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DEVELOPMENT OF SYSTEMIC QUALITY MANAGEMENT MODEL USING THE AXIOMATIC DESIGN FRAMEWORK

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ABSTRACT

In the past years the word quality has been considered a synonymous of success or failure. This situation results from how firms understand quality concepts. The development of such concepts has changed the quality view as a simple way of controlling products and processes to develop a systemic vision of quality management in the whole organization. In this sense, the objective of this paper is to propose a Systemic Quality Management Model based on the precepts of Total Quality Management approach and oriented by the firm's customer needs and attributes. This work was developed using the Axiomatic Design approach, established in function of axioms, corollaries and theorems. The objective is to improve "good practices of design" in the construction of the Systemic Quality Management Model. The proposed model was developed considering three domains in the design of a system: Customer Domain (CA), Functional Domain (FR) and Physical Domain (DP). It was also developed the hierarchy diagram of the FRs and DPs, as well as the functional requirements and design parameters decomposition, pointing out each level of the hierarchy diagram the design equations, steps and leaves that were obtained for the related elements. The model also includes the entire design matrix and module-junction diagram that shows the hierarchical structure of modules. Finally, some conclusions were drawn considering the benefits and constraints faced with the proposed development.

Keywords: design, axioms, software, object-oriented

1 INTRODUCTION

Considering the context which moves the transformations in most industries, the word " quality " has appeared as a factor which could be able to incorporate competitive advantages for the organizations, and on behalf of quality it has altered patterns, demands, social and economic behaviors, creating and consolidating new paradigms inside of the context of the organizations. However, in spite of the unequivocal consent on the important role carried out by the different approaches of the concept of quality nowadays, a paradoxical situation is the nonexistence of consensual definitions on this concept.

The different approaches and dimensions that the quality can assume in the organizations, as well as the evolutionary stages that the concept of quality has presened implies the search of procedures that can be systematized and managed in issues related to quality. In that way, how could quality be better managed? Does quality really constitute a competitive advantage of the organizations? Would it be possible to evaluate the acting of quality? It is in this context that this article proposes the discussion of these issues as one of its main objectives, approaching aspects that enable to systematize in a structured way the construction of a model of systemic administration of quality, considering as main guideline the approach considered by Total Quality Management (TQM) translated in this work as Administration of the Total Quality and contemplating aspects delineated by Global Quality Management (GQM), translated here as Administration of the Global Quality. For such, they intend the application of an approaching methodology denominated holistic Axiomatic Design, which is used for the project and construction of the model of systemic administration of quality, having been such development ruled in which the methodology denominates of " good project " practices, being the same ones established and structured through axioms, corollary and theorems.

2 SOME CONCEPTS ABOUT TOTAL QUALITY MANAGEMENT

Quality is constantly mentioned as one of the largest competitive priorities that organizations should possess in order to succeed in the markets where they are inserted. Much discussion has been conducted in order to consider and give a context to quality. Such approaches treat quality under the philosophical, economical, marketing and operational definitions.

This situation gives quality a concept in evolution where the changes occurred with time have altered the focus by the control for the focus by the knowledge, based on an industrial society guided by the communication and information, where technical and economic bases for establishment of new paradigms are being built

The following stages are considered the main evolutionary stages for the concept of quality:

- Stage 1: called "Inspection based stage", has the main objective based on the mensuration of specifications, having as focus the uniform quality of the products. Patterns and techniques of mensurations are implemented by the organization's Department of Quality Control.

- Stage 2: called "Stastics Control based stage" has the focus on the process control, aiming the reduction of the number of inspections in the process. The use of techniques and tools of statistical control of quality become implemented by the organization's Department of Production.

- Stage 3: called "Quality Assurance based stage" has as the main objective the distribution of responsibilities related to the evaluation of quality, having the same ones to be appraised in several stages in the organization. The documentation of quality systems and its planning becomes the main aspect in all the departments of the organization.

- Stage 4: called "Total Quality Management based stage", the continuous improvement of the quality is sought in all aspects, the one which is based in the customer's (internal and external of the organization) satisfaction. Motivation of the work force; organizational leadership and strategic focus of the quality are some of the important aspects in this stage.

In that way, the development of this paper aims to consider the concept of Total Quality Management (TQM) as the evolutionary stage of quality that is the most adequated for the organizations nowadays

The concept of TQM (Total Quality Management) has consolidated due to extensive use and practice of the main approaches of quality, constituted at the present time as a pattern of model and administration of subjects related which can be denominated total quality. The classic approaches established by the " gurus " of quality (Feigenbaum, Deming, Juran, Ishikawa, Taguchi and Crosby) among others, are visualized inside the approaches of TQM as "speaking a same language through different dialects".

Other authors also highlighted and consolidated the systemic approach in order to evaluate the quality, that is present in TQM. The integrater role of all aspects of quality that involve people, equipment, computer resources and organizational structures, classify TQM as a concept to reach systemic approaches for the quality management, involving the constant search of the customer's satisfaction, through the integrated use of tools and techniques that involve the continuous improvement of the organizational processes (Badiru and Ayeni, 1994). An approach strongly based on a holistic vision, qualifies TQM as modifier agent of values and social practices, in which paradigms would not be firmly based on the the resources of an organization as own resources, but like global resources. (Mohanty, 1997).

An important situation that is placed in the current days is that regardless TQM has been adopted by many companies with considerable positive effects, the subjects placed in many economies are related to the globalization of markets and the structural consequences of these changes. A larger number of companies has frequently come across diversities of needs requested by the markets where they act. This can involve aspects that embrace from geographical locations to habits and different cultural habits.

Therefore, regardless the approach of quality management that an organization seeks to implement, it is greatly verified that such approach should be designed according to specific aspects considered in each case.

2.1 ASPECTS CONSIDERING A SYSTEMIC QUALITY APPROACH BASED ON TQM CONCEPTS

A model of systemic management of the quality should possess wide inclusion domain where is possible the different agents' interaction that, in general, possess desires, needs and different interpretations about the role of the quality within an organization.

This type of consideration of Axiomatic Design's methodology in the development of organizational systems, was already described previously by Suh (1990; 1995-a; 1997; 2001), as well as explored in the design of a manufacture system (Suh, et al. 1998) and also in the segmentation of production systems considering the lean management principles (Cochran, et al. 2000).

Still considering Axiomatic Design's application in the support to the development of systems, Baxter, et al. (2002) have analyzed its use in the process of design and development of a supply chain.

In what refers to the subject of the quality management, Suh (1995-b) has started this discussion proposing Axiomatic Design's utilization in the construction of a system with emphasis in what it was denominated robust quality. However, the project of a model of systemic management of the quality presents a larger complexity, given the fact that should contemplate tangible and intangible factors coexisting in this same systemic model.

Soderborg, et al. (2002) proposed means to improve the formulation process in Axiomatic Design of FR (Functional Requirements) and DP (Design Parameters), however in relation to the administration of the quality the difficulties still persist, mainly for the different approaches and dimensions that the quality concept can assume.

Thus, a systemic quality management model firstly should characterize which will be the stakeholders that would interact, as well as to characterize which could be the CAs (Customer Atributes) of these stakeholders. In the conception of this proposed systemic quality management model, it was taken as reference a manufacturing company, being then defined four groups of main stakeholders, the ones which interact in a direct or indirect way, with the organization: shareholders; work forces; customers and community where this organization is inserted.

For the characterization of the customer's domain it is necessary then to determine which could be the main needs or desires of these stakeholders in relation to the systemic quality management model, constituting like this to the customer's attributes to be considered in the development of the model.

Table 1 indicates for the stakeholders the respective customer's attributes (CAs)proposed in this systemic quality management model.

Having finished the characterization of the customer's domain and of its attributes (CAs) considered with a systemic management quality model, related to the scope proposed in this paper, is defined an important and fundamental stage in the structuring and characterization of the model.

In the next item of this paper it will be structured the systemic quality management model, being defined the functional requirements (FRs) and project parameters (DPs), respectively characterized inside of its functional and physical domains.

Table 1. Stakeholders and Customers Atributes (CAs) related to the Systemic Quality Management Model

Shareholders of the organization	- Maximize the return of the investment
Work Force of the organization	- To create organizational strategies for the prosperity of the business (CEO

	hierarchical level) - To coordinate the application of tactics for the improvement of organizational performance (Managers hierarchical level) - To implement tactics for the improvement of organizacional performance (Support and Operational Planning hierarchical level) - To execute the tasks proposed for the improvement of the organizacional performance (Shop Floor hierarchical level) - Continuous improvement of the activities in the organization (All hierarchical levels of the organization)
Costumers	- To acquire products that contemplate needs of generated value - To receive products according to established expectations
Community where the organization is located	- Harmonious coexistence with the organization

3 AXIOMATIC DESIGN OF A SYSTEMIC QUALITY MANAGEMENT MODEL

The following step in the design of a systemic quality management model is the determination of the functional requirement of highest level of the hierarchical structure in the functional domain, considering that all the structuring of the systemic quality management model will depend on the choice of this functional requirement of the highest level, being the inferior levels unfolded starting from this chosen functional requirement. For this proposed model it was defined the following functional requirement as the one of highest level in the hierarchical structure:

FR1 : Maximize the return of the investiment

The choice of this functional requirement as the one of the highest level in the hierarchical structure was conducted considering the context previously described and established for the development of this model, being also highlighted as other relevant aspects:

a) Such a functional requirement represents a customer attribute related with the shareholders of the organization, which constitute a group of agents that interact in a more secondary way, with the quality management of a company. Thus, under such point of view, the choice of this FR1 would also represent already the attendance of the needs of these stakeholders.

b) The definition of this FR1 is stablished in the presupposition, considering the logic of capitalist economies, that one of the main purposes of the organizations is the appropriately remunerating of the capital invested by the shareholders . Besides, should be considered that starting from the point in that was possible to a company to generate profits and to assist firstly to the customer's of the shareholders' group attributes, conditions adequated for the existence of this company would be created.So, in this sense, it would be created conditions for that the customers' attributes of another stakeholders (intern collaborators of the organization, consumers of the products of the organization and community in which the organization interferes) could also be contemplated.

After the definition of the functional requirement of highest level in the hierarchical structure of functional domain, it should be proceeded the mapping in the physical domain of which could be the design parameters that assist the FR1 at this hierarchical level. It is highlighted that the FR1 can be assisted by different lines of strategic approach, which can embrace from a financial emphasis to an emphasis focused in operational aspects of an organization. However, the proposal of this work is to look for the conjugation of financial and operational aspects, through the creation of a systemic quality management model that can enable the company to obtain competitive advantages, being addressed by the attendance of the its customers' attributes. Then, in that context, the design parameter determined in the physical domain for attendance of FR1 is given for:

DP1 : Systemic quality management model

Step 2: Building the second level of the hierarchical structure by decomposing FR1 in the Functional Domain, finding the corresponding DPs in the Physical Domain and determining the design matrix.

Having defined the functional requirements and design parameters FR1 and DP1 at the highest level, the next step in axiomatic design is to go back (called "zigzag" process in the Axiomatic Design) to the functional domain from the physical domain, if the chosen DP cannot be implemented without further detailed design. The lower level FRs must be determined by decomposing FR1, which is equivalent to determining the functional requirements of the DP1 chosen.

For the decomposition of FR1 initialy it is necessary some considerations concerning the concept of return on the investment. The denominated return on the investment rate, commonly indicated by the acronym ROI (abbreviation of the expression return over investment), was developed and applied initially in the beginning of the 20th century in the Du Pont Company, as an important accounting measure that facilitated the evaluation of commercial success of its operational units and of the organization as a whole (Johnson and Kaplan, 1987). However, in spite of the financial focus of the ROI rate, in this paper it will not be considered in detail such accounting procedures, having such premise already been adopted by Suh, et al. (1998), where the ROI rate was assumed as:

$$ROI = \frac{Sales - Cost}{Investment} \qquad (1)$$

Having done such considerations and given the decomposition of the functional requirement FR1 (Maximize the return on the investment), the functional requirements determined in the 2nd level of the hierarchical structure of the functional domain were defined as: FR11 (Increase sales revenue of products), FR12 (Minimize expenses in the production) and

FR13 (Minimize investments in the production). It is proceeded now the definition of the corresponding design parameters, and the same ones represent the decomposition of DP1 (Systemic qaulity management model) in the physical domain, being for this case defined for: DP11 (Products which maximize the customer's satisfaction), DP12 (Establishment of the target cost of the product) and DP13 (Systemic evaluation of the investment in the production).

Products that maximize the customer's satisfaction (DP11) will be those that will have its purchase preference, so that according to personal approaches the consumer will look for maximize the satisfaction at the moment of the purchasing of the product. Like this, products that maximize the customer's satisfaction (DP11), allow to increase the revenue of sales of products (FR11). Besides, starting from the point where occurs the maximization of the consumer's satisfaction, less changes in the products are necessary, less marketing actions are required, becoming the production resources more adaptive and focused on the customer's satisfaction. This situation also improves the utilization of the productive capacity, making possible an adaptation of the investments that will be done to assist the market demand, assisting the consumer in what he/she wants and in the time in that he/she needs. In that way, products that maximize the customer's satisfaction (DP11), would also facilitate to minimize expenses of the production (FR12) and investments in the production (FR13).

The establishment of a target cost of the product (DP12) is conditioned to the price that the market would be willing to pay for the product, affecting in this sense the level of insertion and competition of the product in the market, that is to say, the target price. The lower is the target price of the product, comparatively with the competitive products in the market, the larger can be the competitive advantage of the product based on the aspect price to the consumer. In that way, the establishment of a target cost of the product (DP12) facilitates to minimize expenses in the production (FR12) and to minimize investments in the production (FR13), since a product will only be produced starting from the point in that its production cost is smaller or equal to the target cost defined by the conditions of the market.

The systemic evaluation of the investment in the production (DP13) is centred in the premise of improvement of investments seeking to obtain a larger financial return for the invested capital, that is to say, for an invested capital aiming to improve the flexibility of the production system considering its productive capacity in terms of quantity and diversity of products obtained. In that way, considering the premisses formerly proposed in this papaer, the systemic evaluation of the investment in the production (DP13) would facilitate to minimize investments in the production (FR13).

Having been determined the group of FRs and DPs, it is necessary to determined the design equation and matrix, verifying if the Independence Axiom is observed. For this case the following situation is determined:

$$\begin{Bmatrix} FR\,11 \\ FR\,12 \\ FR\,13 \end{Bmatrix} = \begin{bmatrix} X & 0 & 0 \\ X & X & 0 \\ X & X & X \end{bmatrix} . \begin{Bmatrix} DP\,11 \\ DP\,12 \\ DP\,13 \end{Bmatrix} \tag{2}$$

X means a strong relationship between FRs and DPs., and is verified in this case that it was obtained a triangular matrix which characterizes a decoupled design and satisfies the Axiom of Independence, having been characterized like this the second hierarchical level of the proposed systemic quality management model.

Step 3: Building the third level of the hierarchical structure by decomposing FR1x in the Functional Domain, finding the corresponding DP1x in the Physical Domain and determining the design matrix.

Starting from the 2nd level of the hierarchical structure, is possible to visualize the formation of 03 branches that were originated respectively by FR11, FR12 and FR13, and each branch assists to the functional requirement of higher level, that in this case is FR1. Each branch will have different influences in the systemic quality management model (DP1), that is why they should be analyzed in an individualized way.

a) FR11: Sales Revenue Branch

Functional requirement FR11 (Increase sales revenue of products) must be decomposed with DP11 (Products which maximize the customer´s satisfaction) in mind.The sales revenue (SR) is obtained through the following formula, considering n as the number of products.

$$SR = \sum_{i=1}^{n} Price_i \times Volume_i \tag{3}$$

Following this logic, FR11 may be decomposed., with DP11 in mind as: FR111(Maximize the price considering the value perceived by the customer) e FR112 (To increase the amount of sold products).

The corresponding DPs may be chosen as: DP111(Product differentiation) e DP112 (Product with larger acceptance in the market).

The design matrix for these set of FRs and DPs is:

$$\begin{Bmatrix} FR111 \\ FR112 \end{Bmatrix} = \begin{bmatrix} X & 0 \\ X & X \end{bmatrix} . \begin{Bmatrix} DP\,111 \\ DP\,112 \end{Bmatrix} \tag{4}$$

In order to maximize the price considering the value perceived by the customer (FR111), it should settle down a product differentiation (DP111) which would contemplate the group of the customer's values when on the act of the purchase of the product. The product differentiation (DP111) can also increase the amount of sold products (FR112), as new potential customers can feel positively influenced by another former captive customer or to be attracted for the adopted marketing strategies. To increase the amount of sold products (FR112), it should be implemented actions that permit that the products have a larger acceptance in the market (DP112), highlighting the premise of free competition of markets, which would impede or minimize the formation of oligopolist markets. It is characterized in that way a decoupled design, satisfying the Independence Axiom at this hierarchical level of the proposed systemic quality management model.

b) FR12: Production Expenses Branch

FR12 (Minimize the production expenses) may be decomposed with DP12 (Determination of the target cost of the product) in mind, as: FR121(Establish the target cost of the production) and FR122 (Establish a limit for the overhead in the produsction activities). At this point, it is important to highlight that in this paper it was considered costs as the expenses consumed in the production processes and overhead as the expenses consumed in order to improve the revenues.

In that conditions, the corresponding DPs may be stated as: DP121 (Focus based in the strategic cost management) and DP122 (Management of the overhead in the production system)

The design matrix for these set of FRs and DPs is:

$$\begin{Bmatrix} FR121 \\ FR122 \end{Bmatrix} = \begin{bmatrix} X & 0 \\ 0 & X \end{bmatrix} \cdot \begin{Bmatrix} DP121 \\ DP122 \end{Bmatrix} \qquad (5)$$

The focus based in the strategic cost management (DP121) is based in the cost analyses considering a broader approach than the tradictional focus which is centraded only in the financial and account matters, considering strategic and operational elements as important subjects in the cost determination. In this context of the focus based on the strategic cost management system it should be then defined the target cost of the production (FR121). The management of the overhead in the production system (DP122), tries to establish a control about possible reductions in the net assets of the company, having seen that the accounting logic of reduction of overhead is directly given by the turnover. In that way, the management of the overhaead in the production system (DP122) can establish bases that permit the company to create politics that control the limits of administrative expenses in the production (FR122), highlighting that in the proposal of the systemic quality management model the expenses related with sales efforts and financings will not be focused.

c) FR13: Investment in the Production System

FR13 (Minimize the investiments in the Production System) may be decomposed with DP13 (Systemic Avaliation of the Production System Investiment) in mind, as: FR131 (Evaluate investments in machines), FR132 (Reduce investments in raw materials and inputs) e FR133 (Evaluate investments in operational infrastructure).

The coresponding DPs may be chosen as: DP131 (Focus in the acquisition of equipments which can be adaptive to the alterations of the demand), DP132 (Focus in low inventory levels) and DP133 (Focus in the implementation of facilities adaptive to changes).

The design matrix for these set of FRs and DPs is:

$$\begin{Bmatrix} FR131 \\ FR132 \\ FR133 \end{Bmatrix} = \begin{bmatrix} X & 0 & 0 \\ 0 & X & 0 \\ X & X & X \end{bmatrix} \cdot \begin{Bmatrix} DP131 \\ DP132 \\ DP133 \end{Bmatrix} \qquad (6)$$

The focus in the acquisition of equipment which can be adaptive to the alterations of the demand (DP131), permit to evaluate the investments in machines (FR131), considering the view of the acquisition of machines and equipment whose productive capacity was dimensioned to assist the customer's demand, presenting low complexity in the configuration and operation, reducing in that way the need of rigid automation incorporated in the machine or avaliable in the production system in the support activities. The acquisition of equipment which can be adaptive to the alterations of the demand also could conduce to the necessity of evaluate investments in operational infrastructure (FR133).

The focus on the low inventory level (DP132) permits to reduce investments in raw materials and inputs (FR132), according procedures well know by the JIT (Just in Time) techniques which are based in the elimination of wastes. It is also possible to evaluate investments in operational infrastructure (FR133), because it would be necessary different activities to support the matters related with logistic distribuition and material management.

The focus in the implementation of facility adaptive to changes (DP133), facilitates evaluate investments in operational infrastructure (FR133), considering that the alterations of shop floor layout were conducted considering the operational infrastructure (electric facilities, nets of compressed air and water, refrigeration systems, systems of collections of residues, etc.) already existent.

Regarding the proposal of a systemic quality management model, it is characterized that the DP132 satisfy at this hierarchical level the functional requirement FR132, and for this branch stopped at this level the process of decomposition.

It is characterized a triangular matrix of a decoupled design, which satisfies the Independence Axiom of the Independence at this hierarchical level of the proposed systemic quality management model.

Step 3: Building the fourth level of the hierarchical structure by decomposing FR1x in the Functional Domain, finding the corresponding DP1x in the Physical Domain and determining the design matrix.

The establishment of the 4th level of the hierarchical structure comes from maintaining the branches previously defined, the functional requirements established in the 3rd level of the hierarchical structure being decomposed, that are: FR111 (Maximize the price considering the value perceived by the customer), FR112 (Increase the amount of sold products), FR121 (Establish the target cost of the production), FR122 (Establish a limit for the overhead in the produsction activities), FR131 (Evaluate investiments in machines) e FR133 (Evaluate investments in operational infrastructure).

a) FR11x: Sales Revenue Branch

Functional requirement FR111 (Maximize the price considering the value perceived by the customer) must be decomposed with DP111 (Product differentiation) in mind, being obtained: FR1111 (Differentiate the price in function of tangible values demanded by the customer) and FR1112 (Differentiate the price in function of intangible values demanded by the customer).

In that condition, the corresponding DPs may be stated as: DP1111 (Products in conformity with the customer's expectations) and DP1112 (Products with superior quality perceived by the customer).

The design matrix for these set of FRs and DPs is:

$$\begin{Bmatrix} FR1111 \\ FR1112 \end{Bmatrix} = \begin{bmatrix} X & 0 \\ X & X \end{bmatrix} \cdot \begin{Bmatrix} DP1111 \\ DP1112 \end{Bmatrix} \qquad (7)$$

Products in conformity with the customer's expectations (DP1111) facilitate to differentiate the price in function of tangible values demanded by the customer (FR1111), because the tangible values are related in a more deterministic way to the primary characteristics of the products, that are demanded by the customer. However, the customers' expectations can also be addressed by intangible aspects, that can vary according to the customers' subjective values. Then, DP1111 also facilitates to differentiate the price in function of intangible values demanded by the customer (FR 1112), as that different customers possess different perceptions of the product. Products with superior quality perceived by the customer (DP1112), are related to each customer's individualized perception, being able in that way to differentiate the price in function of intangible values demanded by the customer (FR 1112). Thus, it is obtained a matrix that characterize a decoupled design, which satisfies the Independence Axiom.

Functional requeriment FR112 (Increase the amount of sold products) must be decomposed with DP112 (Product with larger acceptance in the market) in mind, being in this case: FR1121 (Search new consuming markets) and FR1122 (Conquer markets from the competitors companies).

In that conditions, the corresponding DPs may be stated as: DP1121 (Creation of new products) and DP1122 (Better attendance of the customer's desires).

The design matrix for these set of FRs and DPs is:

$$\begin{Bmatrix} FR1121 \\ FR1122 \end{Bmatrix} = \begin{bmatrix} X & 0 \\ X & X \end{bmatrix} \cdot \begin{Bmatrix} DP1121 \\ DP1122 \end{Bmatrix} \qquad (8)$$

The possibility of increase the amount of sold products (FR112) would happen in two main ways: through creation of new products (DP1121), which facilitates to search new consuming markets (FR1121), implying in diversification of the mix of products offered by the company. This situation would also facilitate FR1122 (Conquer markets from the competitor companies(FR1122), as other options were placed for to the customers facilitating to the same ones the possibility of compare several products. Better attendance of the customer's desires(DP1122) facilitates conquer markets from the competitor companies (FR1122), being this situation restricted to the markets where the company has already been acting, possessing a group of customers.This design is decoupled and thus satisfies the Independence Axiom.

b) FR12x: Production Expenses Branch

Functional requirement FR121 (Establish the target cost of the production) must be decomposed with DP121 (Focus based in the strategic cost management) in mind, obtaining: FR1211 (Reduce raw materials and components costs) and FR1212 (Reduce operational activities costs).

In that conditions, the corresponding DPs may be stated as: DP1211 (Prices negotiation in the supply chain) and DP1212 (Performance improvements of operational activities).

The design matrix for these set of FRs and DPs is:

$$\begin{Bmatrix} FR1211 \\ FR1212 \end{Bmatrix} = \begin{bmatrix} X & 0 \\ X & X \end{bmatrix} \cdot \begin{Bmatrix} DP1211 \\ DP1212 \end{Bmatrix} \qquad (9)$$

Prices negotiation in the supply chain (DP1211) allows to establish opportunities in order to reduce raw materials and component costs (FR1211), as an agreement occours involving from raw materials to finished products suppliers, having as commom objective the determination of target price accepted by the market. The prices negotiation among the suppliers of the chain also create opportunities to reduce operational activity costs (FR1212), as new ways of parthnerships between supplier and customer were established. Performance improvements of operational activities (DP1212) allows generate opportunities in order to reduce operational activity costs (FR1212), fundamentally related with the performance improvement of activities of internal movement, set up of machines and equipment, processing, assembly and maintenance. It is characterized in that way a triangular matrix of a decoupled design, which satisfies the Independence Axiom.

Functional requirement FR122 (Establish a limit for the overhead in the production activities) must be decomposed with DP122 (Management of the overhead in the production system) in mind, as: FR1221 (Adapt functional structures with the necessity of the company) and FR1222 (Outsource administrative activities not important for the company).

In that condition, the corresponding DPs may be stated as: DP1221 (Functional structure driven by process management) and DP1222 (Outsourcing of administrative activities not important for the company).

The design matrix for these set of FRs and DPs is:

$$\begin{Bmatrix} FR1221 \\ FR1222 \end{Bmatrix} = \begin{bmatrix} X & 0 \\ X & X \end{bmatrix} \cdot \begin{Bmatrix} DP1221 \\ DP1222 \end{Bmatrix} \qquad (10)$$

The functional structure oriented by process management (DP1221) allows the company to adapt the functional structure with the necessity of the company (FR1221), in order to answer quickly to the necessities and opportunities of the market, with possibilities of process management through functions. Such situation of restructuring of the functional structure would also allow to create conditions for outsource administrative activities not important for the company (FR1222), because the company starts to focus on its key activities, executing the same with larger competent. The outsourcing of administrative activities not important to the company (DP1222), allows to the company outsource such administrative activities (FR1222), looking for to reduce or to establish limits to the administrative expenses in the production, keeping the focus on those activities that the company really executes with competence. It is characterized in that way a triangular matrix of a decoupled project, which satisfies the Independence Axiom.

Considering the scope adopted in the systemic quality management model, the funcional requirements FR1221 and FR1222 satisfy the necessities at this level of the hierarchical structure and will not be decomposed in inferior levels, being constituted in this hierarchical level with the corresponding design parameters DP1221 and DP1222.

c) FR13x: Investment in the Production System

Functional requirement FR131 (Evaluate investiments in machines) must be decomposed with DP131 (Focus in the acquisition of equipment which can be adaptive to the alterations of the demand) in mind, being obtained: FR1311 (Maximize the flexibility to assist variations of the volume and productive mix) and FR1312 (Maximize the flexibility for introduction of new products).

In that condition, the corresponding DPs may be stated as: DP1311 (Adaptive equipment to the continuous flow of production) and DP1312 (Configurable equipment with low operational complexity).

The design matrix for these set of FRs and DPs is:

$$\begin{Bmatrix} FR1311 \\ FR1312 \end{Bmatrix} = \begin{bmatrix} X & 0 \\ X & X \end{bmatrix} \cdot \begin{Bmatrix} DP1311 \\ DP1312 \end{Bmatrix} \tag{11}$$

Adaptive equipment to the continuous flow of production (DP1311) allows maximize the flexibility to assist variations of the volume and productive mix (FR1311), assisting in the short term alterations in the mix and volume of the production system. The adoption of the continuous flow of production for its time also has influence to maximize the flexibility for introduction of new products (FR1312), in the sense that the production system can faster answer to the alteration on the demand of the market. Configurable equipment with low operational complexity (DP1312) allows maximize the flexibility for introduction of new products (FR1312), contemplating in that way the vision of long term in the concept of the flexibility to substitutions. It is defined in this case a triangular matrix of a decoupled design, that satisfies the Independence Axiom.

Functional requirement FR133 (Evaluate investments in operational infrastructure) must be decomposed with DP133 (Emphasis on the implementation of facilities adaptative to the changes) in mind, as: FR1331 (Facilitate alterations in the configuration of implanted facilities) FR1332 (Guarantee facilities adapted to variations of the productive mix).

The design matrix for these set of FRs and DPs is:

$$\begin{Bmatrix} FR1331 \\ FR1332 \end{Bmatrix} = \begin{bmatrix} X & 0 \\ X & X \end{bmatrix} \cdot \begin{Bmatrix} DP1331 \\ DP1332 \end{Bmatrix} \tag{12}$$

Infraestructure and facilities modulate and removable (DP1331) allow conditions to facilitate alterations in the configuration of implanted facilities (FR1331), facilitating that kind of infraestructure could accompany the modifications imposed due to the alterations in the demand volume. In that way, as are available infraestructure and facilities modulate and removable (DP1331), also better conditions are generated in order to guarantee facilities adapted to variations of the productive mix (FR1332). Infraestructure and facilities oriented to the company´s business (DP1332) allows appropriately guarantee facilities adapted to variations of the productive mix (FR1332), because as the business in process are concluded there would be the possibility to adapt the infrastructure for attendance of new business. Thus, in this situation it is characterized a ecoupled design, which satisfies the Independence Axiom.

At this level of the hierarchical structure, the functional requirements FR1311, FR1312, FR1331 and FR1332, as well as their respective design parameters, will not be decomposed in inferior levels, concluding in this point the analysis related with the branch of investments in the production system. It is considered that the functional requirements and the respective design parameters which were already decomposed satisfies the proposed systemic quality management model.

In that way, being proceeded systematically to the unfolding procedures and decomposition of the functional domains and of project, it is possible the structuring of the denominated nested diagrams of functional requirements (FRs) and project parameters (DPs). The diagrams of nested structures of FRs and DPs are also known like " diagram-tree " of FR and DP, indicating the established hierarchy of FRs in the functional domain and DPs in the physical domain.

4 REPRESENTATION OF SYSTEMIC QUALITY MANAGEMENT MODEL ARCHITECTURE

Through the application of the principles established by Axiomatic Design's methodology the proposal of the model of systemic administration of the quality was developed, being in its totality composed by 50 functional requirements and 50 project parameters, related through 21 project matrices and unfolded in 7 hierarchical levels.

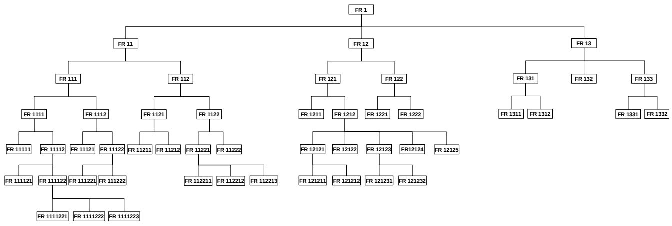

Figure 1: Functional Requirement - Design Parameter Decomposition Hierarchy

The systemic quality management model designed in the preceding section has an architecture – hierarchical structure in the FR-domain and DP domain with a defined relationship given by the design equations and design matrices (Suh, 1990) and according to the manufacturing system design proposed by Suh, et al. (1998).

The system architecture can also be represented by the the module-junction diagram, and the flow diagram (Kim, et al., 1991; Suh, 1997) which is a concise and powerful tool that provides a map for the implementation of the system design. The flow diagram illustrates the design relationships and the precedence of implementation based on design matrices of each level of the design decomposition.

Each design matrix represents a junction and shows how the lower-level modules must be assembled to yield the desired FR. The concept of "modules" is used to relate the FRs to DPs. A module is defined as the row of the design matrix that yields an FR when it is provided with the input of its corresponding DP. The flow chart of the systemic quality management model is showed in the Figure 2.

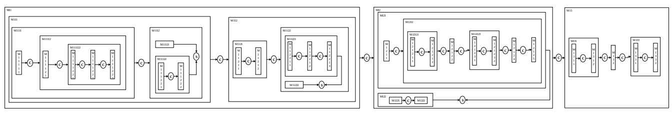

Figure 2: The Flow Chart of the Systemic Quality Management Model

Other important analysis conducted was the development of the Complete Design Matrix as showed in the Figure 3.

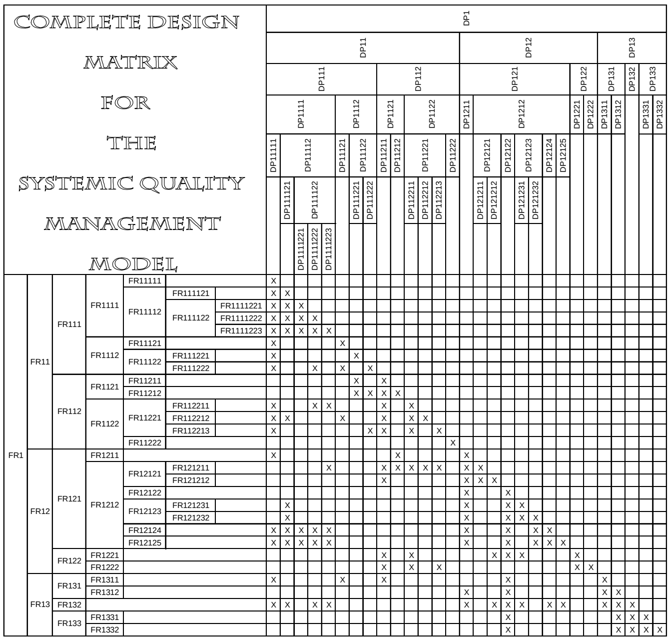

Figure 3 : Complete design matrix for the Systemic Quality Management Model

The determination of this consolidated matrix, was through the established analysis between " DPs leaf " and " FRs leaf " in the proposed model, and X in the matrix indicates the situation of strong relationship between DP and FR. Previously it was marked in the consolidated matrix the relationships established by the matrices. Later on, for the vertical analysis it was verified if a " DP-leaf " (columns) established a strong relationship with them " FRs-leaf " (lines), regardless the level and of the hierarchical branch in that occurred such influence.

In the consolidated matrix, developed for the proposed model of systemic administration of the quality, it is possible to verify that it is a decoupled project, where DPs exercises influence on one or more FRs, without, however, to violate the axiom 1, that is to say, guaranteeing that through an ordered adjustment of DPs there is a possibility to guarantee the independence of FRs. Thus, one of the main characteristics of the consolidated matrix is to verify the consistency of the project in what it refers to constitute in a coupled, uncoupled or decoupled project.

5 SUMARY

The axiomatic approach used in the development of this work showed application viability, as well as a significant potential in the structuring of a methodology for the construction and systematization of a model of quality administration, that should not be only based on the pragmatism of the certifications of quality systems, but also can capture certain abstractions and relative complexities to the context where it interferes in the organizations. The characterization of the customer's attributes (CAs) and the definition of the functional requirements seeking to contemplate such attributes of the customer, addresses what can be denominated as " good project practices ", besides contemplating such mentioned aspects and longed by models of quality administration focusing TQM (Total Quality Management), in the sense to be focused and addressed by the customers.

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