INDEPENDENT JOURNAL OF MANAGEMENT & PRODUCTION (IJM&P)
http://www.ijmp.jor.br v. 4, n. 1, January – June 2013.
ISSN: 2236-269X
DOI: 10.14807/ijm&p.v4i1.79

ASSOCIATION OF COSTUMER VALUE CHAIN ANALYSIS TO QUALITY FUNCTION DEPLOYMENT: DIFFERENT IDENTIFIED COSTUMERS AND REQUIREMENTS ON DEVELOPMENT OF CPM DEVICE

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Submission: 29/04/2013
Accept: 20/05/2013

ABSTRACT

This study aims to present the differences between the use of QFD and its association with CVCA tool in the development of a CPM device for elbow and forearm rehabilitation. To achieve this goal, the study was divided into three steps. The development of a conceptual model that integrates the proposed CVCA + QFD tool for application in the health device development was done in the first step. The second step consisted of applying the proposed model, referring to the QFD method using 8 matrixes: quality matrix, product, characteristics of the parts, process, process parameters, human resources, infrastructure and costs matrix. The proposed conceptual

ISSN: 2236-269X
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model was employed fully in the third step, allowing the comparison between the methods. The results enabled to identify a discrepancy between the critical costumers in the use of mentioned methods. Customers were limited to the direct and indirect users in the QFD application: the patient, physician and physical therapist. This list got a considerable increase when CVCA was applied: the clinical engineering, product engineering, process and reliability engineering, project and product managers, financial sector, quality system and regulatory issues. These results show the importance of analyzing the supply chain systemically in order to consider all stakeholders to the CPM device development. Thus, needs and relationships delineation of all process customers can be done.

Keywords: quality management; QFD; CVCA; product development; continuous passive motion.

1. INTRODUCTION

New technologies are revolutionizing services delivery since the last half century. The health sciences seek to resolve research problems integrating multidisciplinary teams involving engineering skills and other physical sciences into life sciences (SHINE, 2004). This integration is visible in the health products development, such as devices for the application of continuous passive motion (CPM) in the human body's joints, such as the elbow and forearm. These devices are used in post-operative, post-trauma of joint injuries and cartilage avascular healing (MAVROIDIS et al., 2005) and (CALLEGARO, 2010).

According to Gadelha (2006), developed countries that compete in better conditions with advanced countries have associated endogenous basis of knowledge, learning and innovation with a strong industry. Zago (2004) states the acquisition of itself experience is essential to the planning of scientific development in health. As a result, Brazil needs to develop national technology to be able to compete or replace the imported technology.

Shine (2004) emphasizes the development of new devices for health, requires, besides multidisciplinary teams, and the costumer involvement in the value chain of the product. Martin et al. (2006) point out the identification of needs is important to the development of new products, when they are performed early in the process. These needs can ensure the incorporation of new features to prototypes with greater facility and lower cost. According to Rozenfeld et al. (2006), needs become functional

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ISSN: 2236-269X
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requirements of a new product and, in accordance with Silva (2004), they contribute for the development of products with higher quality, safety and reliability.

Andrietta and Miguel (2002) believe the understanding the Voice of Customer (VOC), in others words, their needs, expectations, requirements and desires is a step of fundamental importance. It is in this stage that the VOC are translated on technical requirements, specifications, products, processes and services. Its understanding and exact translation can be obtained by using the Quality Function Deployment Method (QFD Method). Cheng (2003) asserts the QFD method seeks to coordinate the control and quality improvement, integrating them with the market. This method is widely known and applied in the development of several products in the world and it aims at the consensus attainment of agreed actions in development projects to facilitate participants' learning and understanding.

The involvement of customers of the product value chain in product development for health can be understood by the systemic approach of the value chain. This approach allows the viewing of the group of actors that integrates their knowledge and skills to develop products focused on individuals and organizations (KRUCKEN, 2009). Thus, the association of Customer Value Chain Analysis tool (CVCA) to QFD can assist in innovation and consequent creation of value to the health products. The CVCA tool helps in understanding the business unit, product value chain and identification of critical customers (DONALDSON et al., 2006), while the QFD method assists the requirements management, one of the fundamental activities in the product development process (ROZENFELD et al., 2006).

Based in this context, the need to identify the differences between the QFD method application in relation to its association with the CVCA tool is justified when they are used in the development of CPM device for elbow and forearm rehabilitation. Emphasizing differences in the identification of critical costumers of the device value chain and business units of this product as well the demanded quality and results of deployment of QFD matrices.

Thus, this paper aims to present differences between the use of QFD and its association with CVCA tool in the development of CPM device for elbow and forearm rehabilitation. The structure comprises the following sections: (i) the literature review on the research topic; (ii) procedures used to reach the proposed objective, (iii) results and discussion, and (iv) study conclusions.

2. LITERATURE REVIEW

This section presents definitions and theoretical foundations on the development of products in health, CVCA and QFD, which support this study.

2.1 Product Development for Health

The growing technification procedures for health makes this area one of the most dynamic in relation to the absorption of new technologies produced and consumed according to the market logic. Technological advances are related to the introduction of information technology, modern and sophisticated devices that benefited and allowed speed in the fight against diseases (BARRA et al., 2006).

The device industry related to the health field is characterized by a strong interdisciplinary content, in which the involvement of health specialists is crucial to the making of innovations. They give a support to identify needs and possibility of new devices, creating the first prototype and decisive improvement in the development of the devices (ALBUQUERQUE and CASSIOLATO, 2002). Furthermore, Back et al. (2008) assert that differentiated products of high quality are achieved primarily with the high quality of the product design, which is only achieved with teams that integrate different and relevant knowledge's to product design development.

The use of different technologies has increased in Physical Therapy as well as the interest increasing of professionals in this field. Physical Therapists use devices from simple to complex to assist in the kinetic-functional diagnostics, in the prescription, the planning, the managing, the analyzing, the monitoring and the evaluation of treatment (WALDROP, 2003). According to Cooper et al. (2008), the technology used to assist the physical therapeutic treatment qualifies the therapy received by the subject and it improves his engagement with the treatment. The computerized technology assists the patient in performing movements that require assistance of the Physical Therapist. Continuous Passive Motion devices (CPM) are used in the rehabilitation of patient's limb joints (LENSSEN et al., 2008). The use of these devices assists the performing of passive joint movements continuously during the initial phase of rehabilitation (HEBERT et al., 2003). A prototype of CPM device for elbow and forearm rehabilitation can be viewed in the Figure 1 (1); Figure 1 (2) shows how the patient positions his arm at the device.

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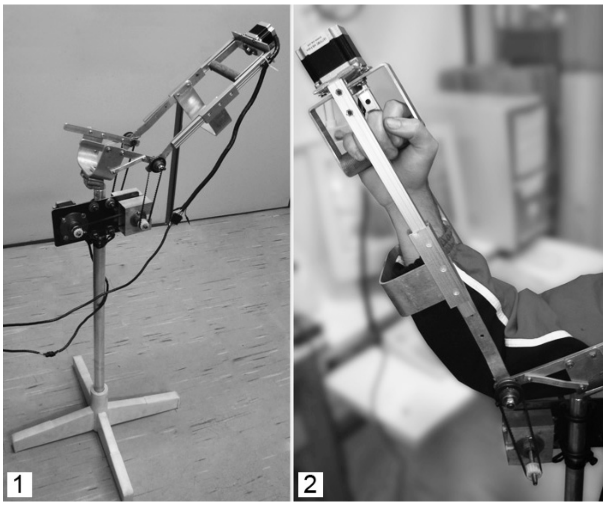

Figure 1: (1) Prototype of Computerized CPM Device for Elbow and Forearm Rehabilitation; (2) Arm positioned on CPM.
Source: Callegaro (2010).

Studies about CPM devices are more advanced for lower limb joints, especially the knee (SPERB, 2006) and (MAVROIDIS et al., 2005). But there is a demand by professionals work in elbow and forearm rehabilitation for CPM devices to help these joints treatment, indicating the need for researches focused on the upper limbs (MAVROIDIS et al., 2005) and (CALLEGARO et al., 2011).

2.2 Customer Value Chain Analysis – CVCA

Value is a concept created by the own value chain that guides each organization or tool management, it is crucial to the survival of a business model (PETETIN et al., 2010). Economy, intellectual capital and intangible assets are included in the values networks of the business model knowledge (ALLEE, 2000). Miccoli (2004) adds there are two types of influencers interfering in the life and values of organizations: external - owners, associates (suppliers, customers, partners and competitors), the employees' associations, trade unions and the various audiences that surround them all; and internal – members of the organization themselves.

When it comes to an innovative product, values that will be created or destroyed by it are key factors in deciding upon its release. It is, therefore, essential the design team early in the process of product development define precisely what types of values a business model has (PETETIN et al., 2010), as well as parties involved in the product's life cycle - stakeholders - and their relationship with the product. That's because interested parties often have different perceptions, including when it concerns about understanding the value assigned by project management

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(DONALDSON et al., 2006). The CVCA is a tool allows, in the product definition phase, the identification in a comprehensive manner of relevant stakeholders, relationships with each other and their role in the product life cycle. This increases the team's ability to recognize the diverse requirements of the product and priorities to define the product.

CVCA is a strategic and tactical tool, implemented from the organization's business model which has seven stages: i) to define the initial business model and its assumptions; ii) to delineate the parties involved with the product; iii) to determine how the parts relate; iv) to identify the relationships between the parties defining flows between them; v) to analyze the resulting CVC (customer value chain) to determine the critical customers and their propositions; vi) to include the information in PDA (Product Definition Assessment); and vii) to use the results of CVCA in the product project process (DONALDSON et al., 2006). These authors state that the CVCA's seventh stage consists in using the results of the value network analysis for the application of other tools such as Failure Mode and Effect Analysis (FMEA); Design for X (DfX); Quality Function Deployment (QFD) and others.

2.3 Quality Function Deployment – QFD

Quality Function Deployment (QFD) can be defined, according to Akao (1996), as a method aims to establish the quality of the project and also to obtain customer satisfaction. The complete conceptual model, originally developed in Japan, consisted of a total of 22 matrices in 27 implementation steps, covering the deployment of four dimensions: quality, technology, cost and reliability. Since its construction depends entirely on the project objectives and the product nature, among other characteristics, has the possibility to adapt it (CHENG and MELO FILHO, 2007). An example of adaptation is the model of 7 matrices proposed by Ribeiro et al. (2001).

Particularly, in the medical field, subject of the present study, some applications were found as follows: i) application of the method in an approach to improving the service offered by a podiatry clinic to relocate operations to provide services more comprehensive and satisfactory for both physicians and patients (MAZUR et al., 1995); ii) understanding of customer requirements and their inclusion to continuous improvement of the quality of the services provided by the health care system (Radharamanan and Godoy, 1996); iii) QFD employed in developing a

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computational network service support for occupational therapists (HALLBERG et al., 1999); iv) method used in the design and development of a range of simple medical diagnosis with a high degree of precision (LIU et al., 2009); v) verification of the ability to plan for quality in family health units, through the use of QFD (VOLPATO et al., 2010); vi) application of QFD in order to improve outpatient services for elderly patients (KUO et al., 2011).

Thus, all the applications listed relate to the services sector in the medical field. A similar situation occurs in the studies developed in Brazil, and not just in this particular area, but in general. Sassi and Miguel (2002) have shown that the use of QFD in Brazilian territory is more frequent in the service sector with the goal of improving the provision of services and, consequently, increase customer satisfaction.

3. METHODOLOGY

This research is characterized as a qualitative study. Based on its overall objectives, it is classified as exploratory as it aims to provide greater familiarity with the problem and thus make it more explicit (GIL, 2002). The definition of methods and techniques involves the methodology used to achieve each specific goal and, consequently, the overall goal of the research. To achieve this goal, the study was divided into three steps. The first step consisted of applying the proposed model, referring to the QFD method using eight matrices: quality, product, parts characteristics, process, process parameters, human resources, infrastructure and costs. The development of a conceptual model that integrates the proposed CVCA + QFD tool for application in the development of health device occurred in the second step. The proposed conceptual model was employed fully in the third step, allowing the comparison between the methods.

3.1 First Step - Application of Adapted QFD

The first step consisted of using a adapted conceptual QFD model from Ribeiro et al. (2001), which employs the use of seven matrices, as follows: quality, product, parts characteristics, process, process parameters, human resources, infrastructure and costs (Figure 2). Instead of seven matrices, eight were applied in this research, because the human resources and infrastructure matrix was deployed into two, i.e. human resources matrix and infrastructure matrix. The identification of the target population to be studied occurred prior to the application of the matrices,

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and relied on the criteria of prior knowledge of device or possible relationship to the value chain of the device in question, according to the perception of researchers.

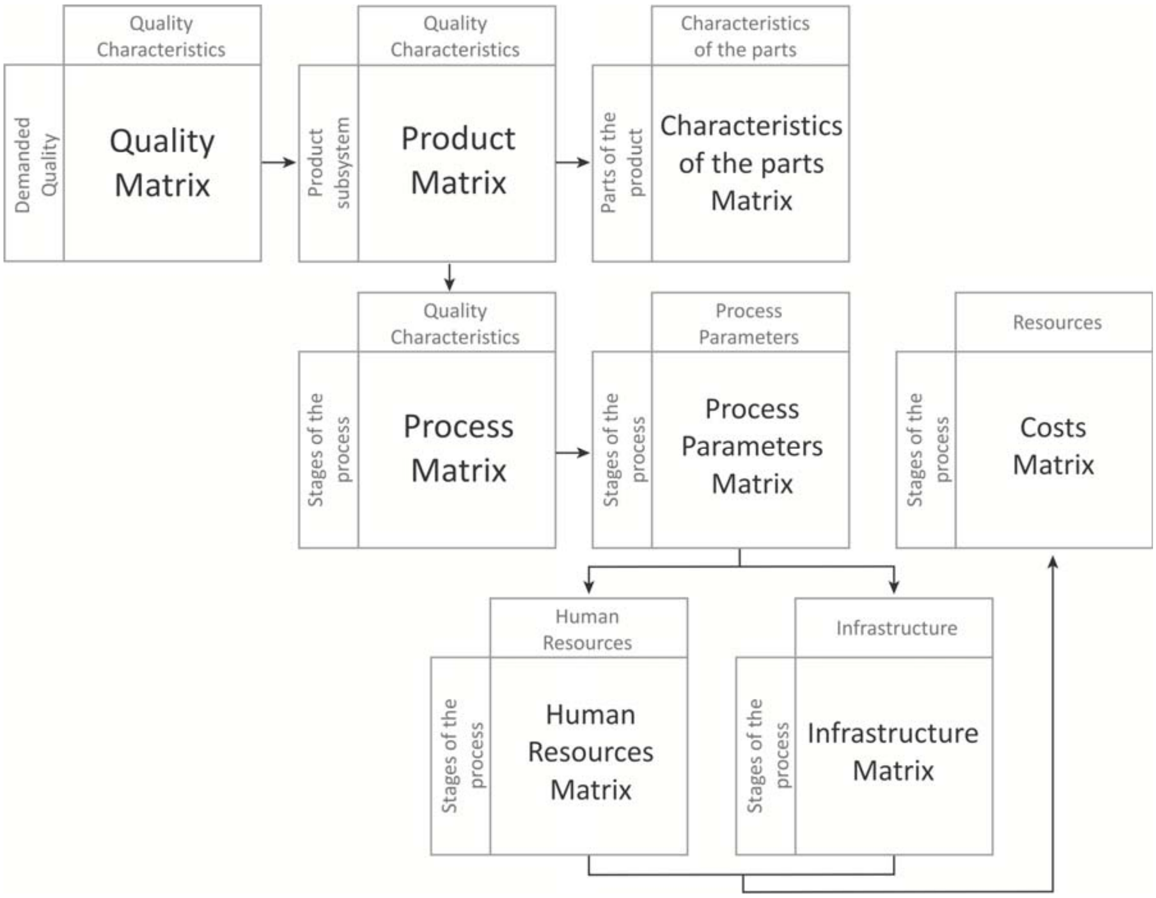

Figure 2: QFD conceptual model adapted from Ribeiro et al. (2001).
Source: primary.

3.2 Second Step - CVCA+QFD: The Proposed Conceptual Model of the CVCA Associated with QFD

A model that integrates CVCA and QFD tools is proposed in this step (Figure 3). The CVCA tool facilitates the identification of critical customers and carries out analysis of the value chain.

First, one analyzes the value chain using the steps of the CVCA. To that end, there was an adaptation of the steps proposed by Donaldson et al. (2006), i.e. used the first five steps that actually related to the customer's value chain. The last two refer to the use of information obtained in the definition of product evaluation and design process. Therefore, the steps were followed:

- Define the initial business model and assumptions;
- Delineate the pertinent parties involved with the product;

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- Determine how the parties are related to each other;
- Identify the relationships among the parties by defining flows between them;
- Analyze the resulting Customer Value Chain to determine critical customers and their value propositions (DONALDSON, 2006).

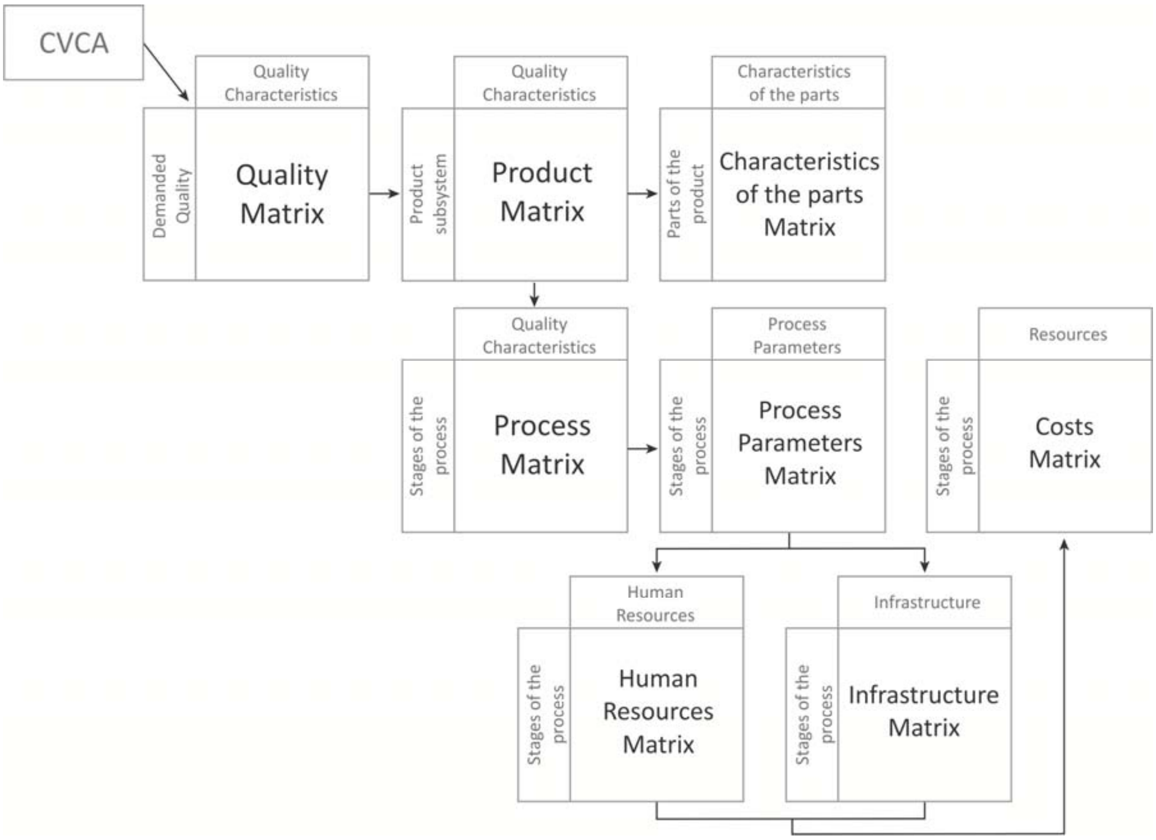

Figure 3: CVCA+QFD model for health product development.
Source: primary.

After identifying critical customers, the remaining steps which coincide with the conceptual model of QFD adapted from Ribeiro et al. (2001) were applied normally until the construction of the quality matrix.

3.3 Third Step – Application of CVCA+QFD

The application of the proposed model CVCA+QFD in the development of a CPM machine for elbow and forearm rehabilitation was in a medical, physical therapy, and hospital products company of a city in the State of Rio Grande do Sul, Brazil. The company was selected because of the developed products technologies and the market areas provided synergies with those of the above-mentioned device. Discourse on the results in the following section.

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4. RESULTS & DISCUSSION

This section presents and discusses the main differences identified in the QFD application related to its association with CVCA in the following steps: critical costumer's definition; demanded quality survey; demanded quality deployment, deployment of product and its parts, deployment of process and its parameter. The human resources deployment, infrastructure deployment and costs deployment are not discussed because there were no differences when compared with the first application. In other words, in the human resources matrix deployment, it was noted in both applications the production supervisor and the process and quality engineers play crucial roles to ensure compliance with the process specifications. In the infrastructure matrix, cutting machines were identified as the most important resources, because its excellence will provide quality in the essential parts of the final product. In the costs matrix, the molding process and the cuts finishing, assembly, polymers and fabrics cuts and finishing had the highest monthly costs.

4.1 Critical costumers definition

The present study revealed a discrepancy between the costumers considered critical, the association between the QFD and the CVCA tools had an effect on the customer's definition. The QFD application showed the costumers were limited to what was considered direct and indirect costumers: patient, physician and physical therapist. The costumers list of the association between the QFD and the CVCA tools had a considerable increase: product and process engineers, clinical and reliability engineering department; product managers; project control department; financial sector; product manager and regulatory affairs (Figure 4). Customers not mentioned during the application of the QFD method were incorporated in this second application, increasing the capacity of the project team of recognizing diversified product requirements and new priorities. These discrepancies allowed noticing that the QFD method refers to the meeting of the product functionalities, while the CVCA considers the system functionalities to which the product belongs. Thus the CVCA helps the research team in determining the critical customers for the application of the market research that aims at gathering data needed to define the demanded quality, the starting point for the QFD.

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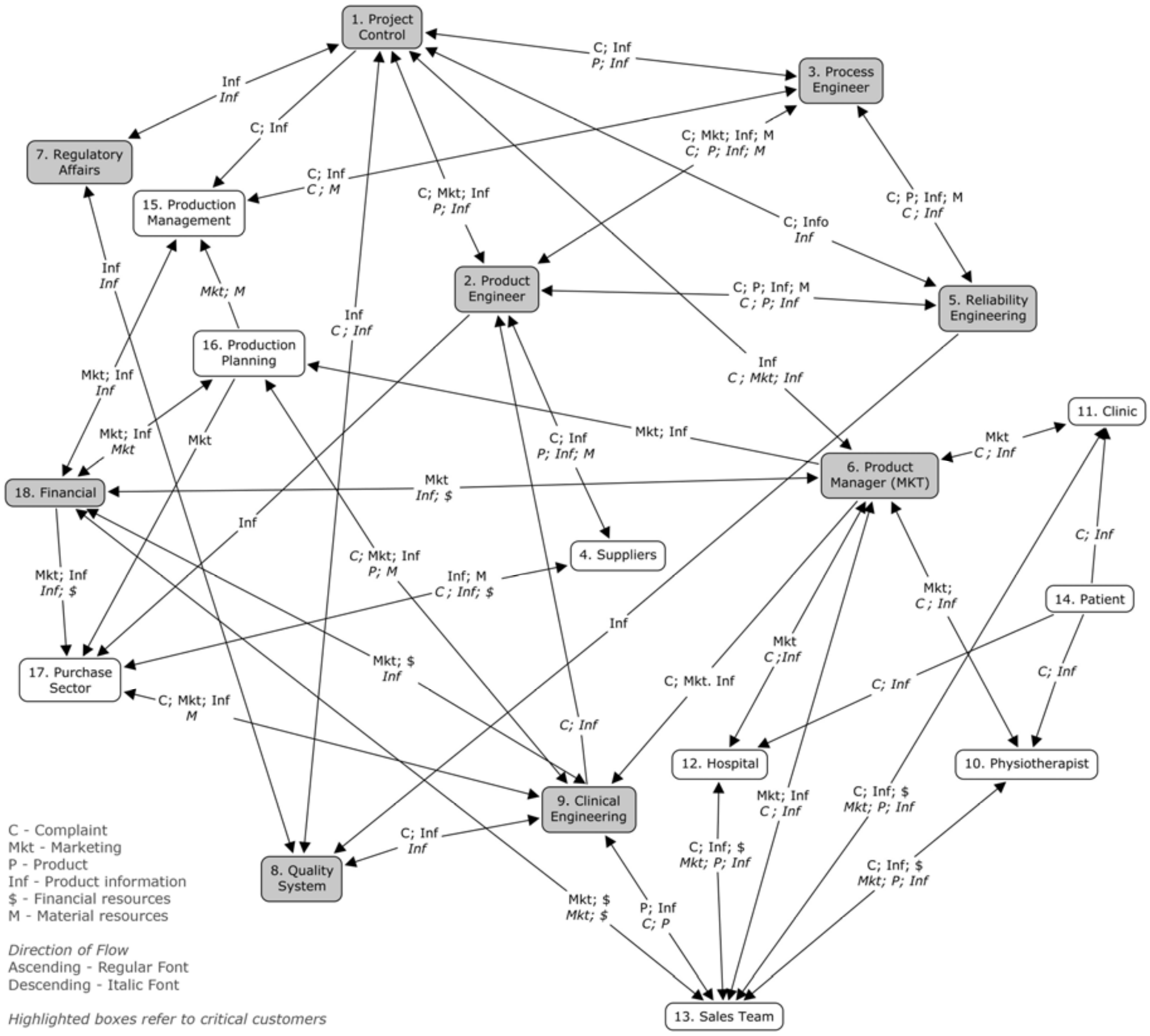

Figure 4: Results of CVCA application to product development in the health area.
Source: primary

4.2 Demanded Quality Survey

The primary attributes ‘aesthetics’, ‘material’, ‘components/elements’, ‘handling’, ‘ergonomics’ and ‘functions’ identified in the QFD application were the same in the CVCA+QFD application. Secondary attributes differ in both applications (see Table 1). Differences were emphasized in the following attributes: i) ‘aesthetics’, the ‘neutral color’ appeared in the first application , it is missing in the second application, in which was identified the secondary attribute ‘innovative’; ii) ‘material’, points the item ‘breathable surface skin contact’ in the first application, and ‘trustworthy’ in the second application, which are related to the reliability of the material used at the production; iii) ‘components/elements’ had in the first application ‘reduced numbers of components’, ‘transport and storage container’ and ‘different energy sources’, while in the second application, ‘safe components’, ‘replacement parts guaranteed’ and ‘reduced maintenance’ were identified; iv) primary attribute

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‘handling’, presents as secondary attributes ‘silent’ in the first application and ‘dismountable’ in the second; v) ‘ergonomics’, the main differences between both applications are between ‘harmonic movements’/’lateral supports for alignment’ and ‘patient’s comfort’/’effective performance’; iv) ‘functions’, differ mainly at ‘programmable functions’ and ‘applicable to various joints’.

The QFD application shows the attribute ‘functions’ has the greatest product’s relative importance (22,90%), and it is deployed in ‘possible physiological range’ (5,93%), ‘assistive, active and resistive programs’ (5,67%), ‘programmable functions’ (5,42%) and ‘simple interface’ (7,17%). The attribute ‘ergonomics’ (21,50%) is deployed in ‘harmonic movements’ (7,62 %), ‘lateral supports for alignment’ (6,03%), ‘not pose a risk to the user’ (5,72%), ‘anthropometric adjust’ (5,44%), and, (see Table 1).

The CVCA+QFD application shows in the secondary levels the attribute ‘ergonomics’ had the greatest product relative importance (19,10%), deployed in ‘patient and operator safety’ (4,88%), ’effective performance’ (4,88%), ‘anthropometric adjust’ (4,78%), and ‘patient’s comfort’ (4,58%). This attribute is followed by ‘functions’ and ‘aesthetics’, both with product is relative importance of 17,90%. The attribute ‘functions’ is deployed in ‘simple and intuitive interface’ (5,72%), ‘possible physiological amplitude’ (4,67%), ‘multiple functions’ (4,35%), ‘applicable to various joints’ (3,67%), while the attribute ‘aesthetics’ is deployed in ‘compact and portable’ (6,62%), ‘organic design’ (4,37%), ‘innovative’ (3,88%), and ‘discrete’ (1,84%) (see Table 1).

The comparison of attributes identified in the demanded quality in both QFD and CVCA+QFD showed in Table 1 highlights the demanded-quality importance index is adjusted using two different factors. The first factor is used to consider the relevance of each item, considering its importance to the company strategy and the second factor is used to consider the company competition position in the market in comparison to a benchmarking organization. The result is the Demanded-quality Importance Index Adjusted (IDi*).

Table 1 - Comparison of attributes identified in the demanded quality in both QFD and CVCA+QFD

Attributes	Demanded Quality (QFD)	Rate Primary Level QFD	*IDi* QFD*	Demanded Quality (CVCA + QFD)	Rate Secondary Level CVCA+QFD	*IDi* CVCA + QFD*
Aesthetics	Neutral color (similar to the skin)	0,114	0,0161	Innovative	0,179	0,0388
	Organic form		0,0277	Organic design		0,0437
	Compact		0,0397	Compact and portable		0,0662
	Discrete		0,0154	Discrete		0,0184
Material	Soft surface skin contact	0,138	0,0480	Soft, breathable and not alergic surface skin contact	0,151	0,0511
	Breathable surface skin contact		0,0342	Trustworthy		0,0410
	Easy to clean / Asespsis		0,0350	Easy to clean / Asespsis		0,0361
	Resistant to conditions of use and maintenance		0,0488	Resistant to conditions of use and maintenance		0,0534
Components / Elements	Reduced numbers of components	0,134	0,0477	Safe components	0,130	0,0491
	Low weight of the equipment		0,0651	Low weight of the equipment		0,0540
	Transport and storage container		0,0164	Replacement parts guaranteed		0,0276
	Different energy sources		0,0322	Reduced maintenance (do not require specific technical care)		0,0399
Handling	Easy to store	0,171	0,0280	Easy to store	0,169	0,0267
	Transport through wheels or car		0,0418	Easy to transport (accessory)		0,0427
	Silent		0,0550	Dismountable		0,0344
	Intuitive use		0,0632	Easy to assembly, to install, to configure, to adjust and to use		0,0486
Ergonomics	Anthropometric adjust	0,215	0,0544	Anthropometric adjust	0,191	0,0478
	Harmonic movements		0,0762	Patient and operator safety		0,0488
	Lateral supports for alignment		0,0603	Patient's comfort		0,0458
	Not pose a risk to the user		0,0572	Effective performance		0,0488
Functions	Possible physiological range	0,229	0,0593	Possible physiological amplitude	0,179	0,0467
	Assistive, active and resistive programs		0,0567	Multiple functions		0,0435
	Programmable functions		0,0542	Applicable to various joints		0,0367
	Simple interface		0,0717	Simple and intuitive interface		0,0572

IDi = corrected importance index*

Source: primary

4.3 Demanded Quality Deployment

The QFD application analysis demonstrates the main demanded qualities are 'harmonic movements' and 'simple interface', associated to 'ergonomics' and 'functions', respectively. The least valued qualities demanded by the costumer are related to the 'aesthetics', and they are 'discrete' and 'neutral color'. Thus, according to the results, it's not necessary to make great efforts towards the appearance of the product, since this is little appreciated by the customer and will not contribute to its further acceptance in the market.

Main demanded qualities in the CVCA+QFD application are 'compact and portable' ('aesthetic') and 'simple and intuitive interface' ('functions'). The least valued qualities demanded by the critical customers are 'discrete' ('aesthetic'), 'easy to store' ('handling'), and 'replacement parts guaranteed' ('components/elements').

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This application differs from the first one especially because of the fact that the demanded quality 'aesthetic' was not valued (see Table 2).

The Table 2 shows the Importance of Quality Characteristics (IQj). The intensity of the relationship between the items of the demanded quality, the quality characteristics and the relative importance of the demanded quality were considered. The Index Importance of Quality Characteristics (IQj*) was adjusted using a correction factor by assessing the difficulty of acting on the Quality Characteristics (Dj) and a competitive assessment with respect to Technical Characteristics (Bj).

Table 2 - Quality Matrix

	Quality Characteristics (QFD)							Quality Characteristics (CVCA+QFD)						
Attributes	Demanded Quality (QFD)	Color similar to the skin	Rounded finish	...	Possibility to program different functions	Compatibility with other devices	IDi* QFD	Demanded Quality (CVCA + QFD)	Innovative	Rounded finish	...	Applicable to various joints of the body	Compatibility with other devices	IDi* CVCA + QFD
Aesthetics	Neutral color (similar to the skin)	9					0,016	Innovative	9			9	3	0,066
	Organic form		9				0,028	Organic design		9				0,018
	Compact		1				0,040	Compact and portable		1				0,051
	Discrete	9	3				0,015	Discrete		3				0,041
Material	Soft surface skin contact		3				0,048	Soft, breathable and not alergic surface skin contact		1				0,036
	Breathable surface skin contact						0,034	Trustworthy		1				0,053
	Easy to clean / Asespsis	3	3				0,035	Easy to clean / Asespsis		3				0,049
	Resistant to conditions of use and maintenance						0,049	Resistant to conditions of use and maintenance						0,054
Components / Elements	Reduced numbers of components						0,048	Safe components		9				0,028
	Low weight of the equipment				1		0,065	Low weight of the equipment						0,040
	Transport and storage container						0,016	Replacement parts guaranteed						0,027
	Different energy sources				1	1	0,032	Reduced maintenance (do not require specific technical care)						0,043
Handling	Easy to store					1	0,028	Easy to store						0,034
	Transport through wheels or car				1		0,042	Easy to transport (accessory)						0,049
	Silent						0,055	Dismountable						0,048
	Intuitive use				9	9	0,063	Easy to assembly, to install, to configure, to adjust and to use						0,049
Ergonomics	Anthropometric adjust				3	3	0,054	Anthropometric adjust				9		0,046
	Harmonic movements				3		0,076	Patient and operator safety		9		9	3	0,049
	Lateral supports for alignment				3		0,060	Patient's comfort				3		0,047
	Not pose a risk to the user		9		9	9	0,057	Effective performance				9	9	0,043
Functions	Possible physiological range				3	3	0,059	Possible physiological amplitude				0,037		0,037
	Assistive, active and resistive programs				9	3	0,057	Multiple functions				0,057		0,057
	Programmable functions				9	9	0,054	Applicable to various joints	9			9		0,000
	Simple interface				9	9	0,072	Simple and intuitive interface					9	0,000
Specifications	*Importance of Quality Characteristics j IQj*	0,4	1,1		3,6	2,8		*Importance of Quality Characteristics j IQj*	0,3	1,2		2,6	1,1	
	Difficulty of Practice (Dj)	2,0	2,0		1,0	1,5		*Difficulty of Practice (Dj)*	1,0	2,0		1,0	1,5	
	Competitive Analysis (Bj)	0,5	1,0		0,5	1,0		*Competitive Analysis (Bj)*	0,5	1,0		0,5	1,0	
	*IQj**	0,4	1,6		2,6	3,4		*IQj**	0,2	1,7		1,8	1,3	

Source: primary

4.4 Deployment of Product and its Parts

In the product matrix at the QFD application, it was observed the necessity to prioritize the following parts of the product: 'support shaft', 'joystick', 'arm support', 'forearm support, 'base support', 'electronic system', 'mechanic system' and

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'software' (see Table 3). After the deployment and the prioritization or the parts, characteristics of parts matrix were filled and the greatest parts were crossed with their quality characteristics. Thus, it was possible to identify which characteristics must be controlled in the critical parts to provide the product quality. Through characteristics of the parts matrix, it was observed the need to prioritize the following characteristics of the parts of the product: 'support shaft angle', 'height adjustment', 'shaft thickness', and 'Joystick dimensions' (see Table 4).

Differently of previous tables, the Table 3 shows the Level of Importance of the Quality Characteristics (IPi*). It was adjusted using a correction factor by evaluating the difficulty of making modifications and the time required for modifications.

Table 3 - Product Matrix

	Quality Characteristics (QFD)									Quality Characteristics (CVCA+QFD)								
Product Parts (QFD and CVCA+QFD)	Color similar to the skin	Rounded finishing	Compact size	...	Assistive, active and resistive movements	Possibility to program different functions	Compatibility with other devices	*IPi* QFD*	*/1000*	Innovative	Rounded finishing	Compact size	...	Possibility of assistive, active and resistive movements	Applicable to various joints of the body	Compatibility with other devices	*IPi* CVCA+QFD*	*/1000*
*IQJ**	0,39	1,55	1,64		1,54	2,56	3,41	-	-	0,48	2,26	1,83		1,47	2,08	1,49	-	-
Base support		9	3				1	224	0,22		9	3				1	187	0,19
Support shaft		9	9				1	293	0,29		9	9				1	239	0,24
Arm support	3	9	9		1		1	246	0,25		9	9		1	9	1	245	0,24
Forearm support	3	9	9		1		1	246	0,25		9	9		1	9	1	245	0,24
Mechanic system		1	9		9			108	0,11		1	9		9	3		104	0,10
Joystick		9	1		1			248	0,25		9	1		1	3		212	0,21
Electronic system					9	9		114	0,11	9				9	9		98	0,10
Software					9	9	9	107	0,11	9				9	9	9	74	0,07

Source: primary

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Table 4 - Parts Characteristics Matrix

Parts Characteristics (QFD)

Product Parts (QFD and CVCA+QFD)	*IPi* QFD*	...	Shaft thickness (mm)	Height adjustment	Support shaft angle (90°)	Arm support dimensions (cm)	...	Shoulder angle adjustment (°)	...	Forearm support anthropometric adjust	Arm and forearm support congruence	...	Joystick dimensions (cm)	...
Base support	224,0													
Support shaft	292,8		9	9	9									
Arm support	245,8					9		9						
Forearm support	245,8									9	9			
Mechanic system	108,0													
Joystick	248,2												9	
Electronic system	113,7													
Software	107,2													
			2634	2634	2634	2211		2211		2211	2211		2234	

Parts Characteristics (CVCA+QFD)

Product Parts (QFD and CVCA+QFD)	*IPi* CVCA+QFD*	...	Shaft thickness (mm)	Height adjustment	Support shaft angle (90°)	Arm support dimensions (cm)	...	Shoulder angle adjustment (°)	...	Forearm support anthropometric adjust	Arm and forearm support congruence	...	Joystick dimensions (cm)	...
Base support	187,0													
Support shaft	238,7		9	9	9									
Arm support	244,8					9		9						
Forearm support	244,8									9	9			
Mechanic system	104,4													
Joystick	212,0												9	
Electronic system	98,2													
Software	73,5													
			2148	2148	2148	2203		2203		2203	2203		1908	

Source: primary

The CVCA+QFD application considers the descending order of priority of the parts is as follows: ‘arm support’ and ‘forearm support’, ‘shaft support’, ‘joystick’ and ‘base support’, ‘mechanic system’, ‘electronic system’ and ‘software’ (see Table 3). The main characteristics of parts must be prioritized in the device development are:

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'arm support dimensions', 'shoulder angle adjustment', 'forearm support anthropometric adjust' and 'arm and forearm support congruence' (see Table 4).

4.5 Deployment of Process and its Parameters

The process matrix deploys the product manufacture process, aiming to highlight the process associated with quality characteristics. The following descending order of priority of the manufacture process was identified in QFD application: 'aluminum profile cuts', 'assembly', 'receiving components', 'polymers and textile cuts', 'steel materials cuts', 'software programming', 'molding and finishing cuts', 'finishing', 'certification processes' and 'expedition' (see Table 5).

Table 5 - Process Matrix

	Quality Characteristics (QFD)									**Quality Characteristics (CVCA+QFD)**								
Process Steps (QFD and CVCA+QFD)	Color similar to the skin	Rounded finishing	Compact size	...	Assistive, active and resistive movements	Possibility to program different functions	Compatibility with other devices	*IPi* QFD*	*/1000*	Innovative	Rounded finishing	Compact size	...	Assistive, active and resistive movements	Applicable to various joints of the body	Compatibility with other devices	*IPi* CVCA+QFD*	*/1000*
*IQJ**	0,4	1,6	1,6		1,5	2,6	3,4	-	-	0,48	2,26	1,83		1,47	2,08	1,49	-	-
Software programming					9	9	3	83	0,08	9				9	9	3	59	0,06
Receiving components	9	9	1					114	0,11		9	1					111	0,11
Aluminum profiles cuts		9	3					250	0,25		9	3					225	0,22
Steel materials cuts		9	1					86	0,09		9	1					90	0,09
Polymer and textile cuts		9	3					105	0,10		9	3					113	0,11
Molding and finishing cuts		9	9					78	0,08		9	9					80	0,08
Assembly			3				3	181	0,18			3				3	183	0,18
Finishing		9					1	59	0,06		9					1	71	0,07
Certification process							3	36	0,04							3	32	0,03
Expedition							1	16	0,02							1	23	0,02

Source: primary

The same processes was observed in the CVCA+QFD application, but in the following descending prioritization order: 'aluminum profile cuts', 'assembly', 'polymers and textile cuts', 'receiving components', 'steel materials cuts', 'molding and finishing cuts', 'finishing', 'software programming', 'certification processes' and 'expedition' (see Table 5).

The results of the process parameters matrix, which are directly related to the process' parameters and the stages of the manufacturing process of the CPM device under study, differed especially in the order of importance of four parameters when

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both QFD and CVCA+QFD applications are compared. In other words, after the matrix deployment it was observed, in the first application, the following descending order of importance of process parameters: ‘cut dimensions’, ‘components positioning’, ‘cutting angle’, ‘number of failures/lack of compliance’, ‘quality of the received components’, ‘possibility and time of programming’, ‘molding angle’, ‘percentage of on-time deliveries’, ‘ANVISA’s evaluation result’, ‘programs storage capacity’, ‘shipping time (logistics)’ and ‘percentage of well packaged device’, respectively (see Table 7). The second application had an exchange of order between ‘cutting angle’ and ‘number of failures/lack of compliance’, and between ‘possibility and time of programming’ and ‘molding angle’ (see Table 7).

Table 6 - Process Parameters Matrix

		Process Parameters (QFD)												
Process Steps (QFD and CVCA+QFD)	*IPi* QFD*	Programming time	Programs storage capacity	Possibility of programming	Percentage of on-time deliveries	Quality of the received components	Cutting angle	Cut dimensions	Molding angle	Number of failures/lack of compliance	Components positioning	ANVISA’s evaluation result	Percentage of well packaged device	Shipping time (logistics)
Software programming	83	9	3	9										
Receiving components	114				3	9								
Aluminum profiles cuts	250						3	9						
Steel materials cuts	86						3	9						
Polymer and textile cuts	105						3	9						
Molding and finishing cuts	78								9	9	9			
Assembly	181										9			
Finishing	59									9				
Certification process	36											9		
Expedition	16												3	9
		748	249	748	342	1027	1321	3962	699	1231	2327	322	47	140

Source: primary

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Table 7 - Process Parameters Matrix – cont.

Process Steps (QFD and CVCA+QFD)	*IPi* CVCA+QFD*	Programming time	Programs storage capacity	Possibility of programming	Percentage of on-time deliveries	Quality of the received components	Cutting angle	Cut dimemsions	Molding angle	Number of failures/lack of compliance	Components positioning	ANVISA's evaluation result	Percentage of well packaged device	Shipping time (logistics)
	Process Parameters (CVCA+QFD)													
Software programming	59	9	3	9										
Receiving components	111				3	9								
Aluminum profiles cuts	225						3	9						
Steel materials cuts	90						3	9						
Polymer and textile cuts	113						3	9						
Molding and finishing cuts	80								9	9	9			
Assembly	183										9			
Finishing	71									9				
Certification process	32											9		
Expedition	23												3	9
		531	177	531	333	1000	1285	3854	722	1363	2365	286	68	204

Source: primary

5. CONCLUSION

This study aimed to present the differences between the use of an adapted method of QFD (compound of eight matrices) and its association with CVCA tool in the development of a CPM device for elbow and forearm rehabilitation.

Results allowed the identification of a discrepancy between the critical costumers and differences in the demanded quality attributes, as well as its prioritization. The importance of the product value chain analysis in a systematic way can be highlighted, considering all the involved parts in the development of a CPM device, besides the ones determined by the researchers themselves.

The differences of the applications allowed noticing that the QFD method refers to the meeting of the product functionalities, while the CVCA considers the system functionalities to which the product belongs. Thus the CVCA helps the research team in determining the critical customers for the application of the market research that aims at gathering data needed to define the demanded quality, the starting point for the QFD. Thus, the proposed association between the CVCA+QFD

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methods was effective to identify needs of all process costumers, incorporating them in the product design and production process.

Such association can modify even the subsequent steps, such as the matrices of quality, parties and characteristics of the parts, for the prioritization of requirements can be differentiated, as observed in this study. The impacts are felt in the subsequent process and QFD resource matrices, equally. That is in reason of the distinct perceptions of the interested parties, including the understanding of the value assigned to the project. Although an exploratory study, the CVCA not only allowed this joint project but also reduced the complexity by highlighting the elements that represent value for stakeholders from the business model of a given organization.

This comparison was done in the product development process of one device specifically. The integration of the two methods and this same methods comparison are suggested for future studies, especially to those that aim the product development for health area, in order to confirm these results and detail more its impacts on the product project and its value network for different products.

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