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AHP QFD methodology for a recycled solar collector

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Abstract
As it is presented in literature, the AHP-QFD method is a method applicable to many sectors, namely industry. The article is a part of this framework, applying this method for the design of a recycled solar air heater according to customer's expectations. The methodology is based on the application of QFD to detect consumer requirements, technical characteristics and their relationship matrices. while the AHP method aims to evaluate the weights of each criterion in order to make the right decision.
In this study, the manufacturing process was projected from upstream to downstream, as well as a market study was established in October 2020, in Khouribga-Morocco, in which 50 people responded favourably to a survey about the most frequently searched requirements which include size, efficiency, design, price and ecology as well as their importance in a solar collector. Besides, relationship matrices and the weight matrices of the technical criteria have been established, by presenting a consistent ratio "CR" less than 10% showing the consistency of the assessment, and finally a priority given to the characteristics of the recycled solar air heater: cans and thermal insulation more superior to the others characteristics.

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1. Introduction

Nowadays, the solar energy and environment protection have become not only a label but an obligation to most strategists in the world. Following this obligation, Morocco, like other countries around the world, is also involved in minimizing their CO_2 emissions which are constantly increasing. The figure below shows the CO_2 emissions of the Moroccan inhabitants since 1960 to 2018. These emissions continue to increase, while recording an emission of 295Kg of CO_2 in 1960 to 1851 Kg of CO_2 in 2018. Additionally, according to a study prepared by an engineering office in Khouribga, on the CO_2 emissions emitted by air heaters used 'coal and electricity' in the city of Khouribga November 2020. The results of this study present huge CO_2 emissions; 593kg of CO_2 emissions for coal and 547kg of CO_2 emissions for electricity. To this end, Morocco hosted in 2016 in Marrakech the 22nd edition of the conference of the parties for climate change "COP22". Morocco owns one of the largest solar parks in the world and has a solar energy potential with an irradiation of about 5 kWh / m^2 / day.

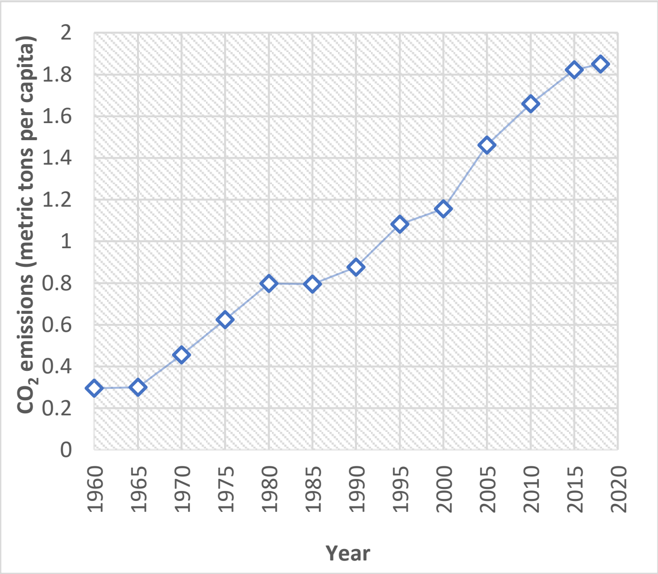


Fig. 1. CO_2 emissions "metric tons per capita "- Morocco

Many strategists in Morocco including industrials such as Afriquia incite green energy by collaborating with Bidaya incubator in "1000 Fikra " or "1000 ideas" is a project encouraging Moroccan researchers to develop and concretize their innovative green projects through incubation and monitoring.The project CanSol is part of it by recycling cans as raw materials to produce a solar air collector while preserving the environment and taking advantage of the abundant heat in Morocco. In order to present this new product to the consumer, a new approach was applied while presenting the characteristics of the recycled solar air heater so that it is competitive in terms of price and quality

In this regard, the AHPQFD method seems the most adequate to identify the customer's needs and translate them into planning. Phase, as well as to establish a hierarchy determining the priority of the stated criteria

2. Literature on qfd method

2.1. General information

The method of deployment quality function "QFD" has its origins in Japan, where it was first developed in the sixties "1966" by two professors; Yoji Akao and Shigeru Mizuno, used at Kobe Shipyards of Mitsubishi Heavy industries 1972, in 1978, the first book was published in Japanese and translated into English in 1994. It is generally used to design a new product and, also in several sectors such as: product design, management quality and decision making. The Quality Function Deployment "QFD" method, also known as "House of Quality: HOQ" or" The Voice of the Customer: VOC" is a matrix approach to product or service design making it possible to respond as well as possible to be cautious. This method takes into account all the needs of the market and / or the desires of future users from the design of a product or a service and makes it possible to develop the best manufacturing and development process in accordance with the quality requirements set.

The main axes for the implementation of the QFD are presented below:

- Prioritize the explicit and implicit needs of the customer;
- Translate these needs into technical characteristics;
- Design a quality product by focusing all services on customer satisfaction.

This method will mainly allow the technical analysis of the product, the study of the behaviour of consumers towards the recycled products. To this end, a European and Moroccan study was established in 2020 in which 58% of consumers, especially millennials, are aware of environmental problems and demand green and non-harmful products. This requires companies to establish structural changes that respect the environment both at the level of production and management. Among the changes encountered, the transition from a traditional production process to a circular one was observed. For example, the international company PRADA has launched a line of handbags based on recyclable materials called PARADA re-nylon.

This paragraph is devoted to advantages and disadvantages of QFD method

Advantages

- Enhanced understanding of customer needs and requirements fairly precisely:
- reduction of product development time, avoiding wasting time spent looking for attributes that are more or less important to the consumer;
- promoting teamwork by encouraging employees to start discussions, which motivates them and promotes total quality.
- helping the company to stay updated as far as changes in customer’s needs are concerned, and to be up-to-date on how the company’s internal processes work;
- bringing out the "unspoken" and customer demands that are not necessarily visible or otherwise definable.

Disadvantages

- Low flexibility to changing needs;
- Heavy reliance on collecting information from the customer;
- Long analysis time, especially when expectations are high.

2.2. The House of Quality "HOQ"

In this paragraph, seven main steps that make up the realization of the quality function house are introduced and explained.

- **Step 1**: This step consists, first of all, in establishing the "WHAT"; namely the needs of the customer in question. To do this, the manager must first collect data from customers using research methods, such as group interviews or a survey. Such research is based on the attributes of the product sought by consumers, which will then be placed according to their priority. For our product, the "WHATS" requires from customers are: Size, Design, Efficiency, Price and Ecology.
- **Step 2**: this step aims to classify the needs according to their importance in relation to consumers. This ranking is assigned to a defined scale of 1 to 10, from which 1 represents the least important, while 10 is the most important.
- **Step 3:** This step determines the technical quality characteristics of the product to be offered, the so-called "HOW". It is important during this step to keep an objective point of view so as not to distort the results, so to establish these particularities without thinking of the resulting solution. In addition, these characteristics must be measurable and realistic regardless of the capacity of the company itself. By collaborating with experts, and by developing studies, the needs are translated into technical characteristics. Each characteristic undergoes an improvement, while specifying whether it should be maximized, minimized or this is the target objective. Projecting this step for our recyclable air collector, we find the "HOWs": Case, Cans, Plexiglass, Thermal insulation and Paint.

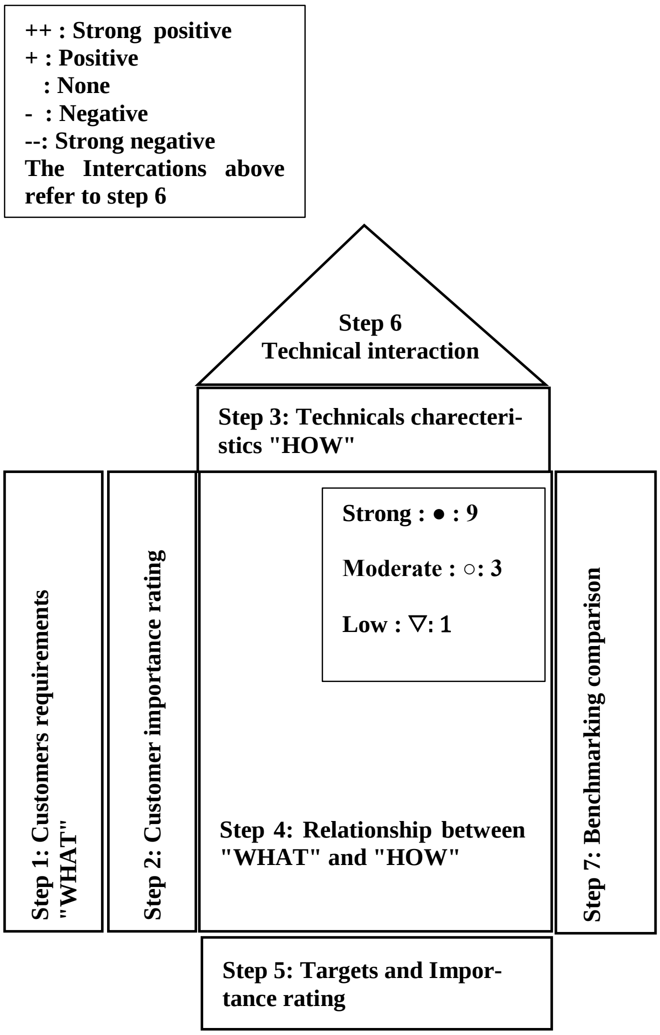


Fig. 2. House of Quality

- **Step4**: Define the link between the two aspects defined previously, the needs of the costumer and the characteristics of the product, in other words the relation "how to what". This relationship is mostly established on a four-level scale that represents a strong, moderate, weak, or negative (non-existent) interaction. These results consist the center of the quality house method. According to expert ratings, for the size of our product, in relation to the technical requirements: a strong relationship for case, a moderate relationship for cans, plexiglass and thermal insulation, then a low relation with paint.
- **Step5**: "The how much" represents the establishment of a standard for the various technical aspects of product quality. These standards must be quantified and can be useful for continuous quality improvement. It is translated by enumerating the specific targets values for technical characteristics, and calculating the absolute and relative importance. The formula below is for calculating absolute and relative importance:

$$Absolute\ importance = \sum(Importance\ rating * ranking\ symbol\ value) \quad (1)$$

$$Relative\ importance = 100 * \left(\frac{Absolute\ importance}{Total\ Absolute\ importance}\right) \quad (2)$$

The ranking symbol value obtained in relationship mat rice "Step4".

- **Step6**: Establishing the relationships between features is the goal of this step. Next, the degree of interrelation between each element of the product to see if two of them conflict is determined. This step makes it possible to bring out the communication links that must exist between the different departments of the company which participates in the development of the products. In order to evaluate the relationship between technical characteristics, a set of representative symbols is used for the different interactions: strong positive, positive, none, negative and strong negative.
- **Step7**: During this step, a certain comparison is made, a satisfaction comparison based on several measures varying from company to other, quoted: Comparison with competitors, potential points of sale, the targets refer to the incremental factor and the strategies to be carried out. On the other hand, the comparison of characteristics which is generally made up of 2 parts: The Benchmarking and the technical targets.

3. AHP Method

Analytic Hierarchy Process "AHP" is a method developed by Thomas L. Saaty in 1970, used to organize and analyse complex decisions involving several criteria and this method represents various interests and allows to

- Refine the definition of a problem;
- Establish priorities;
- Take into account the interdependence of the elements;
- Evaluate the logical consistency of the opinions used.

3.1. Methodology

In order to apply this method, the following algorithm is noted:

- **Build the hierarchy:** Decomposition of the problem into sub-problems
- **Establish the weight of the criteria and sub-criteria:** in order to prioritize the criteria by using the table of scales proposed by Thomas L. Saaty which is presented below

Table 1. Scale of relative importance

Intensity of importance	Definition
1	Equal importance
2	Weak
3	Moderate importance
4	Moderate plus
5	Strong importance
6	Strong plus
7	Very strong
8	Very Very strong
9	Extreme importance

- **Write the comparison matrix for each level:** a comparison matrix was established from Saaty scales as presented below

Table 2. Comparison matrice

Criteria	C1	C2	C3	…	Cn
C1	W_1/W_1	W_1/W_2	W_1/W_3	….	W_1/W_n
C2	W_2/W_1	W_2/W_2	W_2/W_3	…..	W_2/W_n
C3	W_3/W_1	W_3/W_2	W_3/W_3	….	W_3/W_n
…	…..	…..	…..	…..	…..
Cn	W_n/W_1	W_n/W_2	W_n/W_3	….	W_n/W_n

- **Determine the weight of the criterion:** In order to determinate the weight of the criterion, some of parameters must be calculated as following:
  - **Geometric mean:** it calculated as below

$$Row_i = (\prod W_{i,j})^{\frac{1}{n}} \quad (3)$$

With n is the number of criteria and W is the weight of criteria

  - **Priority vector:** Presented as following

$$Priority_i = \frac{Row_i}{\sum Row_i} \quad (4)$$

Consistency index: It is calculated as following

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (5)$$

With n: number of criteria
and $\lambda_{max} = Priority_i * \sum Column_j$

  - **Consistency ratio: C**alculated as following

$$CR = \frac{CI}{RCI} \quad (6)$$

With RCI is the random consistency index provided by the table below:

Table 3. Values of RCI

Number of criteria	RCI
1	0
2	0
3	0.58
4	0.9
5	1.12
6	1.25
7	1.32
8	1.41
9	1.45

- **Evaluate the actions**: In order to decide which actions to take, we calculated the final note following this equation.

4. AHPQFD Method

4.1. Introduction

The AHPQFD method is based on the combination of the two methods the QFD provides the weights of the evaluated criteria as well as the relationship between the selected criteria while the AHP evaluates their consistency. Recently, this method has been adopted in several sectors namely: Higher education, logistics (Chuang, 2001; Partovi, 2006), manufacturing (Wang et al., 1998; Partovi, 1999; Zakarian and Kusiak, 1999; Hsiao, 2002; Kwong and Bai, 2002; Madu et al., 2002; Kwong and Bai, 2003; Myint, 2003; Bhattacharya et al., 2005; Hanumaiah et al., 2006), military (Partovi and Epperly, 1999), and sports (Partovi and Corredoira, 2002). Matrices from this method aim to weaken complexity by degrading it and make it easy to solve.

4.2. Methodology

This paragraph will be devoted to the AHP-QFD method, starting with the identification and determination of the needs of the targeted consumers, while using the QFD method. Then, the AHP method is used in order to determine the weight of each need while calculating the consistency ratio "CR" so as to see if these needs are consistent with each other. In addition, the relationship matrix linking the "WHATs" with the "HOWs" is prepared. Besides, the weight of the "HOWs" is calculated using the AHP method, and finally, the criteria are organized by priorities according to the results presented by the AHP method.

The following algorithm presents the AHPQFD methodology

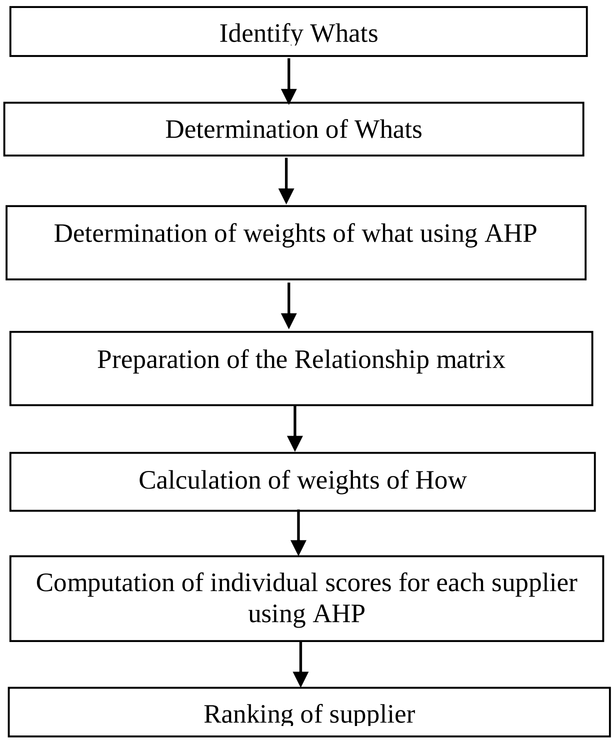


Fig. 3. AHPQFD Methodology

5. Case STUDY: Recycled solar air heater collector

In this study, the AHPQFD methodology will be applied for a recycled solar air heater collector, starting by a process description, then market research, finally, an AHPQFD methodology.

5.1. Process description

In order to manufacture a recycled solar air heater collector, the process of production will be presented below:

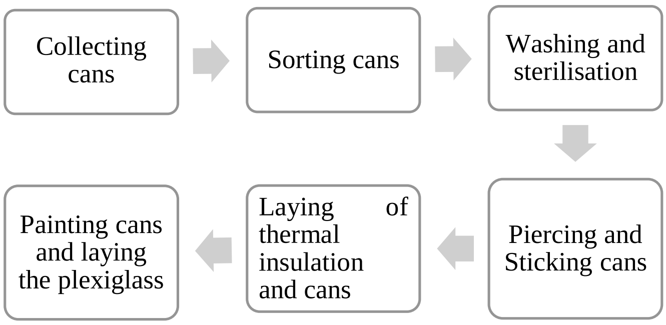


Fig. 4. Process of production of solar air heater collector

Starting with a collection of cans from restaurants, cafes and hotels, the cans are sorted according to their conditions and their lengths. The next step is to the treatment phase of these cans through washing them in hot water "T=100°C", with the addition of acetic acid "CH_3COOH" for 5 minutes and left to sit for other 5 minutes, so that they are ready for use. After this phase, the cans of the two sides are drilled, then glued with a silicone at high temperature"1200 ° C", and painted at high temperature " 1100 ° C". To absorb the maximum heat, the color chosen is black due to its high absorption coefficient compared to other colors, and this is presented in the Table below:

Table 4. Absorption coefficient according to color

Color	White	Red	Dark green	Navy blue	Dark
absorption coefficient	0.18	0.58	0.87	0.89	0.92

In a case, the thermal insulation chosen according to the insulating power, thickness, resistance to temperature and price is installed. Finally, the cans are laid and then the plexiglass, which is also chosen according to an elevated degree of transparency to that of the glass "89%"', a high rigidity, a high melting temperature "160°C", and a fairly huge impact resistance "30 times high compared to glass".

5.2. Market research

A survey was carried out during the month of October 2020, in khouribga city, concerning the most requested criteria for a solar air heater. This study covers a sample including both sexes, aged over 18 years, and having an income. At the end of this survey, 50 people responded favorably and wished to buy the product, this survey achieved the 5 most requested criteria by classifying them according to the importance of the people surveyed. These 5 criteria are: size, efficiency, design, price and ecology.

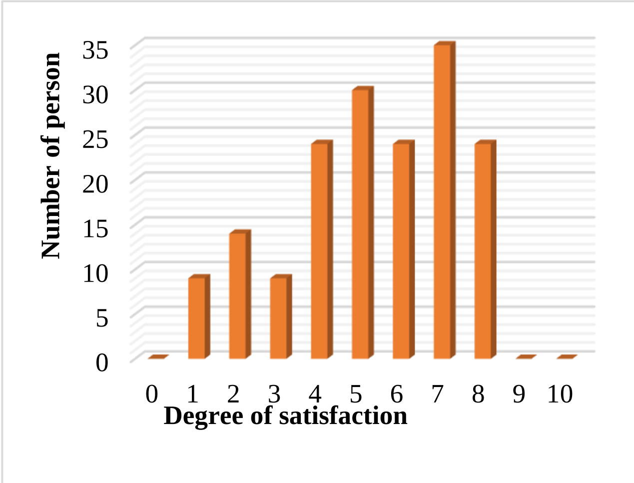


Fig. 5. Degree of satisfaction for size criteria

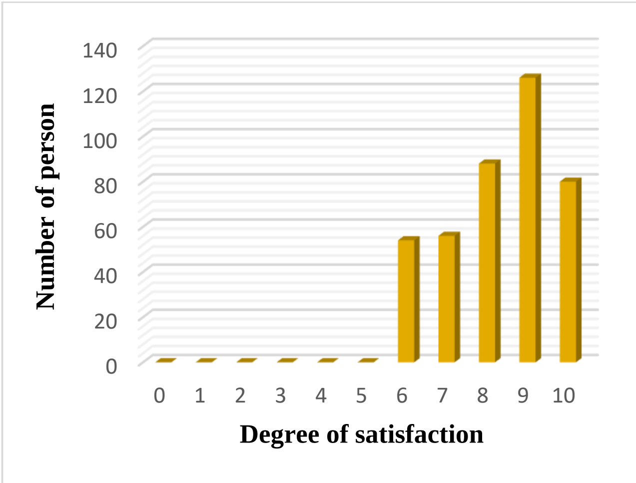


Fig. 6. Degree of satisfaction for efficiency criteria

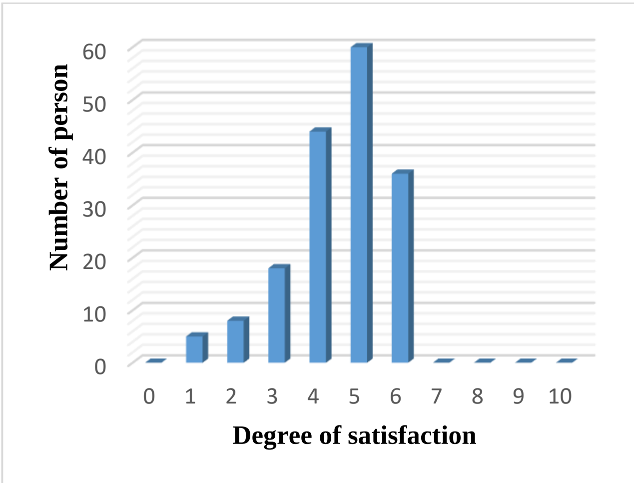


Fig. 7. Degree of satisfaction for design criteria

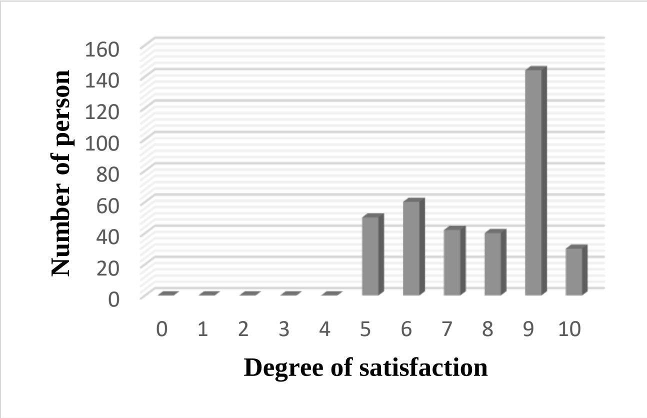


Fig. 8. Degree of satisfaction for price criteria

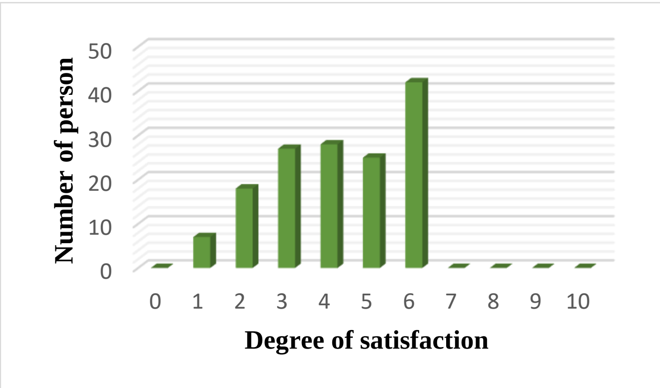


Fig. 9. Degree of satisfaction for ecology criteria

From the graphs above, it can be seen, as far as the first graph is concerned, satisfaction ranges between 1 and 8, recording an average score of order 7, when the second graph of efficiency varies between 6 and 10 records a score of 9, while the design records a score of 5 within a range of 1 and 6, concerning the price registers a score of 9 between 5 and 10, and, finally, the ecology marks a score of 6 vary from 1 to 6.

These results reflect the need for the targeted customer, by giving great importance to both criteria: the price and the efficiency of the product, while the design is at the bottom of the list of criteria.

The importance of these criteria is due to Moroccan economic power. According to the Moroccan High Commission of Planning, the Moroccan gross national product in 2019, counts $ 7680 annually, of which the housing and the energy bill represent 22% of the Moroccan consumption.

5.3. AHP QFD Methodology

- **Identify whats**

During this step, the fundamental characteristics requested by the customers will be presented that are in accordance with the market research in terms of the size, the design, the efficiency, the price and the ecology.

- **Determination of How**

During this phase, the scope of interest is the 'how', that is to say the technical characteristics of the recycled solar air heater. These characteristics are determined following interviews with technical experts and field studies, which are the case, the cans, the plexiglass, the thermal insulation and the paint.

- **Determination of weights of what using AHP**

In order to determine the weight of what, the selected people were asked about the importance of the criteria compared to the size criterion, then we calculate the priority vector as well as the parameters namely consistency index and consistency ratio. All these results are presented in the Table below.

Table 5. Matrix of weights using AHP

	Size	Efficiency	Design	Price	Ecology
Size	1	0.11	0.17	0.11	0.33
Efficiency	9	1	1.5	1	3
Design	6	0.67	1	0.67	2
Price	9	1	1.5	1	3
Ecology	3	0.33	0.5	0.33	1

Table 6. Matrix of weights and priority vector

	Size	Efficiency	Design	Price	Ecology	Priority vector
Size	1	0.11	0.17	0.11	0.33	0.04
Efficiency	9	1	1.5	1	3	0.32
Design	6	0.67	1	0.67	2	0.21
Price	9	1	1.5	1	3	0.32
Ecology	3	0.33	0.5	0.33	1	0.11

λ_{max}= 5.1163
CI=0.02975 =2.97%
CR = 0.0265=2.65%

We notice that the index consistency "CI" and the consistency ratio "CR" are less than 10%, which mean that the assessment are consistent.

- **Preparation of the Relationship matrix**

In this paragraph, we will focus on the relationship matrix between the 'how' and the 'what' while inserting the links by linguistic values such as High "H", Medium "M" and Low "L" schematized respectively by values 9.3 and 1.

Based on the results delivered above, the matrix is a strategic tool, it not only allows to translate the needs of the consumer into technical characteristics, but it helps to improve the quality of the product, while showing the importance of the criteria in relation to one another.

In order to better create a matrix translating, the technical relations with that of consumer expectations, technical experts in solar collectors have been called, this is translated by the linguistic acronyms presented above: H, M and L. Table 7, gives us the two criteria at the top of the list are: efficiency and price, while size occupies the bottom of the list. This helps, to take into account price and efficiency during production, in order to better reflect customer expectations.

Table 7. Relationship matrix "How" and "what"

What	How					
	Importance	Case	Cans	Plexiglass	Thermal insulation	Paint
Size	0.04	H	M	M	M	L
Efficiency	0.32	H	H	H	H	L
Design	0.21	H	L	L	L	L
Price	0.32		H	H	H	
Ecology	0.11		H		H	H

- **Calculation of weights of How**

The Table below presents the numerical translation of the values presented in the paragraph above, while multiplying the importance or the priority vector by the values assigned to the "How".

Table 8. The weight of "How"

What	How					
	Importance	Case	Cans	Plexiglass	Thermal insulation	Paint
Size	0.04	0.36	0.12	0.12	0.12	0.04
Efficiency	0.32	2.88	2.88	2.88	2.88	0.32
Design	0.21	1.89	0.21	0.21	0.21	0.21
Price	0.32		2.88	2.88	2.88	
Ecology	0.11		0.99		0.99	0.99
TOTAL		5.13	7.08	6.09	7.08	1.56
Relative weight (%°)		19	26.3	22.6	26.3	5.8

Translating the acronyms into numbers, and calculating the relative weight for each criterion, the dominance of thermal insulation and cans can be noted, which results from the importance of these two technical criteria during the production of the recycled solar air heater.

For cans, the base material must be in good condition and of the same length in order to have a rigidity of columns of the collector, as well as an aesthetic side attracting the attention of the consumer and encouraging him to buy it.

Thermal insulation is one of the essential elements of the collector, focusing on the coefficient of thermal conductivity which must be less than or equal to 0.07W / mK, the material of composition must be resistant to high temperature, ecological and cost-effective.

- **Computation of individual scores for each supplier using AHP**

TheTable below shows the characteristic weight matrix using the AHP method.

Table 9. Matrix of the weight of the characteristic

	Case	Cans	Plexiglass	Thermal insulation	Paint
Case	1	1/6	1/3	1/5	1/4
Cans	6	1	2	1.2	1.5
Plexiglass	3	0.5	1	0.6	0.75
Thermal insulation	5	0.83	1.67	1	1.25
Paint	4	0.67	1.33	0.8	1

The Table above, presents the matrix of the weight of the technical characteristics using the AHP method, while evaluating the relationship between criteria.

- **Ranking of supplier**

This paragraph presents the final score obtained by multiplying each score of the characteristics presented previously in Table 9 by the relative weight of the characteristics calculated in Table 8.

$$\begin{pmatrix} 1 & 0.17 & 0.33 & 0.2 & 0.25 \\ 6 & 1 & 2 & 1.2 & 1.5 \\ 3 & 0.5 & 1 & 0.6 & 0.75 \\ 5 & 0.83 & 1.67 & 1 & 1.25 \\ 4 & 0.67 & 1.33 & 0.8 & 1 \end{pmatrix} \cdot \begin{pmatrix} 0.19 \\ 0.26 \\ 0.23 \\ 0.26 \\ 0.06 \end{pmatrix} = \begin{pmatrix} 0.376 \\ 2.257 \\ 1.128 \\ 1.881 \\ 1.505 \end{pmatrix} \quad (7)$$

According to the above results, the technical characteristics having a high score: cans and thermal insulation, strongly impact the efficiency and quality of the solar collector.

Hence, the need to focus during the collection on the conditions and lengths of the cans, collaborating with our suppliers "cafes, restaurants and hotels" via the insurance of bags reserved only for cans.

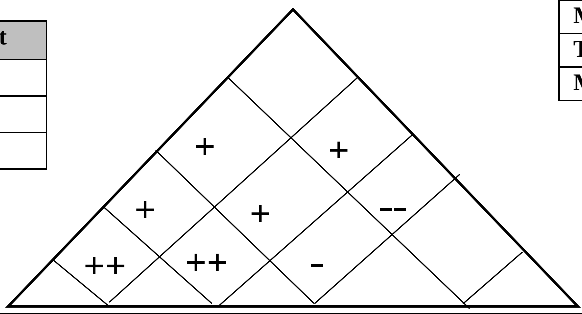
Encouraging customers to collect the cans through discounts and at the same time establishes green culture.

The house of quality above presents the most important needs for the consumer regarding a solar air collector, are: price and efficiency by a factor of importance of 9, followed by the size, ecology then design. Based on customers' expectations , cans and thermal insulation are among of the technicals caracteristics have a high relative importance "24%" compared to case and plexiglass "19%" and paint with"15%".

Interactions	
Strong Positive	++
Positive	+
No Correlation	
Negative	-
Strong Negative	--

Direction of Improvement	
Maximize	▲
Target	□
Minimize	▼

Relationship		Weight
Strong	●	9
Medium	○	3
Low	▽	1



			Functional Requirements								
Direction of Improvement			▼	▲	▲	▲	□	Customer Competitive Assessment			
Customer Require-ments	Customer Importance	Relative Weight (%)	Case	Cans	Plexiglass	Thermal insulation	Paint	Our Product	Batitherm	Bricop	Enerplus
Size	7	19	●	○	○	○	▽	3	2	4	3
Design	5	14	●	▽	▽	▽	▽	4	4	4	4
Efficiency	9	25	●	●	●	●	●	3	1	2	3
Price	9	25		●	●	●		3	1	2	3
Ecology	6	17		●		●	●	5	4	3	3
Difficulties from 1 to 5			2	3	2	2	2				
Measurements units			m^2		%	W/m.K	%				
Targets			2	200 cans	Transpancy = 92	Coefficient of thermal conductivity =0.031	Absorption coeffi-cient = 92				
Absolute importance			189	242	188	242	147				
Relative importance (%)			19	24	19	24	15				

Fig. 10. House Of Quality for the recycled solar air collector

6. Conclusion

Following the adoption of the AHP-QFD method in many sectors: logistics, manufacturing, military and sports.

In this article, it was possible to develop the method for the production of the recyclable solar air collector, via the combined matrices of consumer expectations"WHAT”, and the technical characteristics"HOW"', as well as the evaluation of the weight of the criteria.

During this study, we were able to begin with the description of the manufacturing process of the recyclable solar air collector, from the collection to the assembly. Then, a market study through a survey elaborated on the most requested criteria for a solar collector, of which 50 people responded favourably.

This survey presented 5 criteria most requested including the size, the design, the efficiency, the price and the ecology. whose importance varies from 5 to 9. Then, the relationship matrix "What" and "How" was established, as well as the matrix of weights using AHP, by obtaining a consistency of the assessment results expressed in a consistency ratio "CR" of 2.65% lower than 10%. In the end, a final score was presented for each characteristic, characterized by the dominance of cans and thermal insulation by a respective value of 2.257 and 1.881, this shows the priority and importance of these characteristics during the production of the recyclable solar air collector. Among the futures perspectives, the implementation and experimentation of our product were found.

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Refrences

Ishizaka, A., 2012, Clusters and pivots for evaluating a large number of alternatives in AHP.

Calabresea, A., Costaa, R., Levialdia, N., Menichinib, T., 2018. Integrating sustainability into strategic decision-making: A fuzzy AHP method for the selection of relevant sustainability issues. Technological Forecasting & Social Change.

Ramos, A., Cunha, L., Cunha, P.P., 2014. Analytic hierarchy process (AHP) applied to the landslides study in a coastal area of the central Portugal: Figueira da Foz.

Yadav, A., Jayswal, S.C., 2013. Using Geometric Mean Method of Analytical Hierarchy Process for Decision Making in Functional Layout.

AUT University, 2013. Quality Function Deployment. Creative Industries Research Institue.

Hasna, B., Farah, B., Bhihi Fatima-zahra, El badaoui Meryem. La matrice QFD.

Bruno, G., Esposito, E., Genovese, A., et al., 2009. The Analytic Hierarchy Process in the Supplier Selection Problem. The 10th International Symposium on The Analytic Hierarchy Process, Pittsburgh.

Saldana, C., 2019. Quality Function Deployment and Specifications. Woodruff School of Mechanical Engineering Georgia Institute of Technology Atlanta, Georgia, USA.

Haktanıra, E., Kahramana, C., 2019. A novel interval-valued Pythagorean fuzzy QFD method and its application to solar photovoltaic technology development. Computers & Industrial Engineering, 361-372.

De Felice, F., Petrillo, A., 2010. A multiple choice decision analysis: an integrated QFD – AHP model for the assessment of customer needs. International Journal of Engineering, Science and Technology, 25-38.

Varolgünes, F.K., Canan, F., de la Cruz del Río-Rama, M., Oliveira, C., 2021. Design of a Thermal Hotel Based on AHP-QFD Methodology. Water Journal, MDPI, 13(15), 2109, DOI: 10.3390/w13152109

Rajesha, G., Malligab, P., 2013. Supplier Selection Based on AHP QFD Methodology. International Conference On Design And Manufacturing, ICONDM 2013-Procedia Engineering Science Direct, 1283-1292, DOI: 10.1016/j.proeng.2013.09.209

https://www.afriquiagaz.com, (Accessed on 04 February 2021).

https://www.bidaya.io, (Accessed on 04 February 2021).

https://donnees.banquemondiale.org/indicateur/EN.ATM.CO2E.PC?contextual=default&locations=MA, (Accessed on 02 February 2021).

https://www.iea.org/data-and-statistics/data-tables?country=MOROCCO&energy=Balances&year=2018, (Accessed on 02 February 2021).

Rihar L., Kušar, J., 2021. Implementing Concurrent Engineering and QFD Method to Achieve Realization of Sustainable Project. Sustainability MDPI, 1091, DOI: 10.3390/su13031091

Kowalska, M., Pazdzior, M., Krzton-Maziopa, A., 2015. Implementation of QFD method in quality analysis of confectionery products. Journal of Intelligent Manufacturing, 439-447.

Lombardi, M., Fargnoli, M., 2018. Prioritization of hazards by means of a QFD based procedure. Safety and Security Studies, 163.

Mehdi Rajabi Asadabadi, 2017. A Customer Based Supplier Selection Process that Combines Quality Function Deployment, the Analytic Network Process and a Markov Chain. European Journal Of Operational Research.

EL Badaoui, M., Touzani, A., 2020. Modeling of a parabolic trough using two heat transfer fluids and an economic estimation in the Moroccan dairy industry. IOP Conf. Ser.: Mater. Sci. Eng., 811 012029.

Mukesh Mohan Pandey, 2020. Evaluating the strategic design parameters of airports in Thailand to meet service expectations of Low-Cost Airlines using the Fuzzy-based QFD method. Journal Of Air Transport Management, 101738.

Jain, N., Singh, A.R., 2014. AHP and QFD Methodology for Supplier Selection. IPEDR.

Haber, N., Fargnoli, M., Sakao, T., 2018. Integrating QFD for product-service systems with the Kano model and fuzzy AHP. Total Quality Management & Business Excellence.

Wolniak, R., 2018. The use of QFD method advantages and limitation. Production Engineering Archives, 14-17.

Fattahi, R., Khalilzadeh, M., 2018. Risk evaluation using a novel hybrid method based on FMEA, extended MULTIMOORA, and AHP methods under fuzzy environment. Safety Science, 290-300.

Ginting, R., Widodo, 2019. Technical characteristics’ determination of crumb rubber product by using quality function deployment (QFD) phase I. IOP Conference Series: Materials Science and Engineering, 602 012048, DOI: 10.1088/1757-899X/602/1/012048

Ginting1, R., Eka Periana Pane1, Alfin Fauzi Malik1, 2020. Quality improvement of woods product using the quality function deployment (QFD) method at PT. X. AIP Conference Proceedings, 2217, 030147.

Ginting, R., 2020. Application of Quality Function Deployment (QFD) Method in Meeting Customer Satisfaction in the Bookshelf Industry. IOP Conference Series: Materials Science and Engineering, 1003 012005, DOI: 10.1088/1757-899X/1003/1/012005

Klutho, S., 2013. Mathematical Decision Making -An Overview of the Analytic Hierarchy.

Fehlmann, T., 2016. Using ahp in qfd – the impact of the new iso 16355 standards. International Symposium of the Analytic Hierarchy Process, UK

Vargas, Viana, R., 2010. Using the analytic hierarchy process (ahp) to select and prioritize projects in a portfolio.

Ho, W., Dey1, P.K., Lockström M. Strategic Sourcing: A combined QFD and AHP approach in manufacturing.

Xinglia, W., Huchang, L., 2018. An approach to quality function deployment based on probabilistic linguistic term sets and ORESTE method for multi-expert multi-criteria decision making. Information Fusion, 13-26.

Chen, X., Ding, Y., 2017. A decision support model for subcontractor selection using a hybrid approach of QFD and AHPimproved grey correlation analysis. Engineering Construction And Architectural Management.

Xi, xi, Qin, Qiuli, 2013. Product quality evaluation system based on AHP fuzzy comprehensive evaluation. Journal of Industrial Engineering and Management, 356-366.

用于回收太阳能集热器的 AHP QFD 方法

關鍵詞
层次分析法
合格证
市场调查
再生太阳能空气加热器
标准的权重
稠度比“CR”

摘要
正如文献中介绍的那样，AHP-QFD 方法是一种适用于许多部门，即工业的方法。这篇文章是这个框架的一部分，根据客户的期望，应用这种方法来设计一个再生太阳能空气加热器。该方法基于应用 QFD 来检测消费者需求、技术特征及其关系矩阵。而 AHP 方法旨在评估每个标准的权重以做出正确的决定。 在这项研究中，制造过程从上游到下游进行了预测，并于 2020 年 10 月在 Khouribga-Morocco 建立了一项市场研究，其中 50 人对一项关于最常搜索要求的调查做出了积极响应，其中包括尺寸、效率、设计、价格和生态以及它们在太阳能集热器中的重要性。此外，还建立了技术标准的关系矩阵和权重矩阵，通过呈现小于 10%的一致性比率“CR”表明评估的一致性，最后优先考虑再生太阳能空气加热器的特性：罐头和保温更优于别人的特点。