Garment Design Assessment Using AHP and Choquet Integral

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Abstract. Garment industry is one of the industries that need fast innovation. Fast decision making is needed to identify the best design to keep up with the latest consumer trends. Several studies focusing on the assessment of garment designs using multi-criteria decision analysis approaches have been conducted, but they usually assumed that the garment assessment criteria are independent to each other. In this study, we proposed a hybrid approach that combine Analytical Hierarchy Process and Choquet integral to model dependency between criteria. Results show that the proposed approach not only provides a systemically way to help decision makers select the best alternative of garment design, but also allows the analysts to elicit the magnitude of dependency among decision makers' preference judgments. In conclusion, this study contributes to the field of clothing science by building a framework for garment evaluation and developing a hybrid approach that accommodates uncertain interaction between human judgments.

Keywords: Garment design, Decision analysis, Analytical Hierarchy Process, Choquet integral

1. INTRODUCTION

Numerous approaches were developed to evaluate the best garment design schemes in order to produce garment with deseriable features to meet the need of customers. One of the most critical decisions which should be considered in the early stage of garment evaluation approach is the selection of criteria. Many studies have been conducted before to select criteria to form an appropriate evaluation framework (see, for example, Goncu and Bayazit, 2007; Harr, 2004; Jones, 2002; Kidd and Workman, 1999; Lin, 2014).

For example, Lin (2014) proposed eight evaluation criteria in their decision framework (e.g., theme story, best-seller modification, new idea, fashion forecast, fashion event, opponent ability, brand image, and product position). Three criteria—fabric, color, and style—for analyzing a fashion design was implemented in the study of Goncu and Bayazit (2007). Harr (2004) suggested a different set of criteria including time management, concept, figure development, apparel development and interaction on figure, rendering, figure relationship, composition, quality, style, and presentation. Kidd and Workman (1999) developed a model of evaluation that comprised of design creativity, aesthetic appeal, functionality, appropriateness and originality. Most of the criteria discussed thus far are internal factors of designing a fashion. Jones (2002), on the other hand, concentrated on external factors such as marketing when evaluating a garment design. His criteria included consumer age, gender, demography, lifestyle, physical characteristics, psychographics, social class, value and attitudes, economic circumstances, and religion.

Other than identifying the key criteria for the evaluation framework, numerous researches also developed or adopted different methods to select the best garment design alternative. For example, Goncu and Bayazit (2007) employed the Analytical Hierarchy Process (AHP) to select garment trend for a specific target group. Lin and Twu (2012) presented eleven valuable criteria for garment trend selection. They implemented fuzzy AHP to calculate the weights of the criteria. Lin (2014) compared AHP with the consistent fuzzy preference relation (CFPR). He concluded that AHP was less efficient than CFPR. In his case, AHP needed more data on interval scale for garment design selection among four schemes and eight criteria than CFPR method. Fuzzy Delphi Method (FDM) and Fuzzy AHP were performed by Lin (2013) to determine criteria weights. In the study of Lin (2013), garment design experts first evaluated the criteria using FDM, and then Fuzzy AHP was used to calculate the criteria weights at the second step. Fuzzy AHP and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) were employed by Lin and Twu (2012) to appraise the eight criteria weights of four garment designs. The criteria weights were then used by the synthetic evaluation method to derive the index value of each scheme. Lin and Twu also implemented the TOPSIS to analyze the scheme. The results indicated that TOPSIS perform better than synthetic evaluation method.

The aim of the paper is to develop decision analysis system that could select the best garment design efficiently. This proposed approach combines AHP and Choquet Integral. This study utilizes AHP to determine the weight of garment design criteria at the first step, and employs Choquet integral to aggregate the judgements and decide the best garment design at the second step.

2. THE HYBRID METHOD

2.1 Analytical Hierarchy Process

Saaty proposed the AHP to model subjective decision-making process based on a hierarchical system with multiple attributes. In this method, all decision problems are considered as a hierarchical structure. The goal of the decision problem is defined in the first level. This goal then is decomposed of several criteria in the second level and the lower levels can follow this principal to divide into other sub-criteria (Tzeng and Huang, 2011).

The main steps of the AHP can be summarized as follows (Tzeng and Huang, 2011; Wind and Saaty, 1980):
Step 1. Decomposing the problem into a hierarchy of interrelated elements;
Step 2. Comparing the comparative weight between the elements of the decision elements to form the reciprocal matrix;
Step 3. Synthesizing the individual subjective judgment and calculating the relative weight;
Step 4: Aggregating the relative weight of elements.

In addition, two indices are utilized to ensure the consistency of the subjective perception and the accuracy of the comparative weights that are the consistency index (CI) and the consistency ratio (CR) as follows.

$$CI = (\lambda_{max} - n)/(n-1), \quad (1)$$

where λ_{max} is the largest eigenvalue, and denotes the numbers of the elements.

$$CR = CI/RI \quad (2)$$

where RI refers to a random consistency index (Wind & Saaty, 1980).

2.2 Choquet Integral

Choquet integral is a fuzzy integral based on any fuzzy measure that provides alternative computational scheme for aggregating information. Choquet integral has advantages in measuring or evaluating the priority or the preference of various alternatives while taking the dependency among criteria (which may be elicit from the preferences judgments in a human mind). Through human evaluations, i.e. score system, in Choquet integral method, incommensurable elements are then able to be compared to one another in a rational and consistent way. Choquet integral satisfies a more realistic assumption that there are uncertain interactions between human judgments. Thus, a more accurate index of priority can be obtained in Choquet integral method by adding interaction terms over criteria.

Input vector comprises of information sources, and an integrating function called fuzzy integral that performs the weight function. The λ fuzzy measures are used to present experts or the decision maker's judgments of interactions or interdependence between criteria.

The λ fuzzy measure is one of fuzzy measures which can be identified by interaction index λ (or ξ) and weights of individual evaluation items. In this research, we implemented Singleton Fuzzy Measure Ratio Standard as a method of Choquet integral to identify the interaction degree. This standard is to identify the fuzzy measure that can be expressed as follows (Takahagi, 2005).

$$\mu_\lambda(\{1\}):\mu_\lambda(\{2\}):\ldots:\mu_\lambda(\{n\}) = w_1 : w_2 : \ldots : w_n \quad (3)$$

Hence, this standard makes a point of each input's single influence on the output. Algorithm of singleton fuzzy measure ratio standard to identify the fuzzy measure is described as follows (Takahagi, 2005).

1. Normalize weight where max $w_i = 1$
2. $p := 0.5$
3. $\mu(\{i\}) := pw_i, \forall i$
4. Calculate $\mu(\{1,2,\ldots, j\}) := \mu(\{1,2,\ldots, j-1\}) + \mu(\{j\}) + \lambda\mu(\{1,2,\ldots, j-1\})\, \mu(\{j\})$ for $j= 2, \ldots, n$
5. if $\mu(\{1,2,\ldots, j\}) > 1$ for a j then decrease the p and go to 3.
6. if $\mu(\{1,2,\ldots, n\}) < 1$ then increase the p and go to 3.
7. if $\mu(\{1,2,\ldots, n\}) = 1$ then stop the algorithm.

3. RESULTS AND DISCUSSION

Seven criteria from four clusters were developed based on the previous research (Goncu and Bayazit, 2007; Harr, 2004; Jones, 2002; Kidd and Workman, 1999; Lin and Twu, 2012; Lin and Twu, 2012; Lin, 2014). The seven criteria are product position (cluster of marketing); theme story, and new idea (cluster of theme); garment forecast and user value (cluster of innovation); and comfort of the style, and mix and match (cluster of style). Ten experts, including garment designers and academics, verified the proposed criteria and cluster, appraised the pairwise comparison between the criteria, and evaluated the four alternatives of garment design schemes with respect to the seven criteria.

Through the four main steps of AHP, we get the information of the rank of importance of criteria i.e. comfort of the style (0.2335), user value (0.1863), mix and match (0.1465), new idea (0.1317), product position (0.1182), garment forecast (0.1035), and theme story (0.0802) with the consistency index is 0.09. It means that garment design company should consider the pleasurable feeling of the customers when wearing the garment at the first consideration.

In order to obtain more accurate index of priority by using Choquet integral method, we need to add interaction terms over criteria. According to Elahi and Babamir (2015), we determined the interaction index $\xi = 0.31$ and used singleton fuzzy measure ratio standard as the method to evaluate the fuzzy measure as Table 1. Note that not all fuzzy measures are shown in Table 1.

Table 1. Fuzzy measure when the $\xi = 0.31$.

Sets	Fuzzy Measure	Sets	Fuzzy Measure
{}	0.0000	…….	…….
{E1}	0.0544	{E1,E4,E5,E6,E7}	0.6292
{E2}	0.0369	{E2,E4,E5,E6,E7}	0.5790
{E1,E2}	0.0992	{E1,E2,E4,E5,E6,E7}	0.7579
{E3}	0.0606	{E3,E4,E5,E6,E7}	0.6470
{E1,E3}	0.1280	{E1,E3,E4,E5,E6,E7}	0.8405
{E2,E3}	0.1063	{E2,E3,E4,E5,E6,E7}	0.7783
{E1,E2,E3}	0.1836	{E1,E2,E3,E4,E5,E6,E7}	1.0000

At the last step, Choquet integral was used for evaluation of the four garment design; Design 1, Design 2, Design 3, and Design 4. With respect to the λ fuzzy measure and assuming that X is a finite set, Choquet integral $f{:}X \rightarrow [0, \infty]$ could be defined as follows (Elahi and Babamir, 2015; Grabisch, 1995).

$$C_{\lambda}\,(f(x_1)), \ldots, f(x_n)) = \sum (f(x_{(i)}) - (f(x_{(i-1)}))\,\lambda(A_{(i)}) \\ f(x_0) = 0, f(x_1) \leq \ldots \leq f(x_{(n)}), A_{(i)} = \{x_{(i)}, \ldots, x_{(n)}\} \quad (4)$$

The value of Choquet integral for each garment design is resulted as follows: Design 1 = 7.811 ; Design 2 = 7.752 ; Design 3 = 7.847 ; Design 4 = 7.784 . Hence the best design is Design 3. Based on the sensitivity analysis, Design 3 is the best alternative in some situation (different value of ξ). That is from $\xi = 0$ until $\xi = 0.7$. For the ξ bigger than 0.7, Design 2 is the best garment design while Design 3 is the third.

The highest degree of dependence among criteria (λ= 0.8405) is the interrelation among all criteria except criteria of theme story. Therefore the decision makers of the garment design company could consider those criteria based on the importance degree of each criterion and the interrelation degree of among criteria.

Compare to a traditional multi-criteria evaluation method for human subjective assessment, the Choquet integral is more suitable when the criteria are not mutually independent since it is not necessary to assume additivity and independence. Thus, it is appropriate with the real world in which most criteria are dependent or interactive characteristics. In other words, it implies that the Choquet integral combined with AHP is more appropriate than a traditional multi-criteria evaluation method.

4. CONCLUSION

This hybrid method is capable to provide the information of the importance degree of each alternative. This hybrid method is also more efficient than the traditional pairwise comparison approaches.

This research makes two key contributions as following: a) identify the vital criteria in garment design evaluation based on the expert review; b) offer the best solution that considers interdependent criteria in which appropriate to the real world situation.

REFERENCES

Elahi, A., & Babamir, S. M. (2015). Evaluating software architectural styles based on quality features through hierarchical analysis and Fuzzy Integral (FAHP). *2015 7th Conference on Information and Knowledge Technology (IKT)*, 1–6. doi:10.1109/IKT.2015.7288800

Goncu, G., & Bayazit, N. (2007). An application of AHP in the selection of fashion trends for specific target groups. *Design Principles & Practices*, *1*(3), 573–584.

Grabisch, M. (1995). Fuzzy integral in multicriteria decision making. *Fuzzy Sets and Systems*, *69*(3), 279–298. doi:10.1016/0165-0114(94)00174-6

Harr, S. J. (2004). Development of assessment rubrics for fashion design projects. In *61st Annual Meeting of the International Textile and Apparel Association*.

Jones, S. J. (2002). *Fashion Design*. New York: Watson-Guptill.

Kidd, L. K., & Workman, J. E. (1999). Assessment of Creativity in Apparel Design. *Clothing and Textiles Research Journal*, *17*(1), 58–64. doi:10.1177/0887302X9901700106

Lin, C. (2013). Application of fuzzy Delphi method (FDM) and fuzzy analytic hierarchy process (FAHP) to criteria weights for fashion design scheme evaluation. *International Journal of Clothing Science and Technology*, *25*(3), 171–183. doi:10.1108/09556221311300192

Lin, C. (2014). Application of CFPR to fashion design scheme selection. *International Journal of Clothing Science and Technology*, *26*(4), 316–329. doi:10.1108/IJCST-07-2013-0080

Lin, C., & Twu, C. (2012). Combination of a fuzzy analytic hierarchy process (FAHP) with the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) for fashion design scheme evaluation. *Textile Research Journal*, *82*(10), 1065–1074. doi:10.1177/0040517511429603

Lin, C., & Twu, C. H. (2012). Fuzzy MCDM for evaluating fashion trend alternatives. *International Journal of Clothing Science and Technology*, *24*(2/3), 141–153. doi:10.1108/09556221211205586

Takahagi, E. (2005). Fuzzy Measure Identification Methods using. *English*, *1*(August), 1–5.

Tzeng, G.-H., & Huang, J.-J. (2011). *Multiple attribute decision making: methods and applications*. Boca Raton, FL: CRC press.

Wind, Y., & Saaty, T. L. (1980). Marketing applications of the analytic hierarchy process. *Management Science*, *26*(7), 641–658.