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Continuous improvement of a face protection mask using quality function deployment

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Abstract

This article aims to examine the applicability of the Quality Function Deployment (QFD) and the Kano model considering the expectations of the client, to a personal facial protection equipment against the Coronavirus 2019 (COVID-19), a disease that has caused a global pandemic, posing threats to public safety and social economies. In the first phase of the study, user requirements are identified at the local level based on current designs through the Kano model. This data is then merged with a Voice of Engineer (VoE) chart listing technical attributes and characteristics corresponding to items in Voice of Customer (VoC). The quality characteristics are then obtained by calculating the weights according to the level of importance, which are then transformed into measurable technical attributes in the House of Quality (HOQ). Through the weighting process using the pareto diagram, the main technical characteristics are identified, in which attention must be paid and the resources to be considered to satisfy said requirements must be evaluated. Finally, as a result, a 3D design is defined to make the prototype considering the needs of the client, which allows deducing the good applicability of the Kano-QFD model to carry out the development process of any product.

Keywords: Kano model; house of quality (hoq); quality function deployment (qfd); continuous improvement.

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Mejora continua de un equipo de protección facial mediante el despliegue de la función de calidad

Resumen

Este artículo tiene como objetivo examinar la aplicabilidad del Despliegue de la Función de Calidad y el modelo Kano considerando las expectativas del cliente, a un equipo de protección facial personal contra el Coronavirus 2019 (COVID-19), enfermedad que ha provocado una pandemia mundial, que representa amenazas para la seguridad pública y las economías sociales. En la primera fase del estudio, se identifica los requerimientos del usuario a nivel local en función de los diseños actuales a través del modelo Kano. Luego, estos datos se fusionan con un gráfico Voz del Ingeniero donde se enumeran los atributos técnicos y las características correspondientes a los elementos en Voz del Cliente. Las características de calidad se obtienen luego mediante el cálculo de los pesos según el nivel de importancia, que luego se transforman en atributos técnicos medibles en la Casa de la Calidad. Mediante el proceso de ponderación utilizando el diagrama de pareto, se identifican las principales características técnicas, en la cuales hay que poner atención y evaluar los recursos a considerar para satisfacer dichos requerimientos. Finalmente, como resultado se define un diseño en 3D para realizar el prototipo considerando las necesidades del cliente, lo cual permite deducir la buena aplicabilidad del modelo Kano-QFD para llevar a cabo el proceso de desarrollo de cualquier producto.

Palabras clave: Modelo kano; casa de la calidad; despliegue de la función de calidad; mejora continua.

1. Introduction

The current situation and today's lifestyle in all countries is very different from what it was at the beginning of the year 2020; This is because society is adapting to a new way of living in the face of a common danger: the infectious disease known as coronavirus (SARS-CoV-2) which appeared in China in December 2019 (Liu et al, 2020), causing cases of Severe pneumonia of unknown origin, most severe. International health authorities have warned of the rapid spread of the virus and the World Health Organization (WHO) has classified the outbreak of this infection on March 11, 2020, as a global pandemic (OMS, 2020a), and has declared a major public health emergency International (WHO, 2020, Nievas &Garcia, 2020).

Coronaviruses are a family of viruses that cause illnesses ranging from the common cold to more serious respiratory illnesses, such as SARS-COV2 (WHO, 2020; Gralinski & Menachery 2020; Chu, 2020; Cui et al, 2020).

As of April 12, 2022, around 500.9 million cases of coronavirus have been registered in the world, and more than six million deaths due to the virus. The United States leads the ranking by exceeding one million deaths, followed by Brazil with around 661,700, then India, Russia, and Mexico in fifth place with 323,848 deaths (Statista, 2021).

The recommended prevention measures based on the WHO (2020a) and others (Howard et al, 2020; Rahman et al, 2020; Marasinghe, 2019; Chu et al, 2020; Sohrabi et al, 2020) remain the same: wash hands with soap and water or alcohol-based solution; cover your mouth when coughing; physical distance between people of at least one meter; do not touch eyes, nose or mouth; use of masks that cover the mouth and chin; use of gloves; wear a mask that covers the entire face; self-isolation; go to the doctor if you have symptoms; and monitoring of suspected cases (WHO, 2020a; Zhou, 2020). But even with that, facial protection equipment is still used and required for all those workers who are in daily and continuous contact with many people (Quintero, 2020; Torres et al, 2020; Alarcon, et al, 2021; Vera et al, 2020; Cook, 2020; WHO, 2020b). These must have adequate characteristics according to the needs of the clients, such as being comfortable, safe, and surely economical.

For all the above, in this research work a proposal for the redesign and improvement of a facial protection equipment is presented, considering the needs and requirements of the clients or market in which the product is intended to be distributed to achieve the QFD methodology.

2. Theoretical framework

As part of the main tools to develop the research project, were the Kano model and QFD, methodologies related to the continuous improvement of any product or service.

2.1. Kano Model

The identification and interpretation of the VoC is the first step in the quality management process (Aguwa et al, 2012; Qingliang et al, 2018; Mikulić et al, 2011, Raquel et al, 2021). The good interpretation of these needs allows us to generate a high-quality product that completely satisfies the customer. Only after the latent or explicit needs or demands of the client have been identified, the translation can be made into “functions” and from these to the definition of technical characteristics, which will be the basis for making the definition of the product or service to be developed operational (Mikulić et al, 2011).

The process of “listening” to customer needs presents a fundamental problem: the difficulty of achieving adequate communication between the end user of the product or service and the person in charge of interpreting these requirements and turning them into tangible (Found & Harridon, 2012; Ortega, 2020).

Kano’s model is a method that aims to categorize the attributes of products and services based on their ability to meet customer needs by analyzing customer wishes through five

categories: Required Quality, Desired or Performance Quality, Quality motivating, Indifferent quality, Rejection quality; Based on the results, an assessment of the categories is made, where a diagram is made, identifying how the different types of dissatisfaction affect and thus be able to make decisions based on the product or service (Shanin et al, 2013).

This model can be used to identify and classify quality attributes based on their impact on customer satisfaction into mandatory, attractive, one-dimensional, inverse, and indifferent categories. The essential attributes correspond to the basic requirements of the quality of the product or service, and the absence of these attributes leads to extreme customer dissatisfaction.

Customer satisfaction is directly proportional to the performance level of one-dimensional attributes. The presence of attractive attributes leads to extreme customer satisfaction, but the absence does not lead to customer dissatisfaction. The absence of inverse attributes leads to customer satisfaction. Indifferent attributes have no effect on customer satisfaction or dissatisfaction (Shanin et al, 2013; Hogstrom et al, 2010).

The implementation of the Kano model will allow healthcare providers to understand the complex behavior of patients and their needs related to quality of service (Angamarca et al, 2020), which can be used to improve customer satisfaction. This model can be very useful considering the improvement of products, processes or services in these times of pandemic (Mendoza & Solís, 2022; Morales, 2021; Rocha et al, 2021). A representation of the Kano model as suggested by (Hogstrom et al, 2010).

To categorize service attributes, Kano's model uses a customer-directed questionnaire (Lin et al, 2017; Luor et al, 2015). The questionnaire includes two questions related to each attribute, one positive and one negative (Shanin et al, 2013); The combination of the answers to the two questions allows to categorize the attributes (Luor et al, 2015).

After completing the questionnaire, the questions must be classified according to the answers obtained. The Kano table allows categorizing the requirements according to the relationship between the degree of sufficiency of the attribute and customer satisfaction. Kano used two dimensions to assess quality (Shanin et al, 2013; Hogstrom et al, 2010; Luor et al, 2015; Lin et al, 2017). The performance of a product, and the degree of satisfaction of the customer who uses it.

Each of the questionnaires always has an even number of questions related to the client's requirements. The reason the questions come in pairs is because for each requirement, one functional and one dysfunctional question are asked. For each section, the client answers between 5 unique options, as shown in Frame 1, therefore, each of the questions must have this group of possible answers.

Frame 1
Functional/Dysfunctional evaluation matrix (Kano model)

ATTRIBUTES		Functional Requirements (Negative)				
		I like it	It's so-mething basic	I do not care	I don't like it, but I tolerate it	I don't like it and I can't tolerate it
		2	**3**	**4**	**5**	
Functional Require-ments (Positive)	I like it	Q	A	A	A	O
	It's something basic	R	I	I	I	M
	I do not care	R	I	I	I	N
	I don't like it, but I tolerate it	R	I	I	I	M
	I don't like it and I can't tolerate it	R	R	R	R	Q

Source: Own elaboration based on Luor et al, (2015).

2.2. Quality Function Deployment (QFD)

The QFD is a methodology that is part of the Total Quality Management (TQM), within the philosophy of continuous improvement, along with other techniques that support the development and application of the same in any organization regardless of the line of business (Akao & Mazur, 2003; Chan et al, 2005; Wolniak, 2018). This is also considered as a planning tool, which transforms the needs and desires of the client into product or service design requirements, with the objective of translating the VoC into quality characteristics, to achieve the total satisfaction of the actors involved (Found & Harrison, 2012; Lin et al, 2017; Luor et al, 2015).

It basically consists of transmitting "WHAT customers want" (needs or attributes) in "HOW that need can be satisfied" (technical or design characteristics) successively applying throughout the chain of external and internal stakeholders and their relative valuation (Hauser et al, 2010). The expectations and needs of the clients are collected through market research techniques (interviews, surveys, etc.), as was done in this case, and through the different houses developed, the data obtained is organized to define and weigh the more than the least important, for this there are different accepted and published models referring to the development and implementation of QFD, adapting them to the situation and problems to be solved; some focus on the first house, and others propose different and diverse matrices (Carnevalli et al, 2008).

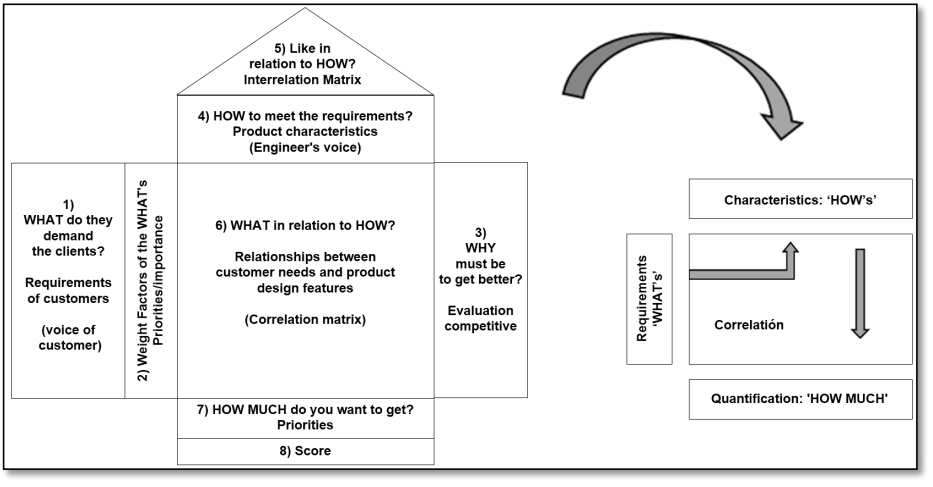
QFD is a modern and novel methodology that is being applied in various areas, mainly for product improvement (Carnevalli et al, 2008; Raharjo et al, 2007; Maritan, 2015; Chan et al, 2007; Hunt et al, 2003; Cohen, 1995; Xie et al, 2003). This seeks to focus product design on responding to customer needs (Hauser et al, 2010; Han et al, 2001; Martins et al, 2001; Govers, 2001; Herzwurm et al, 2003; Raharjo et al, 2007). This means aligning what the customer requires with what the manufacturer produces. The three main objectives in the implementation of QFD are: to give priority to the needs of the customers who request it and not request it; translate these needs into technical

characteristics and specifications; create and deliver a quality product or service focusing everyone on customer satisfaction (Raharjo et al, 2007).

The development of QFD makes it possible to understand the priority of the needs of its clients and to find innovative responses to those needs, through the continuous improvement of products in search of maximizing the value offer. That is, "transmit" the quality attributes that the VoC demands through the organizational processes, so that each process can contribute to the assurance of these characteristics (Maritan, 2015; Chan et al, 2007; Hunt et al, 2003; Cohen, 1995; Xie et al, 2003). QFD was developed in Japan during the 1960s by Professor Yoji Akao and is currently in a phase of expansion throughout the world, with applications in the different sectors of industrial and service activity (Carnevalli & Miguel, 2007; QFD, 2013; Jing et al, 2010; Erkarslan & Yilmaz, 2011).

According to Moges, (2009), it is regularly composed of four phases: product planning, product design, process planning and finally process control. Each of these matrices have their importance, but it is considered that the first, known as House of Quality (HoQ) is the most important, from this in turn others are developed at more specific levels of work depending on the approach that is being developed, product, process, or service. The HoQ is mainly structured by eight parts which are exemplified in Diagram 1.

Diagram 1
Part of HoQ



Source: own elaboration.

3. Methodological aspects

As part of the characteristic process related to the design and manufacture of a product based on (Moges, 2009), the following stages were defined to be carried out, to achieve the objective of the research work, which turns be part of stages continuous improvement of any product (Milton & Rodgers, 2013):

Definition phase. The objectives and functionalities of the new product are established, what exists in the market is identified and characterized (market/ competition analysis).

Concept phase. The specifications and technical characteristics of the product are defined considering the client's requirements.

Detail phase. The manufacturing processes necessary for the prototype are defined. Machinery, equipment and tools that are required.

Simulation phase. In this stage, the final definition of the product, dimensions, tolerances, materials, assembly method, packaging, etc. is made. Considering the process capability and manufacturing resources available to manufacture the product in accordance with the defined process and product characteristics.

Evaluation phase. In the spirit of continuous improvement, using the Deming Cycle (Montesinos et al, 2020). In this case, this work is limited to reaching only the simulation phase, without reaching the prototype production phase either.

Due to its purpose, it is applied due to its scope it is descriptive; with primary sources, transversal dimension, and mixed approach (Hernandez et al, 2020; Rojas, 2008; Mendez, 2007). Additionally, an action method is used since it seeks to transform reality, and the study is immersed within work and production methods, specifically quality management methods since they try to carry out continuous improvement in a tangible product.

This research work may provide scientific opportunities for the development of prototypes in general of any kind and application, with the acquisition of the relevant equipment according to the defined designs. In addition, this methodology can be extended to the management, manufacturing, and evaluation of any other products.

4. Continuous improvement stages of the product

This section describes the stages that were developed throughout the research work, which are divided into four, from the analysis stage, conceptual design, detailed design and simulation of the proposed model.

4.1. Definition stage

There is a wide variety of types of face shields with their advantages and disadvantages for each of them, specifically in characteristics, such as: cost, size, weight, type of material, fit, flexibility, ergonomics, usability, etc. in the end, the intention is to reduce transmission safely and significantly in the community and social setting (Roberge, 2016; Ino et al, 2020).

In this stage, the competition of similar products that existed in the local market was analyzed, although it is not the intention to be better in any specific aspect of any of them, if it was important to compare and consider some type of assembly, material, measurements, quality, etc. at a certain moment. Frame 2 presents information on some of them, as well as the link to their publication.

Frame 2
Analysis of personal protective equipment in the market

Description	Advantajes	Disadvantages	Source
Simple facial protective mask with lenses.	Affordable cost ($15-$30) Easy to clean. Large coverage. Easy to get.	Disposable It can be uncomfortable scratches easily	https://www.amazon.com.mx/CARETA-PROTECTORA-FACIAL-LENTES-PAQUETES/dp/B08D364RVJ
Goggles-type polycarbonate mask.	It is not disposable. Easy to clean. light Resistant	Its cost can be high ($200-$300) Nose fit is uncomfortable Not suitable for people who wear glasses	https://www.amazon.com.mx/Protectora-Transparente-Compatible-Seguridad-Anti
2mm pexiglass professional health mask with harness.	Anti-fog. light Resistant Adjustable ergonomic Alimentary grade.	Not suitable for COVID hospitals hard to get High price ($500-$1200) No other extra accessory such as goggles can be used.	https://articulo.mercadolibre.com.mx/MLM-806104956-careta-profesional-sanitaria-e-industrial-_JM?matt_tool=28238160&utm_source=google_shopping&utm_medium=organic
Removable Googles Mask Premium Facial Protector.	Good Resistance Removable It is not disposable. Design with adequate space for nose and mouth.	High price ($250-$400) Difficult access to acquire it. You need to use googles forcibly.	https://articulo.mercadolibre.com.mx/MLM-874367714-careta-googles-desmontables-protector-facial-premium-_JM?matt_tool=28238160&utm_source=google_shopping&utm_medium=organic
Face Shield Industrial Medical Mask Rough Use Folding.	It is not disposable. Easy to clean. light Durable Adjustable head support and various positions.	Not suitable for COVID hospitals hard to get Fast wear of the head support due to the simplicity. Its cost can be high ($150-$300)	https://articulo.mercadolibre.com.mx/MLM-807445699-protector-facial-careta-medica-industrial-uso-rudo-abatible-_JM?matt_tool=28238160&utm_source=google_shopping&utm_medium=organic
Bakano Health Babies Infant Facial Protective Mask.	Disposable light Adjustable Economy ($20-$50).	It scratches easily. Spring wear. Uncomfortable after some time of use. Uncomfortable for people who wear glasses.	https://www.babalu.mx/products/careta-protectora-facial-infantil-bebe
Model of Polymerfilms Masks.	Disposable Easy to clean light Affordable cost ($10-$45). Easy to get.	It scratches easily. Spring wear. Uncomfortable after some time of use.	https://www.polymershapes.com.mx/producto/careta-polymerfilms/
Adjustable Dipak Protectors.	Affordable cost ($15-$30). Easy to clean. Large coverage. Easy to get. Adjustable.	It scratches easily. Uncomfortable for people with glasses. Uncomfortable for the nose. Spring wear. Uncomfortable after some time of use.	https://www.walmart.com.mx/cuidado-de-la-salud/equipo-medico/instrumental-medico/paquete-de-10-caretas-protectoras-dipak-ajustables_00750228783429
Facetek Facial Protective Masks.	Easy to clean. Large coverage. Reusable. Durable.	Spring wear. Uncomfortable after some time of use. Hard to get. After a long time of use, the supports (green dots) mark the skin. Somewhat high cost ($50-$100).	https://www.amazon.com.mx/Facetek-Caretas-Protectoras-Faciales/dp/B08872FHZG
Adjustable mask with cord.	Affordable cost ($15-$30). Easy to clean. Large coverage. Easy to get. Adjustable.	After a long time of use, the visor marks the skin.	http://www.onipo.com.mx/producto/caretas-c-cordon/

Source: own elaboration.

4.2 Conceptual stage

In this section, the client's requirements were defined Frame 3. The questions proposed based on Kano's model are show.

Frame 3
Survey based on the Kano Model

	Functional question	Dysfunctional question
1.	How important is it for you that the face protection mask (FPM) is comfortable?	How important is it to you that the face protection mask (FPM) is not comfortable?
2.	How important is it to you that the FPM was completely rigid?	How important is it to you that the FPM was not completely rigid?
3.	How important is it to you that the FPM fogs up?	How important is it to you that the FPM does not fog up?
4.	How important is it to you that the FPM was disposable? (That is, it should be single use).	How important is it to you that the FPM was not disposable? (That is, it should be single use).
5.	How important is it to you that the FPM can be used in conjunction with your lenses (prescription, sun or other)?	How important is it to you that the FPM cannot be used in conjunction with your lenses (prescription, sun or other)?
6.	How important is it for you that the FPM has a low cost?	How important is it for you that the FPM does not have a low cost?
7.	How important is it to you that the FPM fastening system be spring-loaded?	How important is it to you that the FPM fastening system is not spring-loaded?
8.	How important is it for you that the FPM has a fastening system on the forehead?	How important is it to you that the FPM does not have a forehead support system?
9.	How important is it for you that the facial FPM is light?	How important is it to you that the face protection mask is not light?
10	How important is it for you that the FPM has a cap fastening system?	How important is it to you that the FPM does not have a cap fastening system?
11	How important is it for you that the FPM screen has some color?	How important is it for you that the FPM screen does not have any color?
12	How important is it for you that the FPM is anti-scratch?	How important is it to you that the FPM is not anti-scratch?

Source: own elaboration.

Being the only answer options, the following: *1. I like it; 2. It is something basic; 3. I don't care; 4. I don't like it, but I tolerate it; 5. I don't like it and I can't tolerate it.*

A questionnaire was created through Google Forms for easy dissemination and interpretation of results. It was answered by 68 people. The questionnaire followed the format according to the Kano model shown in table 1. Distinguishing, identifying, and discriminating according to the type of requirement. Once the type of requirement was discriminated and the surveys were processed, the results were analyzed considering all the functional and dysfunctional responses obtained by those involved (Table 1). The least attractive were requirement #7 and #8. Table 1 shows the evaluation method through the intersection of both requirements. Where the attribute for the client can be: A-Attractive, M-Must be, R-Reserve, O-One dimensional, Q-Questionable, I-Indifferent.

Table 1
Results of the Kano method (Percentages)

#	Atributes	SUMMARY OF CRITERIA							
		A	O	M	R	Q	I	TOTAL	assignment
1	Confort	41%	3%	7%	13%	3%	32%	100%	**A**
2	Rigidity	59%	16%	3%	6%	0%	16%	100%	**A**
3	No fogging	53%	24%	3%	1%	6%	13%	100%	**A**
4	Disposable	62%	16%	3%	0%	4%	15%	100%	**A**
5	Use in conjunction with glasses	66%	22%	1%	3%	1%	6%	100%	**A**
6	Low price	37%	1%	0%	28%	4%	29%	100%	**A**
7	Spring clamp	35%	6%	1%	6%	26%	25%	100%	**A**
8	Cap fastening	40%	9%	1%	15%	13%	22%	100%	**A**
9	Lightness	30%	11%	0%	24%	16%	19%	100%	**A**
10	Not scratch	35%	6%	0%	24%	16%	19%	100%	**A**
11	Feeling of suffocation	54%	9%	0%	4%	1%	31%	100%	**A**
12	color screen	19%	1%	0%	46%	21%	13%	100%	**R**
13	Protection	72%	16%	0%	0%	1%	10%	100%	**A**

Source: own elaboration.

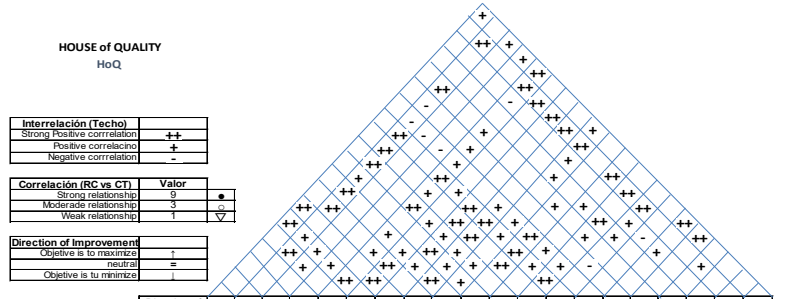
Kano's model fundamentally seeks to discriminate between attractive, mandatory, and one-dimensional requirements. This discrimination is valuable when making strategic decisions, as it is when allocating resources, it is advisable to concentrate them on the design and implementation of those requirements that will make the product more attractive. Since customer requirements are generally numerous, it is important to achieve the right mix of attributes: all mandatory requirements (which make up the core product) must be incorporated, a reasonable number of one-dimensional requirements (equivalent to having a competitive expected product) and some attractive requirements (to offer an expanded product that stands out from the competition).

From table 1 of percentages it can be concluded that, for the innovation in the design of a protective mask, of the eleven attributes consulted in the Kano survey, it is very likely that people are willing to pay more for a mask with attractive characteristics (A). Although it is not possible to make all the improvements that fall into the previous category, it is imperative to make changes based on the highest percentages of the first column of the sum of criteria, which in this case would be: The protection screen against lightning sun, use of recycled material for its manufacture and flexible support. In this way, the Kano model allows us to truly know which are the attributes that would generate greater customer satisfaction.

4.3. Detail stage

In this stage, the HoQ quality matrix was developed (Illustration 1), which is the most important of all. The relationship between the Client's Requirements and the Technical Characteristics specified by the specialists is made.

Illustration 1
Matriz HoQ



	Direction of Improvement	=	=	↑	↑	↑	↑	=	=	↑	=	=	=	↑	=	↑	=	↑	↑	↑	↑				
	Target or Limit Value	Medium	Plastic	250 mm	300 mm	1.15 mm	200 gr	High	High	Low	Cleaning	$5-$100	Duration of two or more months	High	Polished	Keep at room temperature	No aseptic perception	# Recyclable 1	Transparency	$1000-$1500	Medium				
	column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20				
Row #	Quality Characteristics (a.k.a. "Functional Requeriments" or "Hows") / Demanded Quality (a.k.a "customer Requeriment" or "Whats"	Ergonomics	Type of material	Wide	Height	Thickness	Weight	Subjection	Material quality	Material density	Maintenance	Production cost	Lifecycle	Material strenght	Finish	Room temperature preservation	Odor preservation	Recyclable materials	Opaque materials	Material cost	Ventilation	Relative Weight	Weight/Importance	Importance ranking
1	Confort	9	3	9	9	9	3	1							1						1	0.11	*10.9*	16
2	Rigidity		9			9			9	1	1		1	3		1				9		0.08	*7.6*	4
3	No fogging		9						3		1		1			1			1	3	9	0.10	*9.8*	15
4	Disposable		3						3	3			9	3				9		3		0.09	*8.7*	17
5	Use in conjunction with glasses	3		9		9		9							3				9			0.09	*8.7*	5
6	Low price		9					1	9	1		9	3	3	1			1	1	9		0.10	*9.8*	6
7	Spring clamp	3		1				9	9				3	9						1		0.05	*5.4*	18
8	Cap fastening	3	1					9												3	1	0.03	*3.3*	1
9	Lightness		9			3	9		3	3		1		1						1		0.08	*7.6*	11
10	Not scratch		9			1			9	1	9		3	3	3					3		0.09	*8.7*	19
11	Feeling of suffocation	1	1	3	3	3		3		1						3	3				9	0.09	*8.7*	12
12	Protection	9	1	3	3	3		9	3				1	3						3		0.11	*10.9*	7
																					total	**1.00**	**100**	
	Weight/Importance	**257**	**473**	**241**	**157**	**335**	**101**	**302**	**395**	**84**	**96**	**96**	**178**	**193**	**73**	**44**	**26**	**88**	**98**	**294**	**181**	**3710**			
	Evaluation (relative weight)	0.07	0.13	0.06	0.04	0.09	0.03	0.08	0.11	0.02	0.03	0.03	0.05	0.05	0.02	0.01	0.01	0.02	0.03	0.08	0.05	**1.00**			
	Difficulty (0=easy, 10=Very difficult)	8	3	7	7	8	8	8	10	10	6	10	10	10	4	8	6	2	4	10	10				
	Importance ranking	*6*	*1*	*7*	*11*	*3*	*12*	*4*	*2*	*17*	*14*	*15*	*10*	*8*	*18*	*19*	*20*	*16*	*13*	*5*	*9*				

Source: own elaboration.

The second column shows the client's requirements (already specified in the previous table), once having this information, the interdisciplinary work group assessed each one of those needs, translating the client's voice into technical characteristics, which are shown in the row of Functional Requirements (HOW), then the quantitative and qualitative technical evaluation is carried out in the last rows, and thus obtain the highest.

At the top of the HoQ, there are the interrelationships of the "HOW", below these there is the direction of improvement and the target value. On the right side, the degree of importance and relative weight of all the requirements was obtained.

Once the most important technical characteristics were identified, they were ranked based on absolute importance (Table 2). It means that of the 20 generated, 11 are the most important, and in which more attention should be paid, possibly allocating more resources of money, materials and/or human resources if required. These quality characteristics mean that the most

important is the type of material, which must be modified or changed, to meet the needs of most customers, the other two in that order of importance are the quality of the material and the thickness. of the same.

Table 2
Quality characteristics

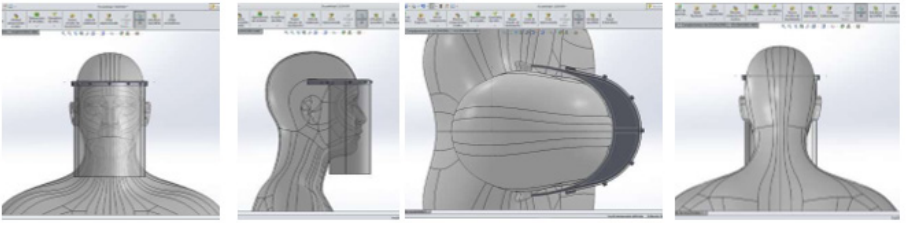
#	Quality Characteristics	COMO'	Imp. Abs.	%	80-20
1	Type of material	Como2	473	12.7%	13%
2	Material quality	Como8	395	10.6%	23%
3	Thickness	Como5	335	9.0%	32%
4	Subjection	Como7	302	8.1%	41%
5	Material cost	Como11	294	7.9%	48%
6	Ergonomics	Como1	257	6.9%	55%
7	Wide	Como3	241	6.5%	62%
8	Material strenght	Como13	193	5.2%	67%
9	Ventilation	Como20	181	4.9%	72%
10	Lifecycle	Como12	178	4.8%	77%
11	Height	Como4	157	4.2%	81%
12	Weight	Como6	101	2.7%	84%
13	Opaque materials	Como18	98	2.6%	86%
14	Maintenance	Como10	96	2.6%	89%
15	Production cost	Como11	96	2.6%	92%
16	Recyclable materials	Como17	88	2.4%	94%
17	Material density	Como9	84	2.3%	96%
18	Finish	Como14	73	2.0%	98%
19	Room temperature preservation	Como15	44	1.2%	99%
20	Odor preservation	Como16	26	0.7%	100%
			3712		

Source: own elaboration.

4.4. Simulation stage

After the analysis and results of the HoQ, considering the most important technical characteristics, an approximate simulation of the design was carried out, which is presented in the Illustration 2. This shows the mask from a front view 4a), side 4b), top 4c) and back 5d). As a summary, it was defined in this way since, after reviewing the literature, it was identified that the eyes, nose, and mouth should be well protected against droplets, for which the height and length of the sheet on the face were increased (22x26 cm). With this, it is possible to better cover the lateral and frontal area of the face, in addition, the visor was given a width of 4 cm, this thinking of the comfort of the user, as well as to avoid a “suffocation feeling” by having it too close to his face; On the other hand, this amplitude helps users who need to use lenses together with the mask to feel more comfortable and not bother or bump into it.

Illustration 2
a) Front view, b) Right side view, c) Top view d) Back view



Source: own elaboration.

Another requirement of the user was that the mask mist up as little as possible, which is why PETG was defined as a material to cover the face, since it is economical, resistant and does not mist up. On the other hand, to reduce the cost of the visor, a thickness of 2mm was established, it is an adequate and sufficient thickness, it extends the useful life of the product, and it also complies with the defined technical characteristics. On the back of the mask, a cord and stop (lock) are displayed for easy and quick adjustment to suit the user's taste.

4.5. Evaluation stage

The general design of this device was carried out in a simple way, considering only the requirements of the clients who applied the survey. Therefore, simplicity will mean constant updating of the engineering requirements of these model proposals in the future. Since the design process took place over a period, face shield designs were constantly changing and conforming to new standards, such as using metric units for the finalized design. Due to this, the design must possibly be constantly updating and improving, however, here basically lies the importance of using a continuous improvement tool such as the Kano model and QFD.

During the design process and specifically in this research article, it was only limited to describing the process up to the simulation of the prototype of the mask. In the future, having the machinery, material, and equipment available, it is expected that it will be manufactured and adapted to a standardized design, adjusting to the exact requirements specified at the beginning of the design process and then moving on to the validation process by end users.

5. Conclusions

There is currently a global problem, and the future is unknown, which is causing human loss, health and well-being problems for many people, as well as serious economic problems for entire families with limited resources, unemployment, paralyzed economies, etc. Which has caused more poverty in society, mainly in those countries with emerging economies.

Managing this type of projects is important to be prepared for future diseases and external situations. This proposal not only raises the generation of knowledge and technological

development, but also attacks a problem that will continue to exist.

The need to generate design proposals for personal protective equipment considering the needs and requirements of potential customers is currently important in all countries and places, this to prevent both non-carriers and carriers of the Sars- Cov-2 disperse particles that emit their own mouth and nose as well as protect them from external conditions related to the pandemic. With the aim of reducing the number of positive cases of COVID-19 due to contagion in closed work areas where there is agglomeration and highly frequented public areas, it is necessary to take the appropriate measures using a mask, for this purpose it was analyzed, identified, designed, and evaluated a product using the quality house methodology, which consists of weighing the critical requirements.

HoQ is a useful method that can be applied during the design process to optimize and improve products, as well as in the post-production process for future development and revision. This allows identifying and weighing the critical requirements of the important ones, appropriately allocating the economic, human, and material resources.

The findings of this study demonstrate that applying the Kano model and QFD earlier in the design phase can help develop a priority matrix of technical needs and responses in the form of a House of Quality. The results were to define the most important characteristics to consider of personal protective equipment, considering the VoC. It is then shown that the Kano-QFD methodology has applicability and effectiveness in the process of conceptual design of products.

Bibliographic References

Aguwa, C. C., Monplaisir, L., & Turgut, O. (2012). *Voice of the customer: Customer satisfaction ratio based analysis. Expert Systems with Applications, 39(11), 10112–10119.* https://doi.org/10.1016/j.eswa.2012.02.071

Akao, Y. & Mazur, G. (2003). The leading edge in QFD: past, present and future. *International Journal of Quality & Reliability Management*, *20*(1), 20-35. https://doi.org/10.1108/02656710310453791

Alarcón, J., Ormeño, G., Durán, E., Bustos, C. & Montoya, P. (2021). Diseño y fabricación de una barrera facial para personal de salud en el contexto de emergencia sanitaria covid-19. *Interciencia*, *46*(5), 224-231. https://doi.org/0378-1844/14/07/468-08

Angamarca, G., Díaz, Y., & Martínez, C. (2020). Calidad percibida por los clientes de los hoteles de la provincia Los Ríos, Ecuador. *Revista de Ciencias Sociales (RCS)*, *26*(4), 380-393. https://produccioncientificaluz.org/index.php/rcs/index

Carnevalli, J. & Miguel, P. (2008). Review, analysis and classification of the literature on QFD-types of research, difficulties and benefits. *International journal production economics*, *114*(2), 737-754. https://doi.org/10.1016/j.ijpe.2008.03.006

Chan, L-K & Wu, M-L. (2005). A systematic approach to quality function deployment with a full illustrative example. *Omega-International journal of management science*, *33*(2), 119-139. https://doi.org/10.1016/j.omega.2004.03.010

Chan, L-K, & Wu, M-L. (2007). Quality Function Deployment: A Comprehensive Review of Its

Concepts and Methods, *15*(1), 23-35. https://doi.org/10.1081/QEN-120006708

Chu, D. K., Akl, E. A., Duda, S., Solo, K., Yaacoub, S., Schünemann, H. J., … Schünemann, H. J. (2020). *Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19: a systematic review and meta-analysis. The Lancet.* https://doi.org/10.1016/s0140-6736(20)31142-9

Cohen, L. (1995). *Quality function deployment: How to make QFD work for you*. Addison-Wesley.

Cook, T. (2020) Personal protective equipment during the COVID-19 pandemic –a narrative review. *Anaesthesia*, *75*, 920-927. https://doi.org/10.1111/anae.15071

Cui, J., Li, F. & Shi, Z. L. (2019). Origin and evolution of pathogenic coronaviruses. *Nature Rev.*, *17*(1), 81–92. http://dx.doi.org/10.1038/s41579-018-0118-9.

Erkarslan, O. & Yilmaz, H. (2011). Optimization of the product design through quality function deployment and analytical hierarchy process: a case study of a ceramic washbasin. *Metu journal of the faculty of architecture*, *28*(1), 1-22. https://doi.org/10.4305/METU.JFA.2011.1

Found, P., and Harrison, R. (2012). Understanding the lean voice of the customer. *International Journal of Lean Six Sigma*, *3*(3), 251-267. https://doi.org/10.1108/20401461211282736

Govers, C. (2001). QFD not just a tool but a way of quality management. *International journal production economics*, *69*(2), 151-159. https://doi.org/10.1016/S0925-5273(00)00057-8

Gralinski, L. E. & Menachery, V. D. (2020). Return of the coronavirus: 2019-nCoV. *Viruses*, *12*(2). http://dx.doi.org/10.3390/v12020135

Han, S., Chen, S. Ebrahimpour, M. & Sodhi, M. (2001). A conceptual QFD planning model. *International Journal of Quality & Reliability Management*, *18*(8), 796-812. https://doi.org/10.1108/02656710110401187

Hauser, J. R., Griffin, A., Klein, R. L., Katz, G. M., & Gaskin, S. P. (2010). *Quality Function Deployment (QFD). Wiley International Encyclopedia of Marketing.* doi:10.1002/9781444316568.wiem050

Hernández, R., Fernández, C., & Baptista, P. (2020). *Metodología de la investigación*. (7ma. ed.). McGraw-Hill

Herzwurm, G. & Schockert, S. (2003). The leading edge in QFD for software and electronic business. *International Journal of Quality and Reliability Management*, *20*(1), 36-55. https://doi.org/10.1108/02656710310453809

Hogstrom, C., Rosner, M., & Gustafsson, A. (2010). How to create attractive and unique customer experiences: An application of Kano's theory of attractive quality to recreational tourism. *Marketing Intelligence & Planning*, *28*(4), 385–402. https://doi.org/10.1108/02634501011053531

Howard, J., Huang, A., Li, Z., Tufekci, Z., Zdimal, V., van der Westhuizen, H.M., von Delft, A., Price, A., Fridman, L., Tang, L. H., Tang, V., Watson, G. L., Bax, C. E., Shaikh, R., Questier, F., Hernandez, D., Chu, L. F., Ramirez, C. M., y Rimoin, A. W. (2020). An evidence review of face masks against COVID-19. *Proc Natl Acad Sci USA*, 26, 118(4), e2014564118. https://doi.org/10.1073/pnas.2014564118

Hunt, R.A. & Xavier, F.B. (2003). The leading edge in strategic QFD. *International Journal of Quality and Reliability Management*, *20*(1), 56-73. https://doi.org/10.1108/02656710310453818

Ino, Y., Yano, T. & Yamamoto, H. (2020). A new simple method of handmade face shield using A4-size OHP sheet, during the COVID-19 pandemic. *Digestive Endoscopy*, *32*(5). https://doi.10.1111/den.13724

Jing, H, Zhang, L. & Wen, B. (2010). Requirement Optimization for House of Quality Based on Product Quality Improvement. *China Mechanical Engineering*, *21*(1), 94-99.

Lin, F-H., Tsai, S-B., Lee, Y-C., Hsiao, C-F, Zhou J, Wang J, et al, (2017) Empirical research on Kano's model and customer satisfaction. *PLoS ONE*, *12*(9), e0183888. https://doi.org/10.1371/journal.pone.0183888

Liu, S. L. & Saif, L. (2020). Emerging viruses without borders: the Wuhan coronavirus. *Viruses*, *12*(2). http://dx.doi.org/10.3390/v12020130

Luor, T., Lu, H. P., Chien, K. M., & Wu, T. C. (2015). Contribution to quality research: A literature review of Kano's model from 1998 to 2012. *Total Quality Management & Business Excellence*, *26*(3–4), 234–247. https://doi.org/10.1080/14783363.2012.733264

Marasinghe, K. M. (2019). A systematic review investigating the effectiveness of face mask use in limiting the spread of COVID-19 among medically not diagnosed individuals: shedding light on current recommendations provided to individuals not medically diagnosed with COVID-19, 1–19. http://doi.org/10.21203/rs.3.rs-16701/v2

Maritan, D. (2015). *Practical Manual of Quality Function Deployment*. (1ra ed.). Springer. https://doi.org/10.1007/978-3-319-08521-0

Martins, A. & Aspinwall, E. (2001). Quality function deployment: an empirical study in the UK. *Total quality management*, *12*(5), 575-588. https://doi.org/10.1080/09544120120060060

Méndez, C. (2007). *Metodología: diseño y desarrollo del proceso de investigación con énfasis en ciencias empresariales*. (4ta ed.). Limusa.

Mendoza, U. & Solís, F. T. (2022). Calidad, conocimiento e innovación de procesos de manufactura en Ciudad Juárez, México. *Retos*, *12*(23), 83-109. https://doi.org/10.17163/ret.n23.2022.05

Mikulić, J. & Prebežac, D. (2011). A critical review of techniques for classifying quality attributes in the Kano model. *Managing Service Quality: An International Journal*, *21*(1), 46-66. https://doi.org/10.1108/09604521111100243

Milton, A. & Rodgers, P. (2013). *Research Methods for Product Design*. Laurence King Publishing.

Moges, A. (2009). Design for Manufacturability and Concurrent Engineering for Product Development. *World Academy of Science, Engineering and Technology*, *49*, 240-246.

Montesinos, S., Vázquez, C. & Maya, I. (2020). Mejora Continua en una empresa en México: estudio desde el ciclo Deming. *Revista Venezolana de Gerencia*, *92*, 1863-1883. https://doi.org/10.37960/rvg.v25i92.34301

Morales, M. (2021). Translation: Covid-19, new technologies, productivity and business' emergency plan. *Telos Revista de Estudios*

Interdisciplinarios en Ciencias Sociales, *23*(3), 764-773. https://doi.org/10.36390/telos233.16

Nievas, B. & Garcia, S. (2020). Salud, una respuesta social frente a la pandemia por Covid-19. *Revista de Ciencias Sociales*, *26*(4), 23-27. https://doi.org/10.31876/rcs.v26i4.34643

Organización Mundial de la Salud- OMS (2020a). Preguntas y respuestas sobre la enfermedad por coronavirus (COVID-19). https://elpais.com/sociedad/2020-03-11/la-oms-declara-el-brote-de-coronavirus-pandemia-global.html

Ortega, M. (2020). Efectos del Covid-19 en el comportamiento del consumidor: Caso Ecuador. *Retos*, *10*(20), 233-247. https://doi.org/10.17163/ret.n20.2020.03

Orús, A. (2021). Statista. https://es.statista.com/estadisticas/1104227/numero-acumulado-de-casos-de-coronavirus-covid-19-en-el-mundo-enero-marzo/

QFD Institute (2013). The official source for QFD. http://www.qfdi.org/

Qingliang Meng, Q. & Dong, J. (2018). Future Direction and Visual Analysis of Kano Model: A Literature Review. *Journal of Service Science and Management*, *11*(04), 399-413. https://doi.org/10.4236/jssm.2018.114028

Quintero, M. (2020). Careta de protección facial para personal médico (col-univalle face shield) de facil fabricación ante desabastecimiento extremo o imposibilidad de acceso en la pandemia por sars cov-2, https://doi.org/10.13140/RG.2.2.28413.92647/1

Raharjo, H., Xie, M. & Brombacher, A. (2007). Prioritizing quality characteristics in dynamic quality function deployment. *International Journal of Production Research*, *44*(23), 5005-5018. https://doi.org/10.1080/00207540600547414

Rahman, M. & Williams, S. J. (2020). Membrane tension may define the deadliest virus infection. *Colloid and Interface Science Communications*, *40*(1), 1-6 https://doi.org/10.1016/j.colcom.2020.100338

Roberge, R. J. (2016). Face shields for infection control: A review. *Journal of Occupational and Environmental Hygiene*, *13*(4), 235-245. https://doi.10.1080/15459624.2015.1095302

Rocha, J. J., Julio, J. J., y Semprun, R. Á. (2021). Economía social como alternativa ante una sociedad post coronavirus. *Revista de Ciencias Sociales*, *27*(2), 147-162. https://doi.org/10.31876/rcs.v27i2.35904

Rojas, R. (2008). *Guía para realizar investigaciones sociales*. Plaza y Valdés.

Shanin, A., Pourhamidi, M., Antony, J., (2013). Typology of Kano Models: A Critical Review of Literature and Proposition of a Revised Model. *International Journal of Quality & Reliability Management*, *30*, 341-358. https://doi.org/10.1108/02656711311299863

Sohrabi, C., Alsafi Z, O'Neill N, Khan M, Kerwan A, Al-Jabir A, Iosifidisa C, Aghad R (2020). World Health Organization declares global emergency: A review of the 2019 novel coronavirus (COVID-19), *Int. J. Surg.*, *76*, 71-76. https://doi.org/10.1016/j.ijsu.2020.02.034

Torres, E. S., Leyva, H. N., García, A. T. R., González, F. J. S. & García, G. H. (2020). Equipo de protección personal y COVID-19. *Cirujano General*, *42*(2), 116-123.

Vera, D., Trujillo R. & Chambo, Y. (2020). Diseño y fabricación de caretas faciales ergonómica para el uso del personal médico asistencial de primera línea de atención para cuatro instituciones hospitalarias del departamento del huila ante la emergencia COVID-19.

Wolniak, R (2018). The use of QFD method advantages and limitation. *Production engineering archives*, *18*, 14-17. https://doi.org/10.30657/pea.2018.18.02

World Health Organization- WHO (2020). Transmission of SARSCoV-2: implications for infection prevention precautions Scientific Brief 9 July 2020. COVID-19: Infection prevention and control / WASH. https://www.who.int/publications/i/item/modes-of-transmission-of-viruscausing-covid-19-implications-for-ipc-precaution-recommendations

World Health Organization- WHO (2020b). Rational use of personal protective equipment (PPE) for coronavirus disease (COVID-19): Interim guidance, 19 March 2020 WHO/2019-nCoV/IPC PPE_use/2020.2. World Health Organization. Geneve, Switzerland.

Xie, M., Tan, K., & Goh, T. (2003). Advanced QFD applications. Milwaukee: ASQ Quality Press. https://doi.org/10.1108/13552510410526901.

Zhou, W. (2020). *The Coronavirus Prevention Handbook*. Skyhorse Publishing.