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QUALITY FUNCTION DEPLOYMENT (QFD): AN APPLICATION IN THE SELECTION OF 3D PRINTERS

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Abstract - In the elaboration of this article a comparative analysis of the Quality Function Deployment (QFD) is made for its application in the selection of 3D printer. The objective of this research is to perform a comparative analysis between 3 3D printers with professionals who know what 3D printing is. The use of the QFD comparative analysis is considered to perform this comparative study because it is one of the most used in marketing to perform a detailed analysis that refers to how to satisfy customers and translate customer desires into a target design, with which customer desires are known and solutions are identified. With this research done and results obtained, we will know what the customer's wishes are when making a selection of 3D printers. In this way it will be possible to build 3D printers with the features that customers prefer and desire.

Keywords: QFD quality house, competitive evaluation, 3D printers, levels of importance.

Abstract*:* In the elaboration of this article a comparative analysis of the Quality Function Deployment (QFD) is made for its application in the selection of 3D printers. The objective of this research is to perform a comparative analysis
between 3 3D printers with professionals who know what 3D printing is. The use of the QFD comparative analysis is considered to perform this comparative study because it is one of the most used in marketing to perform a detailed analysis that refers to how to satisfy customers and translate customer desires into a target design, with which customer desires are known and solutions are identified. With this research done and results obtained we will know what the customers' wishes are when selecting 3D printers. In this way we will be able to build 3D printers with the features that customers prefer and desire.

Key words: Quality Function Deployment QFD, competitive evaluation, 3D printers, levels of importance.

INTRODUCTION

Once upon a time, 3D printing was exclusive to high-tech corporations and laboratories. It was a technology used for research and design areas that wanted to generate prototypes of objects manufacturing. Nowadays, it has applications in the Industrial, Logistics, Manufacturing and small-scale manufacturing, Aerospace, Medicine and architecture sectors [1].

3D printing consists of making a physical object by printing a digital 3D model, layer by layer; that is, it starts with the loose material and then makes an object from a template. This is one of the pillars of what many experts have called the 'fourth industrial revolution' [2].

3D printing technologies are rapidly being created and are getting bigger, faster and cheaper. What the current demand for specialized materials to satisfy with the required properties of the final parts will continue to drive the

great development of the wide range of types of options available [3].

Additive manufacturing, better known as 3D printing, will set the pace at which the material goods we use every day are designed, built and distributed. This technology could set in motion a new industrial revolution [4].
Arguably, not since the introduction of specialized software has there been a technological tool as attractive to designers as 3D printing (3DP).

Formerly known as rapid prototyping (RP), and also interpreted as part of additive manufacturing (AM), it has evolved so fast that it is difficult to predict the practical applications it will have in our lives. For designers, it is already a reality to quickly and accurately convert a two-dimensional drawing into a palpable and usable structure [5].

Quality Function Deployment (QFD).
Quality Function Deployment is actually known by the English acronym QFD (Quality Function Deployment). It was introduced in Japan in the 1960's by Akao ; the Japanese book was published until the end of the 1970's and in the 1990's an English bibliography appeared.
It is composed of two purposes: to deploy the quality of the product or service, i.e., the design of the service or product on the basis of customer needs and requirements; and to deploy the quality function in all activities and functions of the organization [6].

It is the Quality Matrix and is popularly known as the QUALITY HOUSE, due to the shape it tends to [7], which is in essence a table relating the voice of the customer to the requirements that satisfy it [8].

In relation to the literature material we find the Quality Function Deployment (QFD) which refers to how to satisfy customers and translate customer desires into a design goal, that is to capture good understanding of customer desires and identify alternative process solutions. By realizing and defining this relationship, operations managers will be able to develop products and processes with the requirements that our customers most prefer and desire. This relationship marks the construction of the first step of a world class production system. The steps to be followed for the elaboration of this matrix are the following: Identify what the customer wants, Identify how the product and/or service will satisfy the customer's wants, Relate the customer's wants to the product's hows, Identify the relationships between the company's hows, Develop.

significance rankings, Evaluate competitive products, Determine desirable technical attributes, their performance, and the competitor's performance against these [9].

For example, in the house of quality is exposed for this, in which you can clearly see what the customer is what he asks from 3D printers and how to meet those needs on the part of producers.

On the other hand, today it is not only enough to generate products and seek a market for their sale, but it is necessary to immerse the consumer in the design process of the products, in addition to satisfying the needs for which they were conceived, to generate expectations that exceed what the users thought, creating new needs so that these processes are versatile and innovative [10].

In short, the QFD planning methodology was designed according to the user's requirements, outlining the development paths that allowed the execution of the project in a very satisfactory manner [10].

Quality Function Deployment Phases.
• Identify and organize customers. It allows to choose the appropriate user segment(s) to collect the notes or information indispensable to carry out the deployment of the required and expected quality.
• Find the customer's expectations. To design an item or service in relation to the customer, it is essential to understand their tastes and needs.
-The information will be converted into particular verbal descriptions. The above data should be useful to obtain a data base to be examined, with the objective of presenting a complete questionnaire to a wider sample of clients, since normally the approach to demands is not very specific.
-Develop and administer customer surveys. Administer a survey of service users to assess the influence of each of the demands studied and estimate the position of the company itself and that of rivals.
-Deployment of the quality demanded. Having the data, we proceed elaborate the QFD to define in which aspects it is necessary to make a greater effort in order to adapt the service to what the customer wants, WHAT needs to be improved.
-Deployment of quality characteristics. Here is the other question to be answered: HOW to improve. Consequently, it is necessary to establish a double-entry matrix in which the evaluated factors are crossed with the quality characteristics, the elements that the company can modify to a certain extent and which are quantifiable and measurable indicators [6].

The full version of QFD is based on a series of matrices to establish and relate the inputs (What, customer requirements) to the outputs (How, technical requirements) of the different stages of development. The initial matrix, known as the house of excellence, is the only one used in this project [11].

Figure 1 shows an example of the QFD quality house and how it is made up.

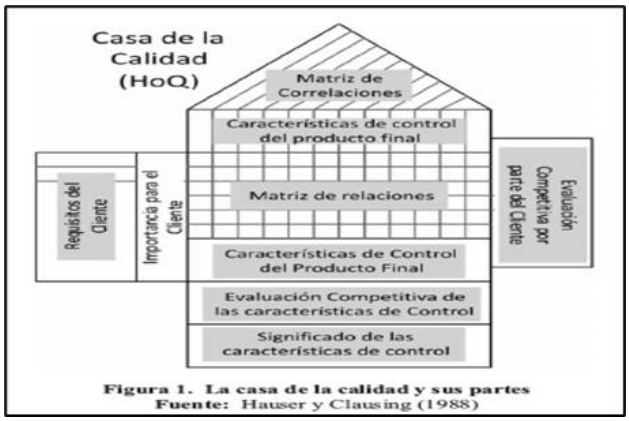

Figure 1. The house of quality and its parts
Source. [6]

Figure 2 shows another example of the QFD quality house. In this house you can see the divisions that form it.

QFD comprises four main stages, in each of these stages a matrix is examined sequentially. The first QFD matrix is the best known of the method and is called the House of Quality. In it the customer requirements, or the WHATs, are correlated with the technical characteristics, or the HOWs [12].

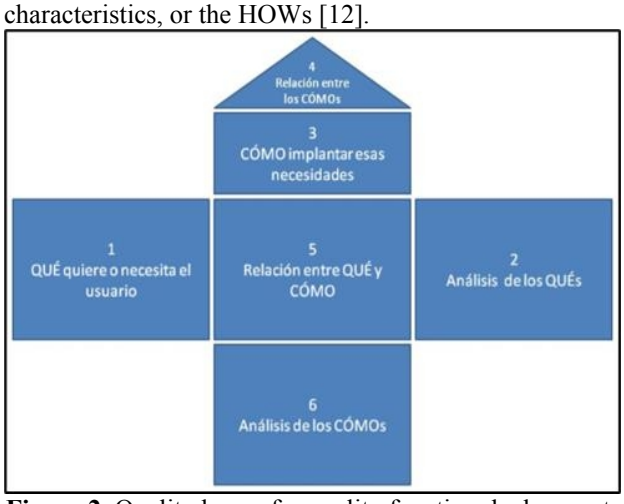

Figure 2. Quality house for quality function deployment (QFD*)*.
Source [13].

I Numbers representing the QFD
In this house of quality come the numbers that represent, which must be followed in order to do the filling, as indicated in the drawing.
The following shows what each number represents in the QFD:
1. List of WHATs
The WHAT list should include the aspects that customers expect from the product. The more things should be listed the better and nothing should be neglected, since the less relevant WHATs will be discarded as a result.

For this purpose, it is advisable to establish a brainstorming session involving an interdisciplinary group [14].
2. Analysis of the WHAT
First, the WHATs will be classified according to their importance. To achieve this, a survey can be made to potential customers where they classify the importance of each aspect between 1 and 5 (1=not important, 5=very important):
Once we have all the filling, we will know which are the most fundamental aspects to improve. By looking at the weightings, we will be able to classify the WHATs according to their importance and implement only those that are most important; we will not include those that are not so influential.
3. List of HOWTOs
Therefore, once we have analyzed the characteristics that our article must have (WHAT), we define the technical requirements necessary to fulfill the WHAT mentioned above. Therefore, we elaborate a list of HOW we can fulfill them. In this way, the list is made and its measurement category is added next to each characteristic.

4. Relationship between HOW
It is represented by the triangle (or roof) above the QFD. In this part of the triangular matrix, the possible interactions between the HOWs, whether positive or negative, are placed. This phase of the QFD is optional unless the interactions are very strong.
5. Relationship between WHAT and HOW
In the center of the matrix, a relation of the WHATs requested by the user with the HOWs is carried out. In this way we manage to interpret the abstract aspects of the WHAT into ponderable characteristics of the HOW list.
In order to so, we ordered between 0 and 9 and the link between each WHAT and each HOW (where 0=no relationship, 1=low relationship, 3=medium relationship, 9=high relationship).
In other words, each WHAT is related to one or more HOWs. It is important to monitor that all the

WHAT plus several HOWs are connected with one or more HOWs, since otherwise there would be points that we would not be contemplating.

6. Analysis of the HOWs

And finally in the QFD, it is here that we calculate the technical objectives that we should achieve in order to realize in the end the details that our product needs. First, we have to set the desired orientation of each HOW (more=better or more=worse) [13].

Benefits of QFD

To mention some of the benefits of QFD, it can be said that it helps to develop products in a preventive way. y corrective, which which makes thatorganizations to work at the highest point of quality. The number of benefits obtained through the implementation of QFD is extremely extensive. According to several authors, the most relevant issue lies in the eventual consumer satisfaction. However, there are advantages that not only satisfy the market, but also the manufacturer [15].

•**Improved Quality**: QFD ensures that products and services are designed for customer requirements, excellence, defect reduction and overall quality improvement.

•**Reduced costs**: By setting up and discarding functions and procedures that are too necessary, Quality Function Deployment helps organizations reduce cost and optimize efficiency.

•**Increased market share**: By providing items and services that meet consumer needs, QFD entities find new customers and increase their market share. According to [16], recognized critical quality peculiarities and QFD sales rates have reported considerable progress identified key quality characteristics and sales rates as an effect of using QFD.

•**Improved communication**: Quality Function Deployment encourages interaction and collaboration between various departments in an organization, fostering a culture of collaboration and continuous improvement [17].

DEVELOPMENT

QFD Quality Function Deployment Analysis and Application

An analysis of the QFD Quality Function Deployment in 3D printers is performed, 3 3D printers are considered; in fact, depending on the use that is given to them, we can contemplate printers that are for amateur use and other industrial printers that are a little more complex. The amateur printers are used mainly for educational and didactic purposes, and are not prepared to work daily 24 hours a day like the industrial ones [18].

Considering 3 different 3D printers: CREALITY Ender 3 S1, FDM 3D printer, MINUCUTE Artillery Genios, FDM 3D printer, ANYCUBIC kobra FMD 3D printer; Fused Deposition Modeling (FDM) which consists of depositing molten polymer on a flat base, layer by layer. The material, which is initially in a solid state stored in rolls, is melted and ejected through a nozzle in tiny threads that solidify as they take the shape of each per layer [18].

For this analysis is to select the 3D printer that can provide us with the best service for the production of 3D printed items.

In this research we consider professionals who know what 3D printing is, who handle and know how to use 3D printers in order to obtain their information and experience regarding 3D printers.

In a sample of 3D printing connoisseurs, a questionnaire is applied to them so that they answer what would be the best selection of a printer that can provide the best service for prototyping and 3D printing products.

First of all, each question is thoroughly prepared to know precisely what we want to know, which allows us to obtain the best information that will provide us with material that can support and guide us for the purchase of a computer and for the production of parts and prototypes with the best 3D printing quality. We choose 3 personal printers to carry out this study, as shown below the three houses

A QFD analysis is performed, for the selection of a 3D printer; it is supported by conducting some surveys with people knowledgeable about the subject and 3D printers. The first analysis is shown in table 1 with the. QFD CREALITY Ender 3 S1, FDM 3D Printer.

Table 1. QFD CREALITY Ender 3 S1, FDM 3D Printer.

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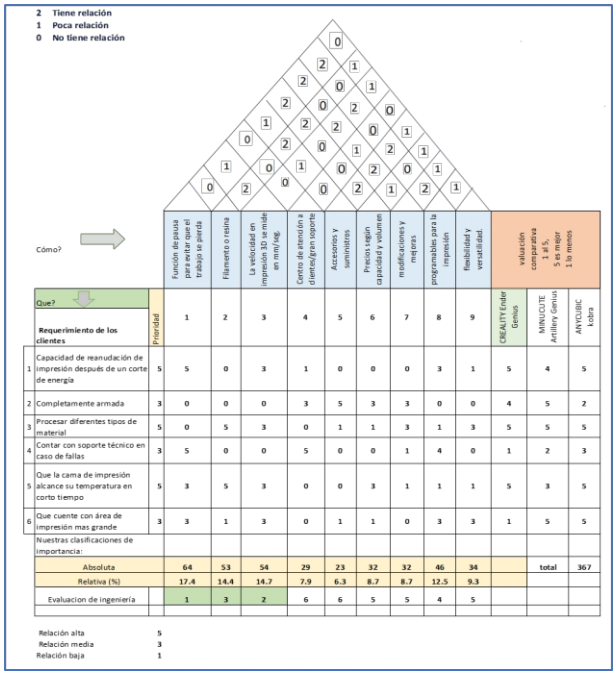


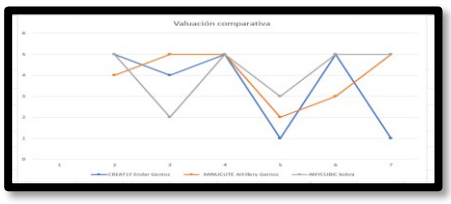
2 Tiene relación
1 Poca relación
0 No tiene relación

Cómo? / Que?

	Requerimiento de los clientes	Prioridad	Función de pausa para evitar que el trabajo se pierda	Filamento o resina	La velocidad en impresión 3D se mide en mm/seg	Centro de atención a clientes/gran soporte	Accesorios y suministros	Precios segun capacidad y volumen	modificaciones y mejoras	programables para la impresión	flexibilidad y versatilidad.	valuación comparativa 1 al 5, 5 es mejor 1 lo menos: CREALITY Ender Genius	MINUCUTE Artillery Genius	ANYCUBIC Kobra
1	Capacidad de reanudación de impresión después de un corte de energía	5	5	0	3	1	0	0	0	3	1	5	4	5
2	Completamente armada	3	0	0	0	3	5	3	3	0	0	4	5	2
3	Procesar diferentes tipos de material	5	0	5	3	0	1	1	3	1	3	5	5	5
4	Contar con soporte técnico en caso de fallas	3	5	0	0	5	0	0	1	4	0	1	2	3
5	Que la cama de impresión alcance su temperatura en corto tiempo	5	3	5	3	0	0	3	1	1	1	5	3	5
6	Que cuente con área de impresión mas grande	3	3	1	3	0	1	1	0	3	3	1	5	5
	Nuestras clasificaciones de importancia:													
	Absoluta		64	53	54	29	23	32	32	46	34		total	367
	Relativa (%)		17.4	14.4	14.7	7.9	6.3	8.7	8.7	12.5	9.3			
	Evaluacion de ingeniería		1	3	2	6	6	5	5	4	5			

Relación alta 5
Relación media 3
Relación baja 1

Continuation of the table.



As shown in Table 1, the QFD of "CREALITY Ender 3 S1, FDM 3D Printer", firstly took into account the requirements of the customers according to the survey carried out, giving them a prioritization from 1 to 5.

In this case the requirements of the "What" customers are: Ability to resume printing after a power outage, that it is fully assembled, process different types of material, have technical support in case of failures, that the printing bed reaches its temperature in a short time, that it has a printing area; and we give them a prioritization of 1, 3, 5 according to the degree of importance. Then we work with the "how to", i.e. how to satisfy those needs or requirements of the customers, these are: Pause function to prevent the job from getting lost, filament or resin, Speed in 3D printing is measured in mm/sec, customer care center/great support, accessories and supplies, pricing according to capacity and volume, modifications and upgrades, programmable for printing, and flexibility and versatility.

Once these two important parts are in place, we continue with the evaluation, which consists of : high ratio 5, medium ratio 3 and low ratio 1.

This evaluation is performed as follows: The first "what" requirement is related to each one in the "how" column and is assigned the ratio of 5,3,1. And this is done until all the requirements are completed.

As an example of the first requirement it looks like this:

-Relationship that has print resume capability after power failure with pause function to prevent job loss is 5.

-Print resume capability after a power failure with Filament or resin is 0.

-Ability to resume printing after a power failure with The speed in 3D printing is measured in mm/sec. It is 3.

-Ability to resume printing after a power outage with Customer Care Center/Great Support is 1.

-Print resume capability after a power outage with Accessories and supplies is 0.

-Print resumption capacity after a power failure with Pricing according to capacity and volume is 0.

-Print resume capability after a power outage with modifications and upgrades is 0.

-Print resume capability after a power outage with programmable for printing is 3.

-Ability to resume printing after a power outage with flexibility and versatility. It is 1.

In the table it can be seen like this 5, 0, 3, 1, 0, 0, 0, 0, 3, 1. Where the numbers 5 means that in two requirements there is a high relationship between the "What" and "How", in other words, that the ability to resume printing after a power failure has a high relationship with the pause function to prevent the job from being lost and that they are programmable for printing; hence they are the two ways of how to satisfy those needs. And this procedure is going to be done with all the requirements until finishing with all of them and filling the table with the information.

Once this valuation is finished, the next line is the one below the table, the first one being the Absolute Importance. This absolute importance will be obtained by multiplying the priority value assigned to each of the requirements of the "What" with the value of the relationship assigned to the "How" and it will be done by column. As an example we mention the first column as follows, it is worth mentioning that in this example we do not take into account what has zero.

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-Ability to resume printing after a power failure with priority 5 by Pause function to prevent job from being lost with high ratio 5 gives a total of 5*5 = 25.
-Have technical support in case of power failures with priority 3 per Pause Function to avoid work being lost with high ratio 5 gives a total of 3*5 = 15.
-The print bed to reach its temperature in a short time with priority 5 by Pause function to avoid job loss with high ratio 3 gives a total of 5*3 = 15.
-To have area with priority 3 by Pause Function to avoid work being lost with high ratio 3 gives a total of 3*3 = 9.
Adding these results we obtain the absolute importance as follows:
(5*5) +(3*5) +(5*3) +(3*3) =64 absolute significance

In summary, adding up all the absolute amounts gives us a total of 367. the importance relative importance of each column respectively.
In this case the relative importance in this example is:
(64*100) /367 = 17.4%, being the highest and the main action to follow with respect to the others. Therefore, it is considered that the function of pause to prevent work from being lost ranks first to give it more consideration to please those customer demands.
In second place, it is with 14.7% Speed in 3D printing is measured in mm/sec. to give the most importance in satisfying those needs of customers. In third , with 14.4% Filament or resin to give the greatest importance in pleasing the needs of customers.

We continue with the comparative evaluation of CREALITY Ender 3 S1, FDM 3D Printer against two other printers with which we are going to perform the comparison of customer requirements "What", these are: MINUCUTE Artillery Genios, FDM 3D Printer and ANYCUBIC kobra FMD 3D printer. We use comparative valuation 1 to 5 where 5 is the best and 1 is the least, to see how much their products contribute according to the requirements.

Then according to the results of the surveys, we take into account these ratings and continue with our example which is the CREALITY Ender 3 S1, FDM 3D Printer. In the ability to resume the printer after a power outage, we gave this printer a 5 because it has a good response performance, with the MINUCUTE Artillery Genios we assigned a 4 and the ANYCUBIC kobra also a 5.
This comparative valuation procedure also continues to be carried until the end of all the requirements between printers, so we can see how a printer is in relation to another and we can make better purchasing decisions. A small graph of this valuation is shown.

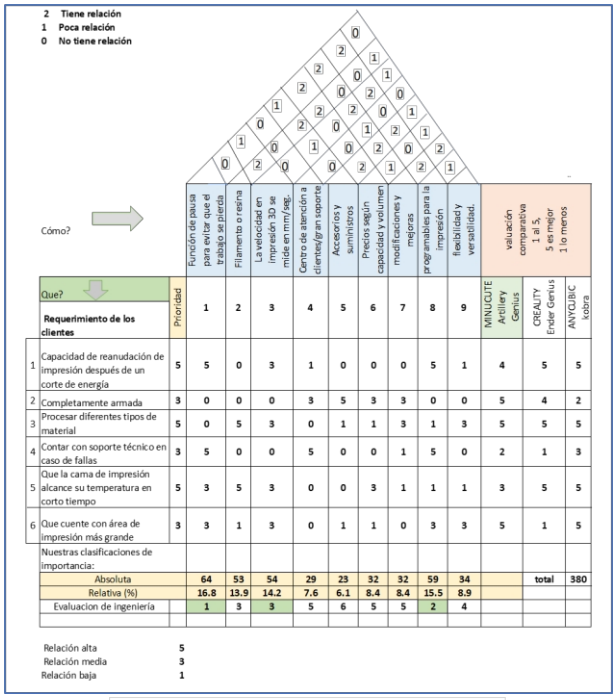
Finally, the ceiling is made, a grid is made to form the ceiling between one column and another and to be able to see how much relationship exists between a requirement "Comos" and another requirement. To measure the relationship we use the following valuation: 2 Has relationship, 1 Little relationship and 0 No relationship.
Finally, of this case, of this printer in the elaboration of the roof, this is to analyze what relationship has a requirement with another where the roof is formed. Next, let's see how to make the first line of the ceiling on the left side that corresponds to the Pause function to prevent the work from getting lost.

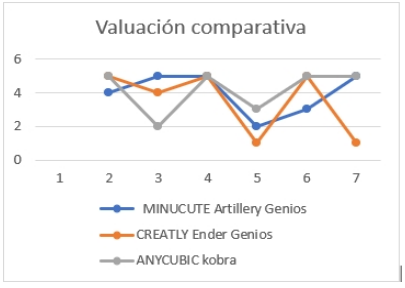
For example, in the first space you can see that it has no communication with any requirement, the box is alone. But in the following boxes if the first requirement has a relationship with the other requirements that are to its right, that is to say, if it forms a roof with another one. As you can see, it looks like this:

-Pause function to prevent work from being lost, forms ceiling with Filament or resin, but do not have "0" relationship.
-Pause function to prevent work from being lost, ceiling shape with The speed in 3D printing is measured in mm/sec. If there is low ratio in 1 between the.
-Pause function to prevent work from being lost, form ceiling with Customer Care Center/Great Support, i.e. 0 no relationship between them.
-Pause function to prevent work from being lost; forms ceiling with Accessories and supplies; has 1 low ratio.
-Pause function to prevent work from being lost, form ceiling with Prices according to capacity and volume; it has 2 high ratio. So if you have a lot of relationship between these two requirements "like".
-Pause function to prevent work from being lost, ceiling shape with modifications and improvements; has 2 high ratio.
-Pause function to prevent the job from being lost, roof form with programmable for printing; has 2 high ratio.
-Pause function to prevent work from being lost, ceiling shape with flexibility and versatility; has 0 no relationship.
In short, it has been presented with practical examples of CREALITY Ender 3 S1, FD 3D Printer, to explain how to work with the (QFD), which refers to how to satisfy customers and interpret the desires of the customers.

The goal is to understand a good understanding of the customer's desires and to identify alternative process outcomes. By realizing and defining this relationship, operations managers will be able to build products and processes with the characteristics that our customers most prefer and desire [9].
A second QFD analysis is performed where we work with the MINUCUTE Artillery Genios, FDM 3D Printer, seen in Table 2.

Table 2. MINUCUTE Artillery Genios, FDM 3D Printer.



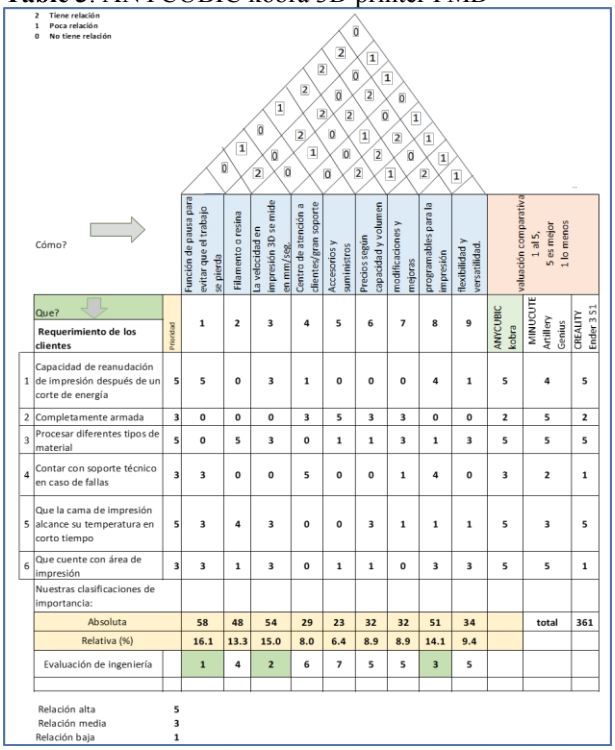


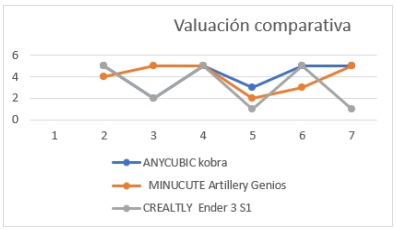
Since the previous printer gave a very extensive explanation of each step, in the following two, we will only mention the final results.
Once finished with the valuation of the requirements, the resulting absolute importance is : 64+53+54+29+23+32+32+32+59+34 = 380. And its
relative importance is: 16.8%, 13.9%, 14.2%, 7.6%, 6.1%, 8.4%, 8.4%, 15.5% y 8.9%. The first three places are:

: Pause function to prevent work from being lost with 16.8%, to attach great importance to meet those requirements of customers.
-Second place: programmable for printing Con
15.5 %, in order to give the greatest importance to satisfying these customer needs.
-Third place: The speed in 3D printing is measured in mm/sec. with 14.2% to give it the highest consideration in satisfying customer requirements.

In addition, a comparative evaluation is made with two other computers to analyze the quality of the product in relation to the other printers. A small graph of this valuation is shown.
Finally, the ceiling is made to analyze the relationship between one requirement and another requirement.
A third QFD analysis is performed where ANYCUBIC kobra 3D printer FMD works with ANYCUBIC kobra printer, seen in the next in Table 3.

Table 3. ANYCUBIC kobra 3D printer FMD





With the valuation of the requirements, the resulting absolute importance is:
58+48+54+29+23+23+32+32+51+34= 361.

relative importance is: 16.1%, 13.3%, 15.0%, 8.0%, 6.4%, 8.9%, 14.1% y 9.4%. The first three places are:
: Pause function to prevent work from being lost with 16.1%, to give it the utmost importance to meet those needs of customers.
-Second place: The speed in 3D printing is measured in mm/sec. With 15.0%, to give the most importance in satisfying those requirements of customers.
-Third place: programmable for printing with 14.1%, to give the highest consideration in satisfying customer requirements.
At the same time, a comparative evaluation is made with two other computers to analyze the quality of the product in relation to the other printers. A small graph of this valuation is also shown.
Finally, the ceiling is made to analyze the relationship between one requirement and another requirement.

DISCUSSION AND ANALYSIS OF RESULTS

The house of quality function is considered to perform this comparative study because it is one of the most used in marketing to perform a detailed analysis that refers to how to satisfy customers and interpret the desires of customers in a target plan, with which the customer's desires are known and solutions are identified. With this research done and with the results obtained we will know what are the desires of customers when making a selection or purchase in 3D printers.

With the use of the QFD comparative analysis to carry out a good selection and purchase of a 3D printer, you can know the characteristics that customers which refers to how to satisfy customers and interpret the desires of customers in a target plan, this is to capture a good understanding of customer desires and identify alternative process solutions and can develop products and procedures with the features that our customers are the most preferred and desired by them.

CONCLUSION

To conclude this analysis of the Quality Function Deployment of the three printers, it appears that for most customers the requirement for the "pause function to prevent the job from being lost" is the most important since without this pause button jobs can be lost and it would be necessary to

On the other hand "The speed in 3D printing is measured in mm/sec" is also another important requirement requested by the customer to be able to do the job faster and thus to have a job to deliver could be done in the shortest possible time and finally "programmable for printing" other such an important requirement since without a program it would be impossible to produce the part.

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