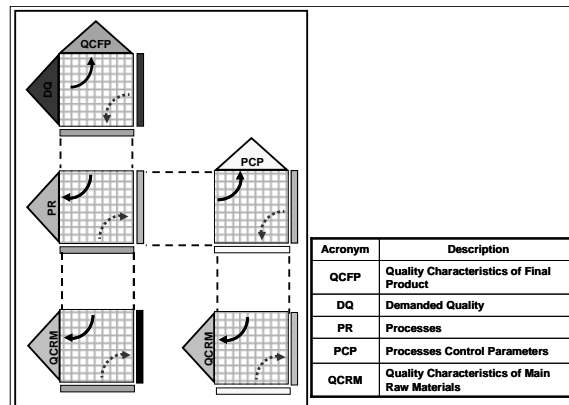


Figure 5 - A conceptual model for a process industry.
Source: Adapted from Melo Filho (2005).

2.3. Example II: building a conceptual model for a product in a product assembly industry

Step 1 – The objective of this project was “to assure the quality of a new product for the factory in the shortest time” (Araújo, 2002).

Step 2 – The quality of the product was defined as “to meet the performance goals”. The development team decided that it needed a more elaborated conceptual model to establish all contributing factors necessary to manufacture the new product.

Step 3 – The team built the production flow in inverted direction, starting from the desired effect of attaining the product, Engine, with the desired qualities. In this project, the use of Demanded Qualities was not important because these were already clear to the development team (see Figure 6).

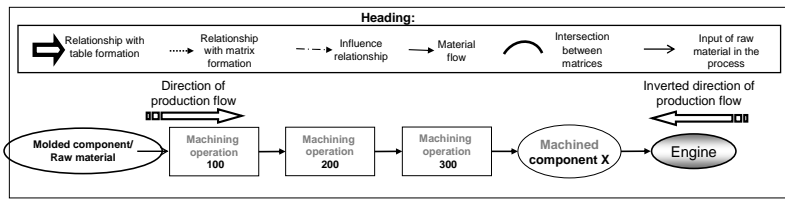


Figure 6 – The production flow having the Engine quality as the final desired effect.
 Source: Cheng and Melo Filho, 2007.

Step 4 – In this step, the team defined the main group of items and linked to it a QFD deployment table (see Figure 7).

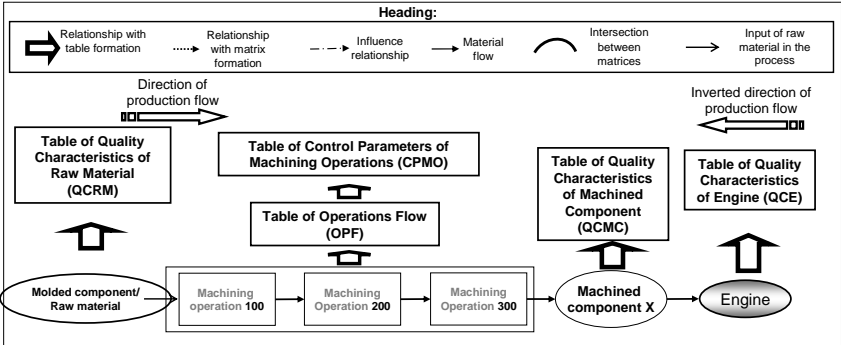


Figure 7 - The tables linked to the contributing factors.
 Source: Cheng and Melo Filho, 2007.

Step 5 – In order to define the matrices, the team carried out an effect-cause analysis based on the table of Quality Characteristics of the Engine (see Figure 8). It was important to establish some influence relationships between contributing factors. The control parameters of machining operations would affect directly the end product instead of affecting the machining operations themselves. Analysis and conclusions about “what affects what” (cause-effect relationship) in the model should be carried out by the development team members, based on their knowledge and experiences.

Step 6 – In order to establish the sequence of matrices, the team followed the same logic presented in step 5 and defined, in inverted direction of production flow, the intersections between matrices (see Figure 9).

Step 7 – The team, thus, constructed the conceptual model in accordance with the effect-cause relationship identified previously. It also defined the extraction and conversion processes that have to be carried out in the matrices (see Figure 10).

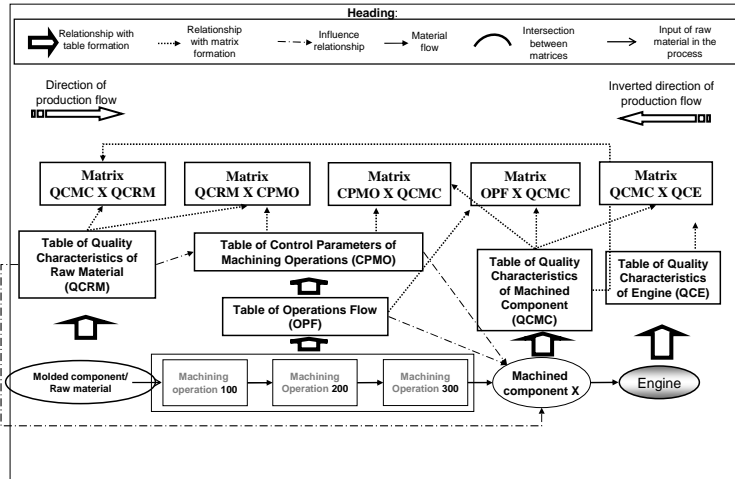


Figure 8 – The definition of Matrices.
Source: Cheng and Melo Filho, 2007.

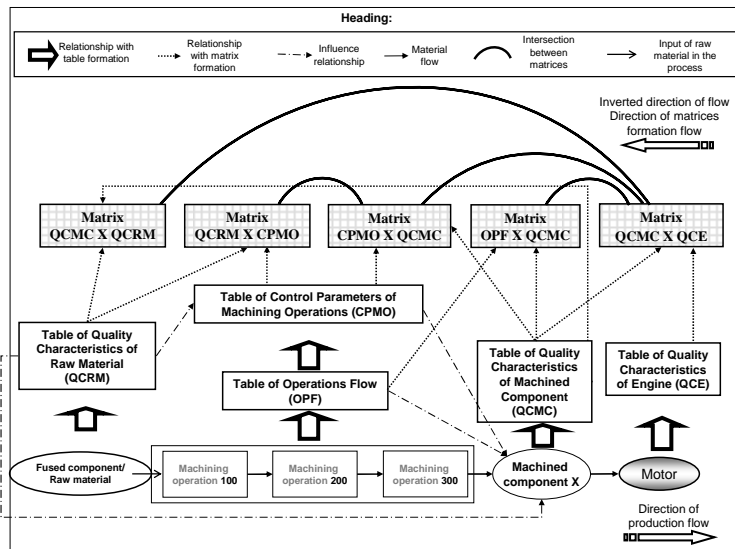


Figure 9 – The definition of matrices intersections.
Source: Cheng and Melo Filho, 2007.

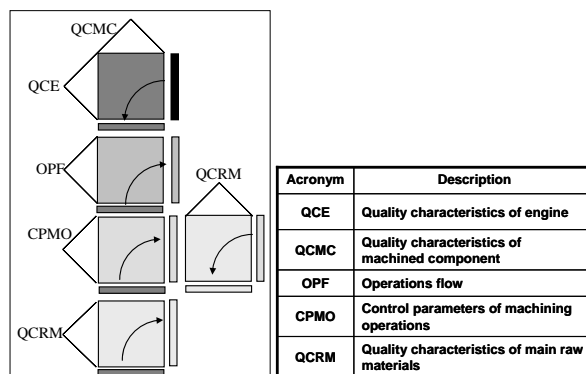


Figure 10 – A conceptual model for a product assembly industry.
Adapted from Araújo (2002).

The seven steps procedure presented above is a path that can be altered according to the needs of each project. In our two cases, both steps 3 and 4 were carried out together, defining tables and matrices that are needed. The effect-cause relationship should always be respected. The examples, shown in Figures 5 and 10, present the group of items that have to be projected in order to develop the desired product.

Any matrix that does not belong to the effect-cause logic of the conceptual model is called auxiliary matrix. It is used when some important auxiliary information is needed for the project, for instance, QCFP x QCFP. If, during the QFD project, the team decides that it is important to build auxiliary matrices, these should be represented in the conceptual model, making its importance explicit (Cheng and Melo Filho, 2007).

3. Factors that Influence the Construction of Conceptual Models

The construction of conceptual models is influenced by three basic factors: (I) type of product; (II) type of manufacturing process; and (III) stages of new product development cycle that are involved. Table 1 shows these factors in details.

Table 1 – Three factors that influence the construction of conceptual models.

Type of product										Type of manufacturing process			Stages of new product development cycle involved						
Nature of product		Type of contact with user		Type of specification		Degree of innovation													
Industrial goods (tangible)																			
Service (intangible)																			
Digitals (intangible)																			
	Direct																		
	Indirect																		
	Hybrid																		
		Product with prior specification																	
		Product without prior specification																	
		New to the world																	
		New to the company																	
		Addition of a new line (product platform)																	
		Improvement of a product (value aggregation)																	
		Repositioning																	
		Cost reduction																	
		Continuous processes																	
		Discrete processes (assembling, machining, etc.)																	
		Service providing																	
		Digital processes (download, reproduction, etc.)																	
		Identification of clients needs																	
		Concept development and testing																	
		Basic project																	
		Detailed project of product																	
		Project of manufacturing process																	
		Preparation for production																	

Adapted from Araujo (2002).

Concerning the factor “stages of new product development involved”, its analysis helps in: the decision on whether to use the Quality Matrix; the definition of tables and matrices that should be included and the way of obtaining them; establishing the sequence of matrices in the conceptual model; the identification of the best form of obtaining client demands; among others. Table 2 shows how the conceptual model presented in Figure 5 is classified under this framework.

Table 2 – The classification of the conceptual model presented in Figure 5.

Type of product											Type of manufacturing process				Stages of new product development cycle involved								
Nature of product		Type of contact with user			Type of specification		Degree of innovation																
Industrial goods (tangible)	Service (intangible)	Digital (intangible)	Direct	Indirect	Hybrid	Product with prior specification	Product without prior specification	New to the world	New to the company	Addition of a new line (product platform)	Improvement of a product (value aggregation)	Repositioning	Cost reduction	Continuous processes	Discrete processes (assembling, machining, etc.)	Service providing	Digital processes (download, reproduction, etc.)	Identification of clients needs	Concept development and testing	Basic project	Detailed project of product	Project of manufacturing process	Preparation for production
X				X		X				X	X			X				X					X

The factor that most distinguishes conceptual models is “Type of Manufacturing Process”, mainly because of the types of tables and matrices used, and of the way how they are arranged by the effect-cause relationship. For example, the QFD tables more frequently used in continuous processes are: demanded quality; quality characteristics of final product; quality characteristics of intermediary products; manufacturing process; processes control parameters; quality characteristics of raw materials; quality characteristics of auxiliary raw materials.

4. Conclusions

For building a conceptual model, the product development team can follow the seven steps procedure we proposed in this article. At the beginning of the project, the team should also analyze three factors that influence the construction of conceptual model: type of product, type of manufacturing process, and stages of development cycle in which QFD will be applied. It is hoped that this article will contribute to further QFD applications, so that they may go beyond the first matrix and broaden the scope of QFD work through a flexible construction of Conceptual Model.

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