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Rating the Importance of Customer Requirements for Green Product Using Analytic Hierarchy Process Methodology

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***Abstract*—**Identification of customer requirements and their preferences are the starting points in the process of product design. Most of design methodologies focus on traditional requirements. But in the previous decade, the green products and the environment requirements have increasingly attracted the attention with the constant increase in the level of consumer awareness towards environmental problems (such as green-house effect, global warming, pollution and energy crisis, and waste management). Determining the importance weights for the customer requirements is an essential and crucial process. This paper used the analytic hierarchy process (AHP) approach to evaluate and rate the customer requirements for green products. With respect to the ultimate goal of customer satisfaction, surveys are conducted using a five-point scale analysis. With the help of this scale, one can derive the weight vectors. This approach can improve the imprecise ranking of customer requirements inherited from studies based on the conventional AHP. Furthermore, the AHP with extent analysis is simple and easy to implement to prioritize customer requirements. The research is based on collected data through a questionnaire survey conducted over a sample of 160 people belonging to different age, marital status, education and income groups in order to identify the customer preferences for green product requirements.

***Keywords*—**Analytic hierarchy process, green product, customer requirements for green design, importance weights for the customer requirements.

I. Introduction

CUSTOMER satisfaction is an important goal in the competitive markets. The key factor for improving customer satisfaction is providing high quality in producing products and services. In order to produce a successful product or service-based design based on fulfilling the customer requirements, recently the customers showed much more concern regarding the protection of the environment and this concern is increasing more and more with the passage of time. As a result, they are starting to change their spending habits and require the manufacturing of green products which have the least impact on the environment [31].

Green products have become essential issue in industrialization, where the industry now focusing on considering the environmental requirements at the same time with the other customer requirements. It is important to integrate environmental requirements into product and process design, and determining the importance weights for customer requirements because these weights have a significant impact on the values related to the technical requirements (engineering characteristics), there are several methods to measure the customer importance weights. Using the point scoring scale such as one to nine or one to five, is the most efficient and simplest method to determine the weight of customer requirements and their preferences [14]. However, this method does not effectively find out the human perception. So, to address the difficulty of isolating a set of acceptable criteria to all individuals, Ho et al. [18] developed a group decision-making technique to obtain the importance weights for the customer requirements.

To determine the relative importance of the customer requirements, Gustafsson and Gustafsson [15] used a methodology that includes the step for comparison of the preferences of customer requirements to determine their relative importance. It is an integrated analysis method which presents the customer requirement priorities as a compound multi-criteria decision-making problem. The AHP, a multi-criteria decision-making method, has been used in weighing customer requirements [28].

The integration of the AHP into the determination of tradeoff weights for the customer requirements was proposed by Akao in 1990 [1] in which AHP was applied to generate importance ratings for the customer requirements by taking a case study into consideration. In the above application of the AHP to the prioritizing of customer requirements, the pairwise comparisons for each level with respect to the goal of customer satisfaction are conducted using a five-point scale expressing the preferences between options as being either: equally preferred, slightly preferred strongly preferred, very strongly preferred, and extremely preferred. These preferences are translated into pairwise weights of one, three, five respectively, with two, four as the intermediate values. The pairwise comparison ratios are crisp real numbers. However, the customers' voice always contains ambiguity and multiplicity of meaning [13], [23]. Furthermore, it is also recognized that human assessment on qualitative attributes is always subjective and imprecise [7]. Hence, the conventional AHP seems inadequate to explicitly capture the importance assessment for customer requirements.

The objective in this paper is to evaluate and rate the customer requirements for green products. The first step in

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this case is to use the customer details which have been collected to reveal the relative importance of their requirements.

The second step for customer details is to rate the importance of the customer needs respectively. The company would work on the most important customer needs and disregard the unimportant customer needs to make best use of its resources. Conventionally, customers are asked to give relative importance ratings for each WHAT using five-point scales. A common and appropriate way of obtaining this information is the surveys. So, the questionnaire will be for this objective and contained the preferences with respect to each attribute (the traditional and environmental customer requirements) of green products. This paper focused on the AHP and it will be used to compute the ranking values for each customer requirements and determining the fundamental importance ratings of customer requirements. Now the questions, what is the green product? What are the requirements for green product? How to identify green customer and the preferences requirements for green products? Which requirements of green products can make them acceptable in the market? Through this paper an attempt has been made to answer all these questions.

II. Literature Review

Jiao et al. [21] in their study an analytical Kano model for customer need analysis the main contribution was to extract useful customer need information from Kano survey for decision support in product design. For that they proposed an analytical Kano (A-Kano) model.

But Kano or A-Kano method models customer preference based on customer's satisfaction and dissatisfaction. And just classifying the customer needs and put those needs in groups and categories them and cannot evaluate and ranking all the needs and the preference for the customers

Facing a purchasing decision, consumers often need to select between alternatives with conflicting objectives. MAUT, which is a part of multiple criteria decision making (MCDM), is a widely used tool to assist a decision maker (DM) in making such choices [11], [22], [39]. Several practical applications of MAUT in numerous fields of research and real-world problems are reported in the literature. Chang and Yeh [8] develop for instance an application in the airline industry. Also, Van Calker et al. [39] provide a farming application.

Rebai et al. [33] in their study "Saidane A multi-attribute utility model for generating a sustainability index in the banking sector" they developed a model to evaluate the priority for the banks this model integrates the sustainability concept. And they used a multi-attribute utility function (MAUF)

Van Calker et al. [39] in their study "Development and application of a multi-attribute sustainability function for Dutch dairy farming systems" they used multiattribute utility theory (MAUT).

Wang et al. [41] in their study identifying target green 3C customers in Taiwan using multiattribute utility theory, in their study the multiattribute utility theory (MAUT) was used to develop an aggregated fulfillment level in relation to obtaining such products.

Regarding the concerned attributes of customers, they can be shown with the weights they have provided; much research has focused on the comparison of different weighting methods [4], [12], [20], [27], [35], [37].

Different results were obtained from different viewpoints, but most studies indicate that different ways of eliciting attribute weights yield similar results [41]. Among them, Chan et al. [7] found that the weights produced by Max100 were somewhat more reliable than DR and that people actually preferred using Max100 and Direct Rating (DR) rather than Min10

Some researchers described the use of an AHP for determining the fundamental importance ratings of customer requirements [2], [7], [24]-[26], [28], [30], [32], [43], [44], [46]. Lately, according to Ho integrating AHP and QFD is one of the most used techniques [17] as fuzzy AHP and AHP's variants [25], [40].

The main reason why the AHP is considered much better than the traditional approach, such as using a scale of 1–5, is its ability to provide ratio scale priorities, judgment's consistency check, and a better group decision making approach. Note that the AHP ratio scale priorities [16] are of great importance due to the fact that only in this type of scale can the customer requirements priorities be meaningful [6] especially when it is dovetailed with an optimization analysis.

The literature review is pivoted around the study of definition of green product and green customers' requirements, the consumer's preference towards green products and AHP.

A. Green Product

Customers are more and more concerned about environmental protection. Thus, they started to change their spending habits and are asked for green products which have manufacture the least effects on the environment [31]. And According to Ottman [29], Green products are typically durable, nontoxic, use recycled materials to make it, and lowest packaging. Differently, there are no exactly green products, because they consume energy and resources and create by-products and emissions during their manufacture, transport to warehouses and stores, usage, and eventual disposal. So green is relative, describing products with less impact on the environment than their alternatives

Green products combine green concepts in the manufacturing use-return process of these products while allowing the products to meet the same manufacturing regulations. Ottman defined green products as the products which are sustainable, without the use of pesticides, made with recycled materials and simple packaging [29] and the green consumers can be defined as those who prefer to buy and consume green products, and choose products which have minimum effects on the environment [3].

Shamdasami [36] defined Green Product as the products that can be recycled, have less packaging and will not cause a

pollution to the earth or drain natural resources, it is a product that are environmentally friendly with less impact at the environmental. Interest in green products has grown in recent years, as indicated by increased consumer demand, increased supply by companies [9], [10]. The consumers consideration about the environmental protection issues and their behaviors effects on the environments have become increasingly important. today's Successful product designs must offer the functions needed to gain adequate business returns, create market competition, and comply with general regulatory standards [42].

In the research of product design understanding of comprehensive consumer requirements and preferences becomes more important and that because customer product design and manufacturing has become the main concern in the academia and industrial field [38].

B. Customer Requirements for Green Design

The concept of "green" products became at the last decades somewhat popular. But it wasn't until the begging of the 21st century when concerns of global warming and natural resource reduction began gaining attention that "green" went main stream and start influencing the production to go more toward green design.

To promote the consideration of environmental products in order to reduce environmental impact, WBCSD indicated seven major requirements for green design [10]:

- Reduce the material intensity of its goods and services
- Reduce the energy intensity of its goods and services
- Reduce the dispersion of any toxic materials
- Enhance the recyclability of its materials
- Maximize the sustainable use of renewable resources
- Extend the durability of its products
- Increase the service intensity of its goods and service.

Today in the industry there is agreement on integrating environmental requirements into the product design with the traditional product requirements such as (Health, Taste, Reuse, status, convenience, Quality, Value for cost, Easy access, Appearance, freshness, and smell). After the changing of the customer requirements which become more aware to environmental issues, so changing in customer requirements can become a very disturbing for many project, it cause many problems and delays in the lifecycle of the product design. It is therefore important to computer changing customer requirements by formulating a proper strategy to avoid any loss or delay in the project.

C. AHP

The AHP is a decision-making method and which introduced by Saaty [34] because AHP method has good mathematical properties and input data required is easy to obtain many researchers prefer to use it to prioritize the customer requirements, all customer requirements are initially structured into different hierarchical levels. An affinity diagram, a tree diagram or cluster analysis can be used for this purpose. The customers' voice can be gathered by a variety of methods, and all of them aim at asking customers to express their needs of a particular product. It is usually expressed in customers' words that are usually too general to be directly used as customer requirements. However, through sorting, classifying and structuring the customer voices, one can finally obtain useful customer requirements. The AHP encompasses six basic steps as summarized as follows:

Step 1. AHP uses several small sub problems to present a complex decision problem. Thus, the first act is to decompose the decision problem into a hierarchy with a goal at the top,

Step 2. The decision matrix, which is based on Saaty's nine-point scale, is constructed. The decision maker uses the fundamental 1–9 or 1-5 scale defined by Saaty to assess the priority score. In this context, the assessment of 1 indicates equal importance, 2 moderately more, 3 strongly more, 4 very strongly and 5 indicates extremely more importance. The assessments of each alternative are included in the decision matrix with reference to the decision criteria. If the decision making composed of n criteria and m alternatives, the form of the decision matrix as follows:

$$D = \begin{bmatrix} d_{11} & d_{12} & \dots & d_{1n} \\ d_{21} & d_{22} & \dots & d_{2n} \\ : & : & : & : \\ . & . & . & . \\ d_{m1} & d_{m2} & \dots & d_{mn} \end{bmatrix} \quad (1)$$

The elements {dij} signify the rating of the ith alternative in respect to the jth criteria.

Step 3. The third step involves the comparison in pairs of the elements of the constructed hierarchy. The aim is to set their relative priorities with respect to each of the elements at the next higher level. The pairwise comparison matrix, which is based on the Saaty's 1–5 scale, has the form:

$$\begin{bmatrix} d_{11} & d_{12} & \dots & d_{1n} \\ d_{21} & d_{22} & \dots & d_{2n} \\ : & : & : & : \\ . & . & . & . \\ d_{m1} & d_{m2} & \dots & d_{mn} \end{bmatrix} = \begin{bmatrix} w_1/w_1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_n \\ : & : & : & : \\ . & . & . & . \\ w_n/w_1 & w_n/w_2 & \dots & w_n/w_n \end{bmatrix} \quad (2)$$

If n(n - 1)/2 comparisons are consistent with n is the number of criteria, then the elements {aij} will satisfy the following conditions: aij = wi/wj = 1/aji and aii = 1 with i, j, k = 1, 2,. . .,n.

In the comparison matrix, aij can be explained as the degree of preference of ith criteria over jth criteria. It shows that using pairwise comparisons is more functional in determining the weight than obtaining them directly, because it is more reliable to compare two attributes than measure overall weight function.

Step 4. AHP also calculates an inconsistency index (or consistency ratio) to reflect the consistency of decision maker's judgments during the evaluation phase. The inconsistency index in both the decision matrix and in pairwise comparison matrices could be calculated with the equation:

$$CI = (\lambda \max - n) / (n - 1) \quad (3)$$

As much the inconsistency index is close to zero as the much the consistency increased. And to accept the AHP results the relevant index have to be less than 0.10. Otherwise we should go back to Steps 2 and 3 and redo the assessments and comparisons.

Step 5. Before all the calculations of vector of priorities, the comparison matrix has to be normalized. Therefore, each column has to be divided by the sum of entries of the corresponding column. In that way, a normalized matrix is obtained in which the sum of the elements of each column vector is 1.

Step 6. For the following part, the eigenvalues of this matrix are needed to be calculated which would give the relative weights of criteria. This procedure is common in mathematics. The relative weights obtained in the third step should verify

$$A \cdot W = \lambda \max \cdot W \quad (4)$$

where A represents the pairwise comparison matrix, W the eigenvector and λmax the highest eigenvalue. The highest weight coefficient alternative value should consider as the best alternative [19], [45].

III. The AHP Methodology

In this paper we propose the AHP methodology for environmental requirements. To find the importance weights for the customer requirements for green products. First the customer requirements will be determined for green products then finding the rating for these requirements for that the people in the research sample will be asked to give relative importance ratings for each WHAT using five-point scales to derive the weight vectors. A common and appropriate way of obtaining this information is the surveys and a questionnaire will be used for this objective and contained the preferences with respect to each attribute (the traditional and environmental customer requirements) of green products.

IV. Case Study

This paper proposes AHP method to evaluate the customer requirements for sustainable design and identify the most significant environmental indicators for design and manufacture of green products. Eco-friendly requirements have to be considered at the early stage of product design and development processes. And collecting the customer's information through one-on-one interview and a questionnaire survey to investigate their requirements and the importance rating for the requirements which related to the green products.

A. Data Collection

The information about what the customers need, and their priorities can be gained through various marketing methods, e.g. questionnaires, interviews, and brainstorming techniques.

The VOC data were collected through one-on-one interview, and questionnaires conducted over a sample of people belonging to different Ages, education marital status and Income groups, In order to cope with the most satisfied and dissatisfied customers, we first collected the customers' information The Primary data collected from Palestinian customers through a questionnaire survey conducted over a sample of 158 people belonging to different Ages, education marital status and Income groups, the ages was 27% under 30 years old and 36% from 30 to 40 and 24% was from 40 to 50 and 12% was more than 50, just 30% of the sample was less than bachelor's degree and the females was presenting 54% of the sample, when collecting this information, the questionnaire explored the customers' personal information in its first part and the second part was for their preferences regarding purchase of the green product.

were contained in the questionnaire and rated by a Likers 5-point scale to test the degrees of the customers feeling, agreement and understanding to the product requirements, as well as to investigate customer satisfaction with green products, the questionnaire contained the preferences of respondents with respect to weighting each product requirements (the green requirements and the traditional requirements) in general.

B. Determination the Customer Requirements Weights by Using AHP

The first step of the customer input is to determine the needs of the customers and their preferences. Customer needs are usually expressed in customers' words that can be collected by focus groups or individual interviews. According to [14], individual face-to face interviews may be more cost effective than focus groups, and at least 20- 30 customers should be interviewed to obtain 90- 95% of all the possible customer needs [5], [14]. Mail/ telephone surveys are not suitable for collecting qualitative data such as customer needs due to the difficulties in controlling the scope of responses. Customers' words are usually too general and/or too detailed to be directly used as customer needs. To facilitate analysis and application, the words collected are usually organized as a tree-like hierarchical structure to form various (usually three) levels of customer needs and, according to the situation, those at a specific level are chosen as the final customer needs.

Due to the environmental consideration, the identification of the voice of customer not only based on the customer traditional needs like (Health, Taste, Reuse, Quality, cost, Easy access, Appearance, freshness and smell), but also have to involve the eco- friendly requirements. The green products eco- friendly requirements like (non-toxic materials, reduce energy consumption, reduce material use, reduce the waste and easy to disposal …) (as shown in Table I):

TABLE I
The Eco-Friendly Products Requirements [9]

Eco- Friendly Requirements
A. Reduce the material intensity of its goods and services
B. Reduce the energy intensity of its goods and services
C. Reduce the dispersion of any toxic materials
D. Enhance the recyclability of its materials
E. Maximize the sustainable use of renewable resources
F. Extend the durability of its products
G. Increase the service intensity of its goods and service

The next step is how to allocate weight to customer

environmental requirements. So, to evaluate the weight for each customer requirements which they are (Health, Taste, Reuse, Quality, cost, Easy access, Appearance, freshness and smell and Eco-friendly) the customers reveal their perceptions on the relative importance of the seventh identified W HATs using the scale from one to five.

Scale used for the design of the questionnaire is a Likert rating scale with a range of 1-5, where (5) mean very important, (4) mean important, (3) medium, (2) unimportant (1) not at all important and which should be done by the surveys where every customer gives a crisp value for each customer requirements CR.

The sum of all customer requirements in normalized priority vector is 1. The priority vector shows relative weights among the customer requirements. Health is 20.40%, Eco-friendly is 19.51%, Cost is 17.20%, Quality is 16.54%, Easy access is 13.25%, Appearance is 7.05% and freshness is 4.95% see (as shown in Table IV).

The most preferable requirements for the green products is Health followed by Eco-friendly, Cost and Quality and the lowest are Appearance and freshness (as shown in Fig. 1). And λ max = 8.520354

TABLE II
COMPARISON MATRIX

	health	freshness	appearance	easy-access	quality	cost	eco-friendly
health	1.00	2.77	1.74	2.85	2.83	2.29	1/3.05
freshness	1/ 2.77	1.00	1/ 2.28	1/ 2.42	1/ 2.22	1/ 2.38	1/ 2.88
appearance	1/ 1.74	2.28	1.00	1/ 2.89	1/ 2.98	1/ 1.93	1/ 2.83
easy access	1/ 2.85	2.42	2.89	1.00	1/ 2.28	2.37	1/ 2.83
quality	1/ 2.83	2.22	2.98	2.28	1.00	1/ 2.75	2.88
cost	1/ 2.29	2.38	1.93	1/ 2.37	2.75	1.00	2.73
eco-friendly	3.05	2.88	2.83	2.83	1/ 2.88	1/ 2.73	1.00

TABLE III
RECIPROCAL MATRIX

	health	freshness	appearance	easy-access	quality	cost	eco-friendly
health	1.00	2.77	1.74	2.85	2.83	2.29	1/3.05
freshness	1/ 2.77	1.00	1/ 2.28	1/ 2.42	1/ 2.22	1/ 2.38	1/ 2.88
appearance	1/ 1.74	2.28	1.00	1/ 2.89	1/ 2.98	1/ 1.93	1/ 2.83
easy access	1/ 2.85	2.42	2.89	1.00	1/ 2.28	2.37	1/ 2.83
quality	1/ 2.83	2.22	2.98	2.28	1.00	1/ 2.75	2.88
cost	1/ 2.29	2.38	1.93	1/ 2.37	2.75	1.00	2.73
eco-friendly	3.05	2.88	2.83	2.83	1/ 2.88	1/ 2.73	1.00
sum	**6.12**	**15.95**	**13.80**	**10.14**	**8.15**	**7.32**	**7.99**

TABLE IV
NORMALIZED MATRIX

CR	Health	Freshness	Appearance	Easy access	Quality	Cost	Eco-friendly	Priority vector
Health	0.0231	0.0243	0.0178	0.0400	0.0500	0.0442	0.0060	**0.2040**
freshness	0.0083	0.0088	0.0045	0.0060	0.0077	0.0081	0.0100	**0.0495**
Appearance	0.0133	0.0201	0.0102	0.0048	0.0060	0.0100	0.0100	**0.0705**
Easy access	0.0081	0.0213	0.0300	0.0140	0.0080	0.0460	0.0100	**0.1325**
Quality	0.0081	0.0195	0.0305	0.0320	0.0173	0.0070	0.1000	**0.1654**
Cost	0.0100	0.0210	0.0198	0.0060	0.0480	0.0200	0.0500	**0.1720**
Eco-friendly	0.0705	0.0254	0.0290	0.0400	0.0060	0.0070	0.0200	**0.1951**

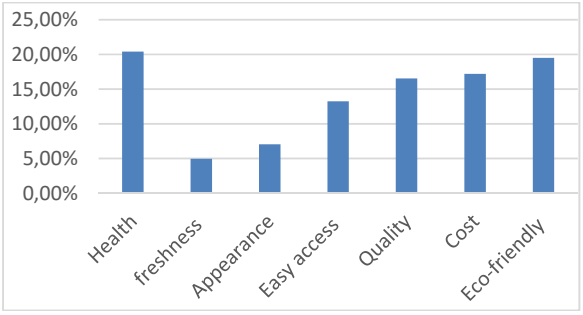

Fig. 1 The priority vector for the customer requirements (by percentage)

V. DISCUSSION

Different weights of customers obtained different result. The ultimate purpose of this research was to determine the Importance Weights for the Customer Requirements for green products, help firms to target their customers, set up proper marketing strategies to increase profits and satisfy the customers' needs by fulfilling the environmental requirements for green products.

The results of the customer important ratings show that the health is the most preferable requirements for green product. Then the second highest customer important ratings is the eco-friendly requirements and win over the other traditional requirements, eco-friendly requirements with Recyclable, Energy Saving, Easily Maintenance, No Toxically Material Released, Durability, less waste are becoming a most important issue for the customers. And reflect the increasing in their awareness of the environmental consideration and green products that would meet the environmental requirements. Which shows how the customer requirements changing towards the environmental requirements and became more aware to the important of reduction of the environmental crises and the pollution, even more than the cost which came in the third place and this mean that the customers are ready to pay more for the green products if it fulfill their requirements toward protecting the environment and save the rare natural resources. Then the quality come next to the cost and this shows how much the customer care for the cost of the product when they buy green products, and this give it the most important competitive prevalence.

At the end freshness was the lowest in the ranking after Appearance, which mean that the customers prefer green products meet their eco-friendly requirements and at same time have good price with the quality requirements to be satisfied then Easy access requirements and at the end they put

Appearance and freshness requirements which didn't take their attention as much as other requirements.

VI. Conclusion

This paper proposes AHP method for designing environmentally friendly product, AHP developed to find the weights of the customer requirements for green products. This method uses the AHP methodology to consider the "voice" of requirements. The AHP offers a methodology to rank the customer requirements based on the decision maker's judgments concerning the importance of the customer requirements. For this reason, AHP is ideally suited for prioritizing of the customer requirements for sustainable design. The weights of WHATs are calculated using AHP. The customer environmental requirements are evaluated and compared with each other using AHP. The results reveal the practical feasibility and practical adaptability of customer eco-friendly requirements for green products in the industry

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