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QUALITY FUNCTION DEPLOYMENT (QFD) AS A TOOL FOR IMPROVING ARTISANAL PROCESSES

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Abstract: Currently, the artisan sector faces an urgent need to optimize its processes. Many of these activities rely on manual effort and often involve a limited number of workers, which frequently results in worker fatigue and poor quality in the finished products. This research aims to demonstrate the application of Quality Function Deployment (QFD) in a case study conducted in a company that sells bee products in Tantoyuca, located in the Huasteca Alta region of Veracruz, Mexico. This company seeks to improve the working conditions of its employees. The methodology used was crucial in defining the necessary characteristics for the design of a labeling machine prototype. The results allowed for the identification of Critical to Quality (CTQ) factors, which are essential for determining the technical requirements of the customer. These requirements will be key in developing a prototype that enhances efficiency and quality at the labeling station through automation.
Keywords: Optimization, Quality, Artisans, Industry 4.0, Automation.

INTRODUCTION

Quality Function Deployment (QFD) is a versatile tool that extends beyond product design to process improvement and quality management. It effectively translates customer requirements into measurable product or process parameters, leading to significant improvements in critical quality characteristics and sales rates (Erdil & Arani, 2019).

The tool integrates the Voice of the Customer with the House of Quality, supporting strategic decision-making in product development and improvement processes; successful implementation of QFD requires a structured approach, proper training, and alignment among all stakeholders, including customers, suppliers, employees, and management (Pedroso de Sales et al., 2022).

The integration of Industry 4.0 technologies with artisanal and small-scale manufacturing presents opportunities to improve the productivity, quality and sustainability of your processes. Quality Function Deployment (QFD) has been applied to prioritize Industry 4.0 implementation strategies in micro, small, and medium-sized enterprises (MSMEs), identifying key challenges such as senior management support and transition costs (Agarwal & Ojha, 2022).

Currently, a framework that combines quality, manufacturing 4.0 and sustainable development goals has been used for microenterprises in the industry, emphasizing the potential to improve processes while minimizing environmental impact (Avilés-Sacoto *et al*., 2024). Research has also explored the correlation between Industry 4.0 and sustainable development in the machine tool industry using QFD and fuzzy multi-attribute decision-making methods (Chang *et al*., 2023).

A study demonstrated significant improvements in the critical quality characteristics identified, as well as in sales rates. This highlights the potential of Quality Function Deployment (QFD) for assessing and prioritizing areas for improvement, ultimately transforming them into measurable requirements for processes or products (Erdil & Arani, 2019).

In addition, a methodology has been developed that incorporates Industry 4.0 facilitators in artisanal activities, with the aim of improving traditional craftsmanship while preserving its identity (Alexandre *et al*., 2017).

Quality Function Deployment (QFD) is a system that helps translate customer requirements into appropriate company parameters at each stage of the new product development cycle, from research and development to distribution and sales (Quesada Madriz, 2005).

On the other hand, QDF also translates as a systematic and organized approach to take into account the needs and demands of the customer when designing new products and services, or when improving an existing product or service (Singh Soin, 1998).

It is important to note that the QFD is not a quality tool in itself, but a planning tool that allows new products to be introduced with greater efficiency and quality (Reyes P, 2011). The QFD process includes the conversion of customer requirements into internal design requirements, the translation of global product requirements into critical characteristics of the parts, the determination and transformation of appropriate manufacturing operations into production requirements (Cuatrecasas Arbós and González Babón, 2017).

The artisanal process is characterized by small-scale production, the direct involvement of the artisan in all stages of production, the use of hand tools and the investment of considerably more time than in the industrial process (Cornejo Rodríguez, *et al.*, 2009). The volume of production within a cottage industry is generally small, but the product is unique and stands out for its technical organization, in which a single person knows the entire production process (González Alvarado, 2020).

To create a product manually, the artisan must have technical knowledge and skills, as well as an understanding of production time to calculate costs and profits, which determine the appropriate demand and sales price (Government of Mexico, 2022).

In Mexico, artisanal branches respond to a set of production techniques in which similar or complementary raw materials are used, processed to create products or objects common to each other, and which in turn can be associated with some sub-branches, which are made up of a variety of particular execution techniques that are applied to achieve the final product (FONART, 2018).

This type of production has been preserved in all markets of the most developed countries until the beginning of the twentieth century and still persists for many products today (Bustos, 2009). The artisanal process stands out for its technical organization, where most of the process is known and/or carried out by a single person.

Figure 1: Artisanal textile weaving process. Source: Authors

Several researchers have explored the application of the Quality Function Deployment (QFD) methodology as a vital tool for problem-solving in various contexts, including the development of new products and the enhancement of existing products or services. Notably, Rodríguez Gasca *et al.* (2016), focused on the development of a 3D printer using the QFD approach, emphasizing client requirements. Their work led to the creation of a critical path for project planning.

Catera (2019), uses the QFD methodology as a process improvement tool, for a company dedicated to the production of feminine protection products, which resulted in the improvement around the qualification of the product, weight and thickness, this mainly due to the strong link with the formation and absorption of the product relating the needs of the users with the technical characteristics of the product.

METHODOLOGY

The objective of the following research is to apply the QFD methodology, for the development of a prototype for the labeling of bottles, which will increase the efficiency of productivity within a company of the artisanal trade, which is dedicated to the production of goods derived from bee honey. In this case, the research design was determined as mixed-exploratory, since both qualitative and quantitative elements are combined within the collection and analysis of data in order to explore the main research problem.

The working hypothesis will be determined with the characteristics of the research design, established as follows: by applying the QFD in the design of a labeling machine prototype, it will lead to a significant improvement in the quality of the finished product, by aligning the technical characteristics with the needs and expectations of the customer or voice of the expert, which will result in higher customer satisfaction and increased competitiveness in the market.

The QFD is a tool that can be applied within a wide range of products and/or services; for practical research purposes, it was decided to apply the QFD matrix to determine the quality characteristics of honey wine products in the 250ml presentation, since, based on the company's indicators, it is the product with the highest demand, which is equivalent to 45% of total sales. which indicates that it is the product with the highest profit margin.

The development of the QFD methodology follows a series of steps referring to the filling of the six parts of the matrix, which are shown in Figure 2;

1. Voice of the customer (What, hierarchical customer requirements scale 1 to 5)
2. Voice of the organization (technical requirements, how)
3. Relationship matrix (impact of technical requirements on customer requirements)
4. Competitive analysis (benchmarking and planning strategy)
5. Correlation matrix
6. Process objectives (priorities for technical requirements) (Gutiérrez Pulido & De la Vara Salazar, 2013).

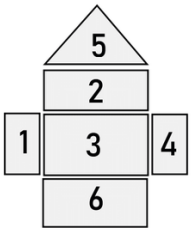


Figure 2: QFD (Quality Function Deployment).

RESULTS

For the development of this article, a feasibility study was carried out with the aim of collecting information through surveys. The goal of this census was to gain a clear understanding of what customers value in a product, which is critical for the application of the QFD methodology effectively. By collecting information through surveys, it was possible to gain direct insight into the expectations of the customers to whom the product is intended and used that information as the basis for the development of the QFD.

SURVEY APPLICATION

The following survey was carried out specifically with artisans from various localities, including La Estanzuela, Mata del tigre, Cerro Botica, Lindero Tametate, La Tinaja, Xilozúchil, and Tecomate. These communities are part of the municipality of Tantoyuca, in the state of Veracruz, México. In addition, a group of workers belonging to a beekeeping microenterprise was included in the research. This group is not only in charge of the production of products, but also plays a crucial role in the collection of information since they serve as the voice of the expert, since the way they work is in an artisanal way.

In addition, with the help of this questionnaire, the development of the QFD methodology was given.

VERBALIZATION

Once all the needs of the customers were obtained, the verbalization of these requirements was carried out, this with the aim of being able to give a better interpretation which expresses in a clear and concise way the requirements that the customer requires, that is, in measurable and verifiable terms.

In addition, with verbalization, the QFD facilitates the identification of the client's key and priority requirements, which helped to establish the basis for the development of specific strategies and actions. This allowed informed decisions to be made about which aspects of the product or service should receive the most attention and to what extent customer needs and expectations should be met.

FREQUENCY OF REQUIREMENTS

During the information gathering stage of the QFD, the identification of the client's needs and expectations was carried out. In this phase, data were collected through surveys, and interviews with artisans and experts. Therefore, each time a certain requirement or characteristic was mentioned or requested by customers, its frequency was recorded (Table 1). This helped determine the relative importance of that requirement compared to others.

Characteristics	Frequency	Characteristics	Frequency
Speedy	14	Resistant	8
Economic	12	Good design	7
Multifunctional	12	Low cost	7
Energy saver	10	Efficient	3
Easy to use	9	Easy to acquire	2
Low cost	9	Easy to clean	2
Ergonomic	8		

Table 1: Frequency of customer requirements.
Source: Authors.

Subsequently, each element that makes up the QFD matrix was filled.

VOICE OF THE CUSTOMER (WHAT, HIERARCHICAL CUSTOMER REQUIREMENTS SCALE 1 TO 5)

In the first phase of the matrix, the client's requirements were determined, through the brainstorming technique, by the members of the organization, based on the experiences obtained and collected (Mendoza Núñez , 2005).

That is why, during the application of the QFD methodology, the opinions of the customer or the voice of the expert were collected, applied in the market study stages to identify the needs and preferences of the product according to the customers. In this first stage for the construction of the quality house, the results obtained through the application of the survey and interview were carefully analyzed.

Therefore, once the client's requirements were obtained and verbalized, they were ordered according to their requirement group, defining the case study as follows; three subgroups of need composed of different types of requirements. 1) Design, in this first group refers to the modeling characteristics, the type of material and some of the mechanical characteristics with which the prototype must comply. 2) Structure, the second group is to verbalize the main points of design and the modes of use of the prototype. 3) Market, in this genre the points related to technical characteristics and reliability are grouped.

With these first data, the first stage of the matrix is filled, specifying the needs of the customers, (Table 2).

Maximum Ratio ↓	Need Sup.	Requirements Functional → / Requirements From the customer
1	Design	Good design
2		Resistant
3		Easy to clean
4		High temperature resistant
5		Multifunctional
6	Structure	Easy to use
7		Ergonomic
8		Speedy
9		Efficient
10	Market	Reliable
11		Economic
12		Easy to acquire
13		Energy saver

Table 2: Customer requirements (What's). Source: Authors.

VOICE OF THE ORGANIZATION (TECHNICAL REQUIREMENTS, HOW)

In the next stage it was necessary to define the How's? or functional requirements, which involved the company's operating procedures to establish the activities, or specific characteristics that must be implemented both technically and operationally, to meet the customer's requirements and achieve maximum customer satisfaction.

This section lists the technical characteristics of the product "how-to" that are related to customer demands and are identified and defined in the process of deploying the quality function, the core methodology of the QFD. (López Alcausa, 2016)

RELATIONSHIP MATRIX (IMPACT OF TECHNICAL REQUIREMENTS ON CUSTOMER REQUIREMENTS)

Once the requirements of the customers and the functional requirements were defined, the relationship matrix was developed, this implies the impact they have between them. Different authors use symbology to relate the (What's?) with the (What's?).

In this case, a numerical assignment was used for the symbols according to the authors Camisón, *et al*., (2006), where (9) it is used to interpret that there is a strong relationship between both parameters, (6) for a medium relationship and (3) to represent a weak relationship, in addition to the fact that the empty boxes or cells indicate the lack of relationship between the requirements, In the case of this house, quality was handled with a (0), (Table 4).

COMPETITIVE ANALYSIS (BENCHMARKING AND PLANNING STRATEGY)

The future viability of a product or service, which starts with inferior characteristics to those of its current competitors, is mired in uncertainty. Therefore, it is imperative to carefully evaluate whether the products or services offered by the competition include these essential characteristics and determine the level of excellence they have achieved in them.

This part analyzed the assessment known as "needs benchmark", which obtains a solid criterion to establish objectives of excellence in the fulfillment of these essential characteristics "Whats". This process involved taking as a reference the leading competitor in each aspect evaluated (Table 5).

However, at this stage, it is crucial to avoid falling into two potential risks:

Requirements Functional / Requirements From the customer	CUSTOMER PRIORITY	3D Modeling	Material selection	Sensor accuracy	Prototype construction	Engine Power	Automated	Prototype height

Table 3: Functional requirements (such as's). Source: Authors

Maximum Ratio	Need Sup.	Requirements Functional / Requirements From the customer	CUSTOMER PRIORITY	3D Modeling	Material selection	Sensor accuracy	Prototype construction	Engine Power	Automated	Prototype height
1	Design	Good design	4	9	9	0	9	0	0	6
2		Resistant	5	9	9	0	6	0	0	0
3		Easy to clean	3	0	0	0	3	0	0	3
4		High temperature resistant	4	0	9	0	3	6	0	0
5		Multifunctional	3	3	0	0	3	0	6	0
6	Structure	Easy to use	3	0	0	3	6	0	9	0
7		Ergonomic	4	0	0	0	0	0	9	9
8		Speedy	5	0	0	9	0	9	9	0
9		Efficient	2	0	0	6	0	9	3	0
10	Market	Reliable	1	3	9	9	3	3	3	0
11		Economic	1	0	9	3	6	0	0	0
12		Easy to acquire	1	0	0	0	0	0	0	0
13		Energy saver	3	0	0	0	0	0	6	0

Table 4: Matrix of relationships. Source: Authors

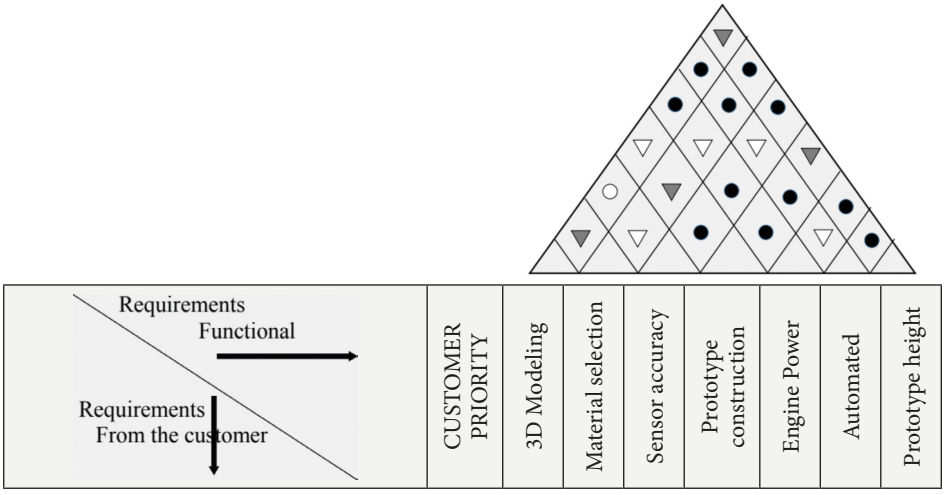


Figure 6. Correlation matrix. Source: Authors.

Evaluation of imp.	93	135	78	123	90	153	69
Relative Evaluation	12.55	18.22	10.53	16.6	12.15	20.65	9.312
Cumulative %	9	27.22	37.74	54.34	66.49	87.14	96.45

Table 6: Design priorities (Process objectives). Source: Authors.

S.C. Packaging Technology	BELLA-TR, Notaris panel labeler	HERMA bottom labeler 552C
9	6	9
9	9	9
0	0	0
6	6	3
3	6	6
0	0	0
9	6	9
9	9	9
3	6	3
6	0	0
0	0	0
0	0	0
0	0	0

Board 5: Competitor analysis. Source: Own elaboration.

CORRELATION MATRIX

In this phase of the methodology, the determination of correlations happens on the roof of the house of quality and is reflected graphically, this is done between the functional requirements (the Como's), with the aim of understanding how the satisfaction of one requirement affects others and to make informed decisions about the allocation of resources and priorities during the process of design and development of the product. If the relationship is strong positive, the sign (▼) is placed), if the relationship is positive (▽), if the relationship is negative, the sign (◯) is used, and if the relationship is negative, the sign(●) is used (Figure 6).

PROCESS GOALS

For the last part of the QFD matrix, which leads to the definition of the objectives for the technical characteristics, it will depend on the prototype being automated. This is calculated as the sum of the values assigned to each customer demand, as well as their interpretation as a percentage.

For example, for the "Automated" feature, the following is done: the customer's priority is multiplied, according to each requirement, this, by the functional requirement and the following requirements are added by multiplying by the same requirement (4x0 + 5x0 + 3x0 + 4x0 + 3x6 + 3x9 + 4x9 + 5x9 + 2x3 + 1x3 + 1x0 + 1x0 + 3x6 = 153) (table 6). After calculating each of the values in the QFD, an interpretation was made that reveals that, in order to improve a workstation of the artisanal type, it is essential to have a solid design that ensures the durability of the device. In addition, the device must be fast in the execution of operations, so it is required to be automatic.

The QFD matrix is shown in full in Figure 4.

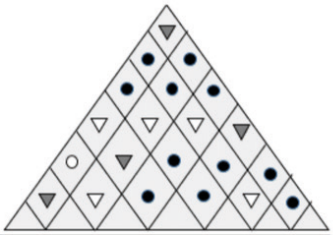
After the application of the QFD methodology, an interpretation was made that reveals that, in order to improve a workstation of the artisanal type, it is essential to have a solid design that ensures the durability of the device (Figure 4). In addition, the device must be fast in the execution of operations, so it is required to be automatic.

CONCLUSIONS

The application of QFD in the beekeeping company of Tantoyuca has made it possible to accurately identify the Critical Quality Critics (CTQs) necessary to meet customer demands and improve the efficiency of the labeling station. This approach helps align technical requirements with customer expectations, addressing crucial aspects such as work fatigue and product quality.

Using the QFD methodology, specific characteristics have been established for the design of the labeling machine prototype. This ensures that the new design not only meets the required technical standards, but also improves the working conditions of the operators, thus contributing to better quality in the final product.

The automation proposed by the labeling machine prototype is presented as an effective solution to reduce dependence on manual effort. This not only minimizes work fatigue, but also optimizes the labeling process, increasing



Relación máxima	Necesidad Sup.	Requerimientos Funcionales / Requisitos Del cliente	PRIORIDAD DEL CLIENTE	Modelado 3D	Selección de material	Precisión en sensores	Construcción de prototipo	Potencia de motor	Automatizada	Altura del prototipo	S.C. Packaging Technology	BELLATR, Notanis panel labeler	HERMA bottom labeler SS2C
1	Diseño	Buen diseño	4	9	9	0	9	0	0	6	9	6	9
2		Resistente	5	9	9	0	6	0	0	0	9	9	9
3		Fácil de limpiar	3	0	0	0	3	0	0	3	0	0	0
4		Resistente a altas temperaturas	4	0	9	0	3	6	0	0	6	6	3
5		Multifuncional	3	3	0	0	3	0	6	0	3	6	6
6	Estructur	Fácil de usar	3	0	0	3	6	0	9	0	0	0	0
7		Ergonómica	4	0	0	0	0	0	9	9	9	6	9
8		Rápida	5	0	0	9	0	9	9	0	9	9	9
9		Eficiente	2	0	0	6	0	9	3	0	3	6	3
10	Mercado	Confiable	1	3	9	9	3	3	3	0	6	0	0
11		Económica	1	0	9	3	6	0	0	0	0	0	0
12		Fácil de adquirir	1	0	0	0	0	0	0	0	0	0	0
13		Ahorradora de energía	3	0	0	0	0	0	6	0	0	0	0
		Evaluación de imp.		93	135	78	123	90	153	69			
		Evaluación relativa		12.55	18.22	10.53	16.61	12.15	20.65	9.31			
		Acumulada %		9	27.22	37.74	54.34	66.49	87.14	96.45			

Figure 4: Full quality house. Source: own.

productivity and consistency in labeling quality.

The integration of QFD has made it easier to identify critical aspects that affect labeling quality. The development of the prototype, based on these requirements, will allow a significant improvement in the presentation of the beekeeping product, which can positively influence market perception and customer satisfaction.

It is recommended to continue using the QFD approach in future process developments within the artisanal sector. The methodology provides a solid foundation for the identification of key requirements and the implementation of practical solutions, contributing to continuous improvement and competitiveness in local and global markets.

The QFD methodology proves to be a valuable tool not only for the company in question, but also for the artisanal industrial sector in general. Its application can serve as a model for other artisanal enterprises facing similar problems, providing structured guidance for improving their processes and working conditions.

The outcome of the research is carried out with respect to the objectives and hypotheses.

Utilizing the QFD methodology offers a powerful strategy to drive quality, continuous improvement, and customer satisfaction in any organization. This tool complements each other, addressing different aspects of the process of design, development and production of products, processes and services.

In this research, the QFD focused on understanding and translating the customer's needs and requirements into technical product features and specifications. Allowing you to set priorities and align design and development decisions with customer expectations, ensuring that the final product meets their needs.

That is why by using the QFD tool, organizations can address both internal quality aspects (failure prevention, reliability, efficiency) and external quality aspects (customer satisfaction, compliance with requirements).

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