MARKETING

EVALUATING COMPETITIVENESS IN PRODUCT DESIGN BY USING ANALYTIC HIERARCHY PROCESS

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ABSTRACT

In this study, the use of the Analytic Hierarchy Process (AHP) method in the evaluation of the competitive properties of industrial product designs is investigated. After giving information about the usage of the method and the related literature, a field study is presented in which 5 vacuum cleaner designs were evaluated to find the one that would be the most competitive in markets. During this study, initially the main objective and the appropriate evaluation criteria were determined followed by the determination and comparison of the importance values of the criteria and design alternatives. Afterwards, design alternatives were evaluated by using AHP method-specific tools and the performance values of the 5 design alternatives were found. These values were listed in a descending order, determining the competitiveness of each design alternative according to each other. At the final sections the findings were interpreted and conclusions about the use of the method were presented.

Keywords: ***Household appliance design, Analytic hierarchy process, Competitiveness, Product design,***

PAZARLAMA

ÜRÜN TASARIMINDA REKABETÇİLİĞİN ANALİTİK HİYERARŞİ SÜRECİ YÖNTEMİYLE DEĞERLENDİRİLMESİ

ÖZET

Bu çalışmada endüstri ürün tasarımlarının rekabetçi özelliklerinin değerlendirilmesinde Analitik Hiyerarşi Süreci (AHP) yöntemi kullanımı incelenmiştir. Yöntemin kullanımı ve ilgili literatür hakkında bilgi verildikten sonra 5 elektrik süpürgesi tasarımın değerlendirilip piyasada en rekabetçi olacak tasarımın belirlendiği bir alan çalışması sunulmuştur. Alan çalışmasında öncelikle ana hedef ve buna uygun değerlendirme ölçütleri belirlenmiş, ölçüt ve tasarım alternatiflerinin birbirlerine göre önem dereceleri incelenmiştir. Sonrasında tasarım alternatifleri yöntemce sağlanan araçlar yardımıyla değerlendirilmiş ve eldeki 5 tasarımın başarım değerleri ortaya çıkartılmıştır. Elde edilen sonuçlar, büyükten küçüğe sıralanmış ve en yüksek başarım değerine sahip tasarım, en rekabetçi ürün olarak belirlenmiştir. Sonuç bölümünde bu bulgular yorumlanmış, yöntemin sağladığı faydalar açıklanmıştır.

Anahtar Kelimeler: ***Ev araçları tasarımı, Analitik hiyerarşi süreci, Rekabetçilik, Ürün tasarımı***

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1. INTRODUCTION

Design's positive effect on the competitiveness of a product has been researched and presented in many academic studies (Berger, Dertouzos, Lester, Solow, & Thurow, 1989:21–29; Freeman, 1994:463–514; Hertenstein, Platt, & Veryzer, 2013:8–21; Suarez & Utterback, 1995:415–430; Wray, 1991:153–170)· In today's world, the most efficient methods that can be used to increase the global competitiveness of a product are design based ones (D'Ippolito, 2014:716–730). The structure of the industrial design is widely investigated in design literature and presented in various distinct steps (Ulrich & Eppinger, 2011). During these steps of the industrial design process, numerous design ideas are created for specifications, parts, materials, form, style, production method and other details of products. These ideas are usually evaluated by the designers by means of their personal approaches which are mostly intuitive and very subjective. Corrections and redesigns are done in the designs according to the results of these personal evaluations. This process of iteratively redesigning-evaluating is repeated until the design is found as competitive enough again by the designers. Proper evaluation of design ideas in earlier phases of the design process is vital for the final success of a product (Roy & Riedel, 1997:537–594). Reducing subjectivity and methodizing design evaluations are expected to make the design process more accurate, efficient, and fast. This can be accomplished by introducing a systematic method into evaluations.

This article investigates the Analytic Hierarchy Process (AHP) method for this purpose and proposes a model to use it to evaluate product designs according to selected criteria. During the course of the article, AHP and its relevant literature are presented. Then the method' application to the industrial design is explained and then demonstrated on a field study in which, five vacuum cleaner designs are evaluated and the most competitive one is selected for further design development. Obtained findings and produced conclusions are presented in the last sections of the article.

2. LITERATURE REVIEW

Relevant studies selected from the literature are listed as follows. Walsh has made an attempt to analyzing the design function from various multi-disciplinary viewpoints. She investigated design and compared it to research and development as well as technological innovation. She also examined the role of design in the context of other company activities and produced useful conclusions by interpreting her findings (Walsh, 1996:509–529). Roy and Riedel investigated product competition and the role of design-innovation in achieving success by using a conceptual model they developed. They used the data obtained by investigating over 220 different products to analyze the design and innovation-related factors affecting product success (Roy & Riedel, 1997:537–594). Trueman and Jobber have investigated the effects of design on market competition. They stated that industrial design has the potential to increase product value and strengthen the company as well as brand identity while reducing the overall costs (Trueman & Jobber, 1998:594–605). Hsiao comparatively used AHP with other methods to introduce a process for designing toys for infants. He concluded that products better satisfying consumer needs can be designed by properly managing the quality of the design process (Hsiao, 2002:41–55). Kwong et. al. used AHP and triangular fuzzy numbers to improve hair drier designs by determining importance values for the user needs. They also compared fuzzy AHP and traditional AHP methods stating that both methods gave satisfactory results in prioritizing customer requirements while the fuzzy method is easier to understand and implement (Kwong, Bai, & Bai, 2003:619–626). Nagahunumaiah et al. have developed a research model in which Fuzzy AHP and QFD (Quality Functions Deployment) were used together in a visual C++ environment for evaluation and selection of rapid prototyping tools. They have also compared traditional manufacturing methods with today's rapid methods in terms of selected factors. They concluded that rapid prototyping and production methods are valuable tools that enable the designers to quickly convert designs into usable products, giving companies the ability to test their products before market release (Nagahanumaiah, Ravi, & Mukherjee, 2007:1161–1181). Hambali et al. have investigated the use of the AHP for design concept selection during the design process. They demonstrated their research model with a field study in which several disability chair designs were evaluated and the best one was selected for production. They concluded that AHP methodology is useful for the designers as it enables corrective iterations to be made in the design process before the real production begins (Hambali, Sapuan, Napsiah, & Nukman, 2008:1–18). Hambali et al. utilized AHP for evaluating production methods for a newly designed product. They demonstrated the use of their process model on an application in which various production methods for a vehicle part were evaluated. They concluded that the AHP method is useful for performing concurrent design and engineering evaluation-selection tasks (Hambali, Sapuan, Ismail, & Nukman, 2009:49–61). Felice and Petrillo used AHP and QFD together to collect data about the needs of ceramic product users. They stated that with its rigorous and proven mathematical process, the AHP method is useful for decision-making by reducing complex evaluations into multiple simpler comparisons and then easily converting these comparisons into final results. They also added that the use of AHP together with other methods is not difficult and greatly increases the reliability of the final results (De Felice & Petrillo, 2011:25–38). Toksari et al. used fuzzy AHP to evaluate strategies for evaluating target markets for white goods. They also stated that the use of proven methods in evaluation and selection tasks greatly increases the reliability of the obtained results (Toksarı & Toksarı, 2011:51–70). Sarfanaz and Jenab proposed a research model based on fuzzy AHP for use in design evaluations. They demonstrated the use of this model with an application in which several hospital bed designs were evaluated. They concluded that fuzzy AHP is more robust than stand-alone AHP and it is also better in eliminating inconsistencies resulting from personal feelings or subjective judgments (Jenab, Sarfaraz, & Ameli, 2013:293–304). Battistoni et al. used AHP to estimate users' responses to the products during the design process, emphasizing the importance of using internally consistent and reliable data for obtaining accurate results (Battistoni, Fronzetti Colladon, Scarabotti, & Schiraldi, 2013:1–8). Gupta et al. proposed a research model based on TOPSIS and fuzzy AHP for use in design evaluations. They demonstrated their model in an application in which various suitcase designs were evaluated according to criteria such as cost, quality, human and environmental factors. They stated that the input requirements of fuzzy AHP create a considerable work load during the process, rendering its use difficult and tedious for the researchers (Gupta, Singh, Agrawal, &

Nagaraju, 2015:6072–6080). Ayağ used the AHP to evaluate CAD systems for use in product design. He stated that introducing fuzzy logic into the AHP increases its reliability and robustness (Ayağ, 2015:30–38). Ahmad et al. researched the conceptual design selection process while designing wheelchairs for the elderly by using AHP. They performed a field study in which various wheelchair designs were evaluated and stated that the use of AHP increases the speed of the product design process while also improving the quality of the final product (Ahmad, Maidin, Rahman, & Osman, 2017:6710–6719). Moretti et al. performed a study about the use of the AHP for prototype evaluation in fashion garment design by using criteria defined according to global needs. They stated that the AHP method enables the decision-making process to run more smoothly and reliably (Moretti, Aldo, & Colmenero, 2017:367). Prabhu et al. used Fuzzy AHP together with PROMETHEE for the evaluation and selection of new product ideas for farmers. They tested their research model by evaluating several single-wheeled pushcart designs and emphasized the virtue of using multiple methods for mutual verification (Prabhu, Chaudhari, Pathak, & Rajhans, 2018). Peko et al. investigated rapid prototyping methods and evaluated them according to selected criteria by using AHP and PROMETHEE methods. They concluded that it is best to use multiple methods on the same data set for obtaining and verifying the results (Peko, Gjeldum, & Bilić, 2018:453–461).

3. ANALYTIC HIERARCHY PROCESS

AHP was first proposed by Myers and Alpert (Myers & Alpert, 1968:13–20) and further developed for application in Wharton School of Business (Saaty, 1980), establishing a place for itself as a tool of decision making and priority identification as seen in following scientific studies (Cheng, Chou, Yang, & Chang, 2005:495–505; Lai, Trueblood, & Wong, 1999:221–232; Min, 1994:25; Vaidya & Kumar, 2006:1–29). It is basically a measurement theory based on priority values obtained from pairwise comparisons between criteria and selection alternatives and can be used for solving decision-making problems belonging to systems with complex interior relations (Saaty, 2008:83). It works by analyzing and modeling these systems heuristically as simplified hierarchical structures (Özden, 2008:299–320). By using this simplified structure, AHP prevents costly, distractive and delay imposing problems frequently encountered in large decision-making processes such as lack of focus, lack of involvement and planning mistakes (Koçak, 2003:67–77).

In AHP, the relation between the decision processes is unidirectional and the overall process is comprised of three steps (Wind & Saaty, 1980:641–658). For the solution of the problem, first, the hierarchical structure is formed (An, Kim, & Kang, 2007:2573–2579). Then a pairwise comparison matrix determining the relative importance values of the criteria is formed (Basak, 2002:200–216; Cao, Leung, & Law, 2008:944–953). Saaty's Eigenvector method is used to calculate the required relative importance values (García-Cascales & Lamata, 2009:1442–1451). To verify these values, their consistency ratio is calculated (Chou, Hsu, & Yen, 2008:141–153). If this consistency ratio is within acceptable limits, the process continues with ranking the priorities of the alternatives according to each criterion. Finally, the alternative which has the highest overall priority in terms of all the criteria combined, is

determined and declared as the most successful alternative to be selected (Yılmaz, 2010:206–234).
The process flow chart can be seen in FIGURE 1 and the process steps in detail are as follows:

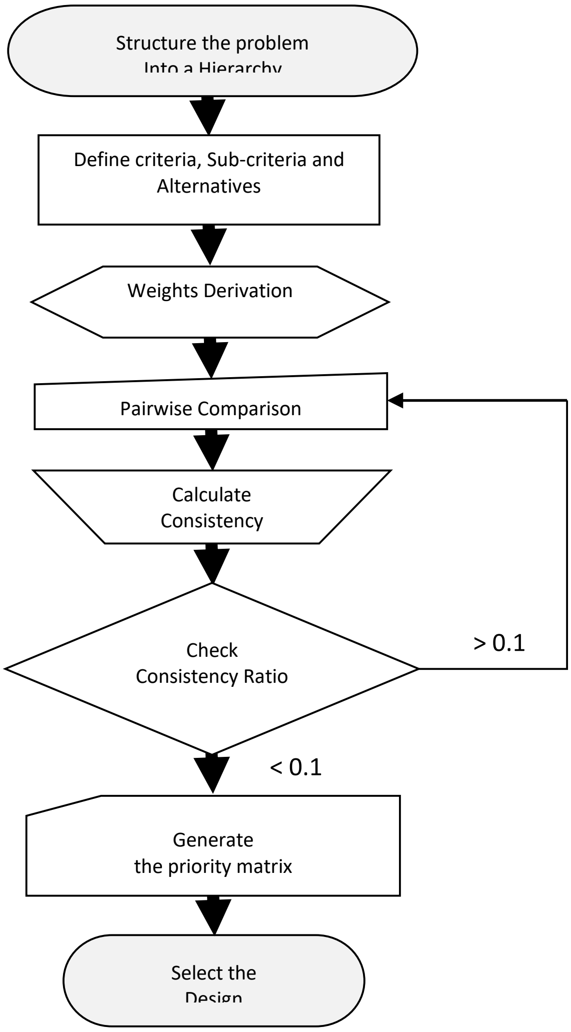

Figure 1. Flow Chart of the Analytic Hierarchy Process

- Setting up the model (structuring the hierarchy): Structuring the problem as a hierarchical schema divides it into separate parts (Chandran, Golden, & Wasil, 2005:2235–2254; Xuning & Feng, 2009:178–180). This process, which is also called modeling gives the decision-makers the ability to easily see and compare the criteria, sub-criteria, and the alternatives with each other (Lee & Hwang, 2010:161–167). The main purpose of the evaluation procedure forms the top level or the header of the hierarchy (Pineda-Henson, Culaba, & Mendoza, 2002:15–28). At the medium level, the evaluation criteria are listed, followed by the alternatives to be evaluated at the bottom level (Braunschweig & Becker, 2004:77–86). The resulting hierarchical structure schematic can be seen in Figure 2 (Wang, Liu, & Elhag, 2008:513–525).

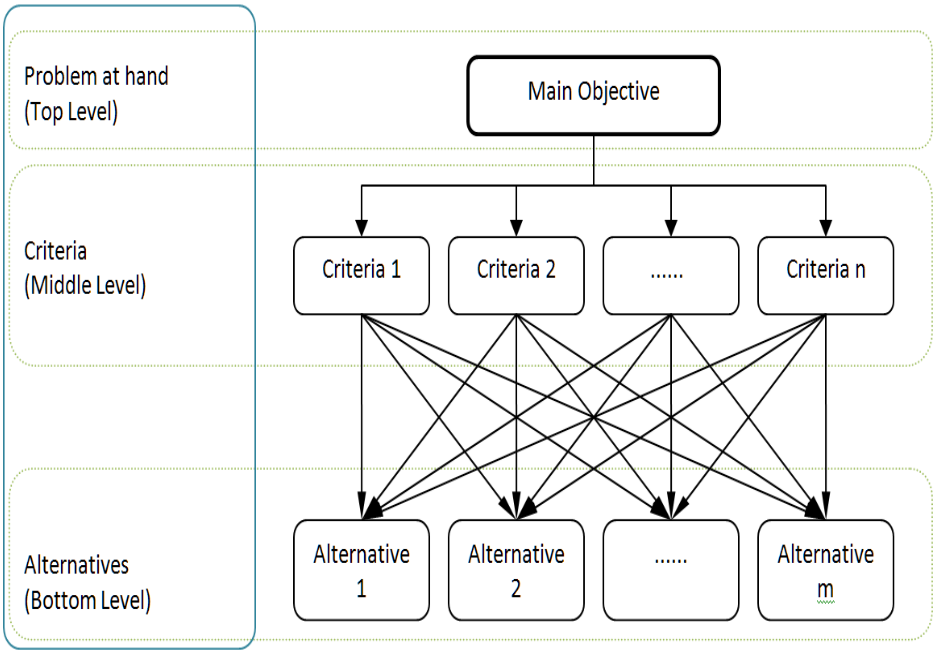

Figure 2. AHP's Hierarchical Structure

- Forming the pairwise comparison matrices and designating the weighted values: In the second step of AHP, comparison matrices are formed and the importance of each criterion relative to others is investigated. For this, pairwise comparisons are done by the people participating in the study through surveys. The criteria importance values are calculated by evaluating the results of these comparisons (Sharma, Moon, & Bae, 2008:256–265). As the reliability of the overall evaluation and the final result completely depend on obtaining correct data from these comparisons, it is very important to select the participants with the correct expertise (Chandran et al., 2005:2235–2254). The structure of the pairwise criteria comparison matrix is shown in Table 1.

Table 1. The Pairwise Comparison Matrix for the Criteria

	Criteria 1	Criteria 2	Criteria ...	Criteria j
Criteria 1	$\frac{w_1}{w_1}$	$\frac{w_1}{w_2}$	...	$\frac{w_1}{w_j}$
Criteria 2	$\frac{w_2}{w_1}$	$\frac{w_2}{w_2}$	...	$\frac{w_2}{w_j}$
Criteria ...	...	...	...	...
Criteria i	$\frac{w_i}{w_1}$	$\frac{w_i}{w_2}$	...	$\frac{w_i}{w_j}$

The next step is to calculate the importance of the criteria relative to each other. The decision-maker uses Saaty's 1-9 scale (Table 2) to give importance values to compared criteria pairs. All criteria are evaluated in pairs against each other in this manner within multiple comparison operations (Saaty, 1986:841–855).

Table 2. The Scale Used for determining relative importance in AHP

Relative Importance Rank	**Meaning**	**Explanation**
1	Equal value	Both requirements are equal
3	A bit more value	One requirement is a bit more valuable than the other
5	Essential or strong value	One requirement is quite more valuable than the other
7	Very strong value	One requirement is strongly more valuable than the other
9	Extreme value	One requirement is very strongly more valuable than the other
2,4,6,8	Intermediate values	These values should only be used when a compromise is needed.

Then the overall relative importance sequence of all the criteria is calculated. The preferred method for this calculation is Saaty's Eigenvector method (Hurley, 2001:185–188).

- Calculation of the relative importance of the criteria-subcriteria and the consistency ratio:

The Eigen Vector is calculated by using the formula 1 (Ramadhan, Wahhab, & Duffuaa, 1999:25–39).

$$w_i = \frac{1}{n}\sum_{j=1}^{n} \frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}} \qquad (1)$$

The next step is to calculate the Consistency Ratio (CR) of the comparison matrix (Hafeez, Malak, & Zhang, 2007:3592–3608). The purpose of this is to determine whether the participant gave consistent information while comparing the criteria. Having a CR value over 0.10 means that the matrix data is inconsistent, and the comparisons should be reviewed and repeated (Stein & Mizzi, 2007:488–497). So the consistency of the matrix is inversely proportional to the CR value and the most consistent matrix is achieved with a CR of zero (Xu, Wang, & Lu, 2008:219–224). Saaty prefers to use formula 2 to calculate the consistency of the comparison matrix (Saaty & Özdemir, 2003:233–244).

$$CR = \frac{CI}{RI} \qquad (2)$$

Consistency Index (CI) in formula 2 can be calculated with formula 3 (Zhou & Shi, 2009:236–238).

$$CI = \frac{\lambda_{max} - n}{n-1} \qquad (3)$$

The λ_{max} in formula 3 which is the maximum Eigen Value is calculated with formula 4 (Xuning & Feng, 2009:178–180).

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n}\frac{(Aw)_i}{w_i} \qquad (4)$$

By adding the values obtained by multiplying the relative priorities with the columns of the comparison matrix, the weighted total vector is formed. The arithmetic average of the values is obtained by dividing elements of the weighted total vector into the corresponding relative priority value, giving the λ_{max} value (Güngör & İşler, 2005:21–33). The values of RI according to matrix size are given in TABLE 3 (Karagiannidis, Papageorgiou, Perkoulidis, Sanida, & Samaras, 2010:251–262).

Table 3. Random Index(RI) Values Versus Matrix Size

n	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

For the final verdict, a hybrid vector of priorities that will be used to rank the alternatives is generated by calculating the weighted average of the vectors for all variable priorities. The final priority values of the alternatives, obtained by using these averages are called decision points and they are placed in a hybrid vector by which the decision-makers can see and easily compare the performances of the alternatives, easily selecting the best option (Kuruüzüm & Atsan, 2001:83–105).

4. USING AHP FOR THE EVALUATION OF VACUUM CLEANER DESIGNS

In this part, the case study which has been performed to demonstrate the applicability and validity of the AHP method is presented.

The AHP method is used to evaluate five vacuum cleaner designs and the most competitive one is selected for further design and development. The details about the structuring of the AHP, selection of criteria and the overall evaluation process together with findings and their interpretations can be found in the following sections.

4.1 The Method

After investigating the utilization of AHP in the literature, our adaptation of the method into the industrial design is planned. As mentioned in the previous section, the AHP method requires the main objective, set of criteria-subcriteria and selection alternatives to be arranged within a hierarchical structure. In this structure, firstly, the top level is determined as 'Selection of the best vacuum cleaner design'.

Then possible criteria and sub-criteria are researched, and five of the criteria used for the Red Dot Design Competition were considered to be suitable for assessing the competitiveness of industrial designs and they are accepted as the evaluation criteria. Subcriteria for these main criteria are chosen among the criteria used in similar evaluations presented in various literature articles (Ayağ, 2005:687–713; Hambali, Sapuan, Ismail, & Nukman, 2009:198–211; Hambali et al., 2008:1–18; Hsiao, 2002:41–55). The list of the evaluation criteria and subcriteria are finalized as shown in Table 4. These criteria and sub-criteria are placed at the middle level of the hierarchical structure.

Table 4. List of Criteria and Their Definitions

Degree of innovation	The amount of completely new, desirable qualities, specifications and/or technologies in the product? <u>New and novel properties, new technologies</u>
Functionality	Can the product perform its functions adequately? <u>Handling, usability, safety, maintenance requirement</u>
Formal quality	Does the form relate to the product's functions? <u>Aesthetic quality, functional form</u>
Ergonomics	Does the product fulfill the physical needs of the user? <u>Easy of holding-carrying, user-friendly interface</u>
Symbolic content	Does the product convey self-explanatory and/or incentive information? <u>Self-explanatory features, the possibility of a playful use</u>

Then five vacuum cleaner designs (Figure 3) are selected among a number of designs belonging to an earlier study performed in our university (Bayrakçı, 2012).

Figure 3. Vacuum Cleaner Design Sketches to be Evaluated

The properties of the 5 selected designs are as follows;
VC -1: Is a vacuum cleaner enabling users to do general or regional cleaning while simultaneously purifying the air. In addition to the domestic use of large families, it is also suitable for places such as cinemas, theatres, classrooms, mass transport vehicles which are used by crowds and frequently need to be cleaned-refreshed in short periods of time. The form of the product enables it to be used both vertically and horizontally. The suction head and telescopic pipe can be detached from the main unit and used to reach narrow gaps between furniture etc. The product can also be folded for storage.

VC -2: Is designed to be practical and capable of cleaning and sterilizing large areas despite its small size. The product can be used as a handheld unit for detail cleaning or can be converted into a self-standing unit by adding a telescopic handle and a wider suction head for cleaning larger areas. The cleaning is done by vacuum and sterilization is done by using steam. For performing two tasks, the front tip has two openings, one for air suction and one for steam ejection.

VC -3: Is a product inspired by a snail and it can transfer the collected dust directly into its bin, bypassing the piping and therefore improving suction strength. To work in this mode, the suction head needs to be attached directly to the main product body. The body and the suction head can also be detached and used separately by using the provided hoses, giving the user more precise control of the cleaning spot, reaching narrow places between furniture and higher areas such as curtains etc.

VC -4: Tries to tackle the general problem of accessory storage when not in use. It has fewer accessories each of which serves multiple uses and is stored directly inside the product. The dust storage area is also designed for achieving a compact overall product size. Finally, some styling and surface graphics are used for further improving the aesthetics of the product.

VC -5: Is intended to be used in living spaces that are swept and mopped every day due to sicknesses or having a newborn baby etc and it saves energy and time by sweeping and moping simultaneously. The product has been ergonomically designed and it is easily controlled by the user with its curved handle that also matches its overall curvy form. General cleaning is done at the front of the suction head by air vacuum and mopping is done at the rear by using 150 °C hot steam. The water and dust chambers are removable. A cable re-winder is also added to the product for easy carrying and storage.

These product designs are placed at the bottom level of the hierarchical structure as the alternatives to be evaluated as shown in Figure 4.

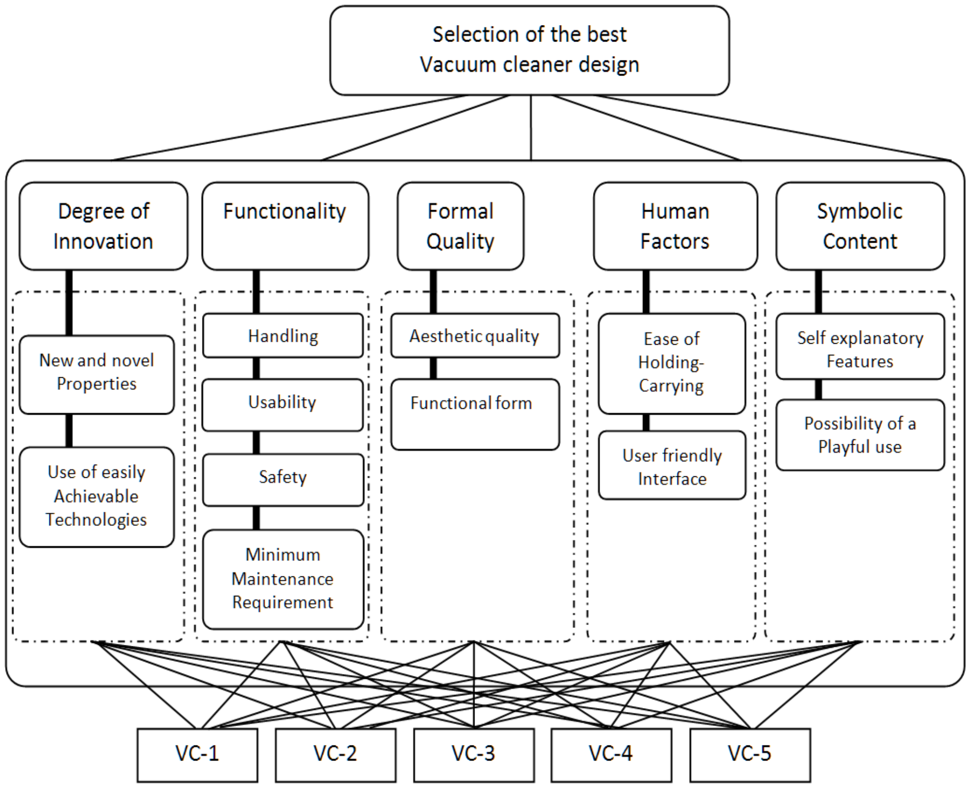

Figure 4. The Hierarchical Model of the Process

4.2 Data Gathering

AHP is recognized to work with both objective and subjective input data and there is no strict number for the required samples to obtain reliable results (Kuruüzüm & Atsan, 2001:83–105). Therefore 15 people were deemed adequate to take part in the study and were randomly selected among the researchers attending the university's design research center. These participants consisted of a professor and 8 designers to represent design teams and 6 design students to represent the users. Interviews are done with them to rank the criteria priorities and performance of alternatives in terms of the criteria.

The interviews were conducted by using a computer in a private room furnished with a table and two seats which the participant and the interviewer used while the participant is asked to do the required comparisons. The pictures of the alternatives are shown all together to the participants on the LCD screen at first and then two by two during the comparisons. Each comparison is given to the participant orally as a question such as 'Please state importance values for performance and safety, which one do you think is more important for a vacuum cleaner?', 'Which one of VC-1 and VC-2 is safer to use? Please comparatively rank each design according to safety', 'Which one of VC-4 and VC-5 has a better performance? Please comparatively rank each design according to performance', 'Which one of VC-2 and VC-3 is cheaper to manufacture? Please comparatively rank each design according to manufacturing cost'. The participants were asked to do their rankings by using Saaty's 1-9 scale provided at the survey form (Saaty, 2008:83). The ranks were entered into the empty pairwise comparison matrices displayed by the program on the screen. This oral and visual approach enabled us to perform surveys easily like an informal conversation. To create a common decision for the whole sample group, the geometric mean of the input data is calculated by the Expert Choice program when data was entered by the interviewer during the interviews. This PC program which has been specifically designed for the use of AHP proved to be very useful for our research.

4.3 Application of the AHP

When the interviews were completed, the Expert Choice version 11 PC program performed the AHP-specific calculations and automatically generated tables containing quantitative findings.

4.4 Findings

The priority values obtained for the criteria are presented in Table 5. The inconsistency ratio of the criteria comparisons is found to be 0.02, which is less than 0.1 and therefore validates the results.

Table 5. The Main Criteria's Pairwise Comparison Matrix

	Degree of innovation	**Functionality**	**Formal Quality**	**Human factors**	**Symbolic Content**
Degree of innovation		2,25869	2,44949	2,44949	1,37411
Functionality			1,7299	1,18222	1,59714
Formal Quality				2,04767	1,1487
Human factors					1,31951
Symbolic Content					
IR: 0,02					

According to these findings, the most important criterion for the vacuum cleaner design is human factors, followed by performance, cost, safety and maintenance.

Figure 5. Criteria Priorities With Respect to the Goal

The subcriteria comparisons' inconsistency rate is also found as smaller than 0.1, validating the results. The calculated values for the relative importance Load (L) of the subcriteria are given in Figure 6. The subcriterion with the highest load value under each main criterion is the most important subcriterion within that group.

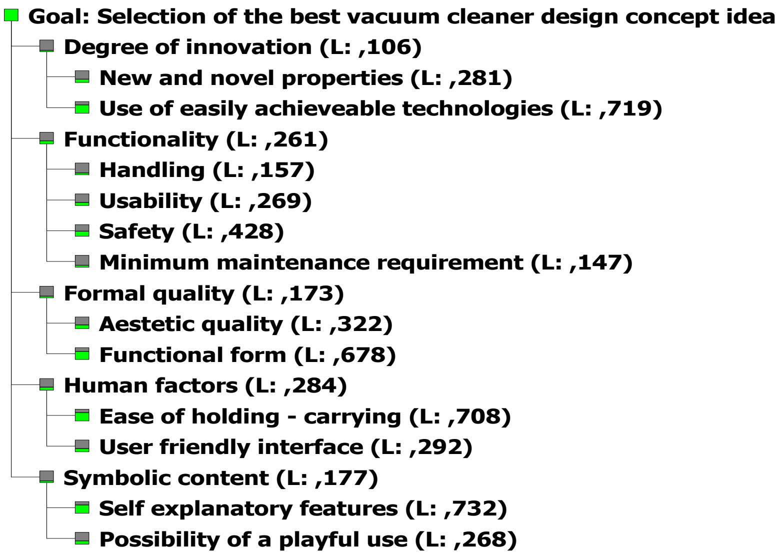

Figure 6. Importance Load Values Schematic for all Criteria

According to this, the most important subcriteria are the use of easily achievable technologies, safety, functional form, ease of holding-carrying and self-explanatory features.

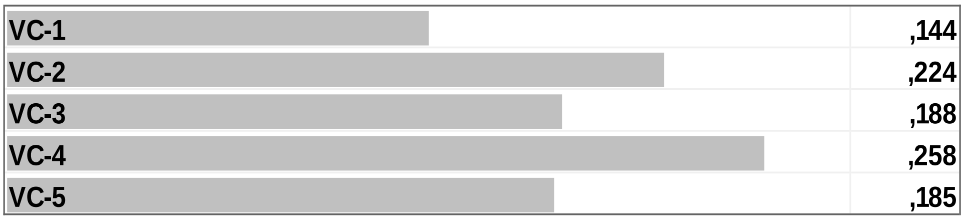

Figure 7. Decision marks of the alternatives

The resulting weighted importance values or decision marks for the five vacuum cleaner designs are obtained as listed in Figure 7. It can be seen that VC-4 has the highest performance (25.8%), followed by VC-2 (22.4%), VC-3 (18.8%), VC-5 (18.5%) and VC-1 with the lowest performance (14.4%). Therefore after considering all criteria and subcriteria, VC-4 is found as the best design alternative for further design development as shown in Table 6 which also lists the other Product Designs according to their overall performances.

Table 6. Product Designs and Their Overall Performances in Descending Order.

Alternative Product Designs	Overall Performance
VC-4	25.8%
VC-2	22.4%
VC-3	18.8%
VC-5	18.5%
VC-1	14.4%

To assess the obtained results, a validation survey was also done with the participation of a professional industrial designer working in a household appliances firm. Similar to the validation procedure performed in a relevant academic study (Harputlugil, Gültekin, Prins, & Topçu, 2014:139–161), the survey questions were answered by this expert designer using marks between 1 and 10. After this survey, expert opinions about the design qualities of each product are gathered by the scores as shown in Table 7. It is seen that the validation results closely match the results obtained from the AHP analysis results given in Table 6.

Table 7. Interview Evaluations of the Product Designs and the Scores Each Have Received.

	Expert views about each product design according to his professional experience	**Score** (1-10)
VC-1	This product seems to have tried to mix and match the old and new trends in this type of household appliances. It is also large and probably heavy with its large water reservoir. Its size and weight might reduce its success chance in the market.	2
VC-2	This product is portable and has modern lines matching current trends. While it's large size and multiple accessories might	7

	complicate its use and storage, the standalone operation capability of its handheld unit makes up for this problem and might increase its chance in the market.	
VC-3	This product has quite modern, even somewhat experimental shapes and forms which might be a reason for not being preferred widely by the consumers.	5
VC-4	This product has formal qualities inspired by the generally pure lines of today's electronic products. It also has pragmatic qualities like intelligent displays and touch-controls which also refer to the modern electronics used inside. Therefore this product generally matches people's product selection preferences of the day.	10
VC-5	This product has lines similar to the products of the '50s and '60s, with not enough improvements in other qualities. Therefore its chance in the market will be limited.	4

5. CONCLUSION

This article has demonstrated the application of the AHP multi-attribute decision-making technique to the competitiveness evaluation of consumer product designs. The method is explained in detail and then demonstrated with an industrial design application. In the application, a group of vacuum cleaner product designs are evaluated according to several criteria and the most successful one is selected for further design development.

While AHP methodology was introduced and outlined through the paper, various ways of visualizing, and analyzing the results generated by the method also have been shown. Then the method was demonstrated on a practical industrial design application including a field research and survey. The field research has been divided into three steps. The first step involved setting up the problem by defining objectives, priorities, design attributes, and design alternatives to be evaluated. The second step involved data collection from participants. The last step was the execution of a PC program specific to AHP to process the gathered data to generate result tables. Finally, the most competitive design alternative was selected by interpreting these tables. Using computer programs in the application of AHP simplifies the use of the method, ensures the process steps are executed in the right order and prevents mistakes which are likely to happen when manually entering data during interviews and doing matrix calculations in later stages. It also enables the method to be used on more complex problems which would be very hard to implement manually.

The AHP can best be used for situations where a relatively small number of design alternatives are needed to be evaluated very accurately. According to the experience gained during this research, a suitable number of alternatives to be evaluated can be between 5-10. If the number of designs to be evaluated is more than 10, other methods can be used to reduce them to a smaller number which is manageable by the AHP method. The use of additional methods can also be useful to help making the final decision in instances in which several design alternatives rank closely in AHP results. Finally, this paper intends to present an analytic and systematic tool for use in the industrial design process for making more accurate design decisions. The presented method should not be used to make the decision singlehandedly by itself. Using various methods that verify each other to make the final decision in choosing the most reasonable design alternative among the candidates should always be the ultimate responsibility of the designer.

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