A Fuzzy Mathematical Approach for Measuring Multi-facet Consumer Involvement in the Product Category

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In this paper, we propose a new version of the study of consumer involvement. Mathematical definition is created to replace the traditional semantic definitions for the consumer involvement. A single synthetic index ranged in [0,1] can be manipulated to measure the degree of multi-facet consumer involvement, which is obvious and objective.

Keywords: consumer involvement, multi-facets, fuzzy mathematics

An Introductory Note

This paper has two aims. Our first aim is to redefine the definition for consumer involvement mathematically by using the fuzzy set theory. Our second aim is to manipulate a single synthetic index so that it will be ranged in between the interval [0, 1] to measure the degree of multi-facet consumer involvement. We now discuss our two aims as separate topics.

Why should consumer involvement be redefined?

Since the publication of Krugman's seminal work (1965), the concept of involvement has been applied in explaining how consumers react to advertisements. Involvement has been variously conceptualised as personal relevance (Engel & Blackwell 1982; Zaichkowsky 1985; Greenwald & Leavitt 1984), amount of arousal, interest, or drive evoked by a particular stimulus (Mittal 1983), a person's activation level (Cohen, 1982), goal-directed arousal capacity (Park & Mittal 1985), and attention to something because it is somehow relevant or important (Ratchford 1987).

Day, Stafford and Camacho (1995) propose that involvement consists of two types: the enduring type and the situational type. In the enduring type, Laurent and Kapferer (1985) claim that involvement has five different facets. They are product interest (the importance of personal meaning in purchasing a product), hedonic value (emotional or sensory pleasure), sign value (the degree to which a product can express one's personality), risk importance (the importance of negative consequences in case of poor choice), and risk probability (the probability of making a wrong choice). These multiple indicators must be measured simultaneously in order to specify the full nature of the relationship between a consumer and a product category. In the situational type, Ratchford (1987) suggests that purchase decision time (the thought that requires for making a purchase decision) should also be taken into consideration as one of the indicators in the consumer involvement. Rothschild (1984) concludes that (1) no single indicator of involvement could satisfactorily describe, explain, or predict involvement; (2) there is no commonly accepted definition, but viable theories abound; and (3) no single direction in which involvement research is going.

Since Rothschild's claim is still valid today, what we are trying to do is to contribute some new ideas to the conceptualisation and measurement of consumer involvement. The first aim of this paper is to give a more scientific and generalized mathematical definition of consumer involvement by using the fuzzy set theory.

Business researchers use the statistical terms like convergent, discriminant, and criterion related validity to assess a consumer involvement measuring scale. The indicators that determine the degree of involvement of a consumer to a product are exactly the so-called facets in the paper written by Laurent and Kapferer (1985). One study (Celuch & Evans 1989) has examined the convergent and discriminant validities of the Zaichkowsky (1985) and Laurent and Kapferer (1985) scales which possess quite different point of view toward the definition of the consumer involvement. The study concludes that for both a high-involvement (calculator) product and a low-involvement (facial tissue) product, the 2 scales demonstrate acceptable convergent validity, and they both show discriminant validity with measures of global innovativeness and confidence in information processing.

Celuch and Evans (1989) clearly declares that either the definition given by Zaichkowsky (1985) or the one by Laurent and Kapferer (1985) results in the same validities. Our position is to adopt the concept of consumer involvement given by Laurent and Kapferer (1985) simply because it is not only more up-to-date to go with the modern approach in decision theory but also it is more analytical than the others.

In fuzzy set theory, an abstract concept such as a sunny day can be considered as a fuzzy set and defined mathematically by assigning to each individual in the universe of discourse a value representing its grade of membership in the fuzzy set. This grade corresponds to the degree to which that individual is similar or compatible with the concept represented by the fuzzy set. Thus, individuals may belong in the fuzzy set to a greater or lesser degree as indicated by a larger or smaller membership grade. These membership grades are very often represented by real-number values ranging in the closed interval between 0 and 1. Thus, a fuzzy set representing our concept of sunniness might assign a degree of membership 1 to a cloud cover of 0 percent, 0.8 to a cloud cover of 20 percent, 0.4 to a cloud cover of 30 percent and 0 to a cloud cover of 75 percent. These grades signify the degree to which each percentage of cloud cover approximates our subjective concept of sunniness, and the set itself models the semantic flexibility inherent in such a common linguistic term.

Vagueness in describing "*involvement*" is intrinsic, not a lack of knowledge about the available rating. That is why a great variety of definitions of involvement exist and none of them can describe the fuzzy concept "involvement" completely. So long as the semantic assessment facets in the product category can be quantified and explicitly defined by corresponding membership functions, the initial steps of the mathematical definition for consumer involvement are achieved.

A new measure of consumer involvement

Previous researches have provided us with various methods and scales for measuring the level of consumer involvement (e.g. Zachkowsky's PII 1985/1994; Laurent & Kapferer's CIP 1985; Mittal 1988/1989; Slama & Tashchian 1985; Feick & Price 1987). They have, however, different number of items, different types of questionnaire (e.g., the 5-point and the 7-point

Likert-type response formats), and different number of subjects, which can result in a completely different meaning of the score points measured by the questionnaire. By PII or CIP, if a researcher only gets the information about the total score points of a specific product, he can say nothing about the degree of involvement. In other words, he does not obtain the consumer involvement unless he has all information about the questionnaire applied in detail. But many marketers are merely interested in distinguishing between the high and low involvement in a specific object.

The second aim of this paper is to combine different facets into a single dichotomous index to represent the degree of consumer involvement in the product category by using an aggregate operator in the fuzzy set theory.

A mathematical definition for consumer involvement and the degree of consumer involvement is created in this paper to replace the traditional semantic definitions so that a single synthetic index ranged in [0,1] can be manipulated to measure the degree of multi-facet consumer involvement, which is objective and obvious. Recognizing the difficulty of accurate quantification of the semantic assessment facets like product interest, hedonic value and others, we utilize the fuzzy mathematical method (Klir & Yuan 1995; Zimmerman 1991) to quantify the assessment facets by membership functions so that the results obtained are more accurate than the traditional statistical methods (e.g. Zachkowsky's PII 1985/1994; Laurent & Kapferer's CIP 1985) and more suitable for the semantically modified assessment facets.

A numerical example of fuzzy method is presented at the end of this paper to show the difference between the fuzzy mathematical method and the crisp method (Hsu, 1996; Hsu, et al. 1996). Since, so far, no other researches have proposed any adoptable new indicators, the assessment facets of consumer involvement we apply in the example are composed of those indicated in Laurent and Kapferer (1985) and Ratchford (1987). They are product interest (*I*), hedonic value (*H*), sign value (*S*), and risk probability (*P*) risk importance (*R*), and purchase decision time (*T*). The reason to take Ratchford's (1987) "decision time" as one of the facets to evaluate consumer involvement is that involvement with purchase leads one to search for more information and spend more time to make the right selection. In addition, decision time is clearly an independent facet of the other five facets and is important in the process of decision making. The questionnaire we use in the example is 5 - point Likert type response format. Each facet consists of one or three items.

A definition and a synthetic index of consumer involvement

For generalization, we use the index set J and the number n to indicate the total number of facets in the definition of consumer involvement and synthetic index of the degree of consumer involvement respectively to provide more research room for the future discovery of new indicators of consumer involvement.

Definition: Consumer involvement

Consumer involvement can be construed as a fuzzy set. It is a family of pairs $(A_i, m_{A_i}(y))$, where for each i in the index set ϑ, A_i is a fuzzy set of assessment facet and m_{A_i} is a membership function from A_i to the unit interval [0,1] which describes the behavior of the fuzzy

set A_i, $m_{A_i}(y)$ is the membership function of the assessment facet that takes value on [0,1] for all y in A_i.

i.e.

Consumer Involvement = $\{(A_i, m_{A_i}(y)) \mid m_{A_i} : A_i \to [0,1] \ni m_{A_i}(y) \in [0,1] \forall y \in A_i$

and $i \in \vartheta$, A_i, is a fuzzy set of assessment facet$\}$

Synthetic index of consumer involvement

The synthetic index of the degree of multi-facet consumer involvement of a product is an improvement of the aggregation of the degrees of measuring facets by g -operator. The g -operator was originally suggested and empirically tested by Zimmermann and Zysno (1980) to aggregate the membership degrees.

$$m_g(y) = \left\{\prod_{i=1}^{n} m_{A_i}(y)\right\}^{1-g} \left\{1-\prod_{i=1}^{n}(1-m_{A_i}(y))\right\}^{g}, 0 \le g \le 1 \qquad (1)$$

For improvement, we extend the formulas (1) to (2) to aggregate the membership degree of n fuzzy facets

$$m_{\text{involvement}}(y) = \left\{\prod_{i=1}^{n}(m_{A_i}(y))^{l_{A_i}}\right\}^{1-g} \left\{1-\prod_{i=1}^{n}(1-m_{A_i}(y))^{l_{A_i}}\right\}^{g}, 0 \le \gamma \le 1 \qquad (2)$$

where

$m_{A_i}(y)$, i = 1,..., n represents the membership functions of the fuzzy sets A_i.

l_{A_i} = the weight of the fuzzy facet A_i given by respondents, and computed by Shin's (1993) method.

n = total number of the facets.

Takes g = 0.5 as conventional agreement.

$m_{\text{involvement}}(y)$= the synthetic index of the degree of multi-facet consumer involvement of a product. The closer the $m_{\text{involvement}}(y)$ to the value 1, the higher the consumer involvement is.

The improved formula (2) clearly satisfies the required axioms of aggregation operator for fuzzy sets (Dubois & Prade 1982).

The membership functions of fuzzy sets, product interest (*I*), hedonic value (*H*), sign value (*S*), and risk probability (*P*), have the same character. Thus we define these four fuzzy sets by one membership function of the following form:

$$m_{I,H,S,P}(y) = \begin{cases} 0 & y \le 2 \\ y - 2/13 & y > 2 \end{cases} \qquad (3)$$

where

y = the average score points of total subjects of a product obtained from the items related to the facets *I*, *H*, *S*, *P* in the questionnaire.

13 = 15-2.

15 = maximum point of the facets -- I, H, S, P -- obtained from 5-point Likert type response format. Each facet consists of three items.

2 = the starting of involvement of the membership function given by respondents. In the questionnaire, each facet consists of three items, the minimum points of The facets -- I, H, S, P -- obtained from 5-point Likert type response format are 3, the facets scored below 2 with more than one item not answered are meaningless.

$m_{I,H,S,P}(y)$ = the membership functions of the fuzzy sets, *I*, *H*, *S*, *P*.

The membership functions $m_{I,H,S,P}(y)$ are depicted in Fig. 1.

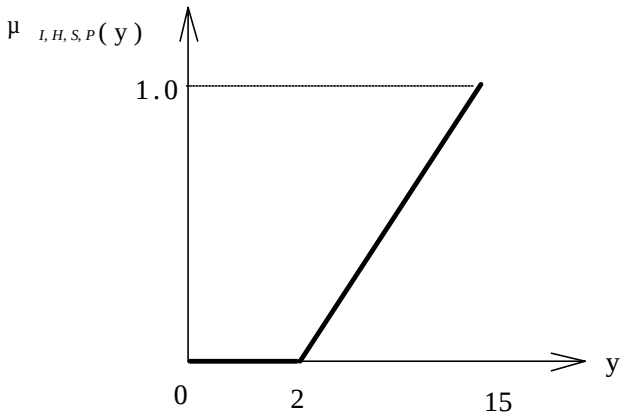

Fig.1. membership function for facets I, H, S, P

The membership function of the fuzzy set, risk importance (*R*), is defined as follows

$$m_R(y) = \begin{cases} 0 & y \le 0.0001 \\ y - 0.0001 \,/\, 11.9999 & 0.0001 < y < 12 \\ 1 & y \ge 12 \end{cases} \qquad (4)$$

where

y = the average value of risk importance of total subjects of a product from the questionnaire.

11.9999 = 12-0.0001.

0.0001 = the threshold value of the membership function given by respondents and computed by Shin's (1993) and Smithson's (1982) method.

12 = the starting of maximum involvement of risk importance given by respondents and computed by Shin's (1993) and Smithson's (1982) method.

$m_R(y)$ = the membership function of the fuzzy set R.

The membership function $m_R(y)$ is depicted in Fig 2.

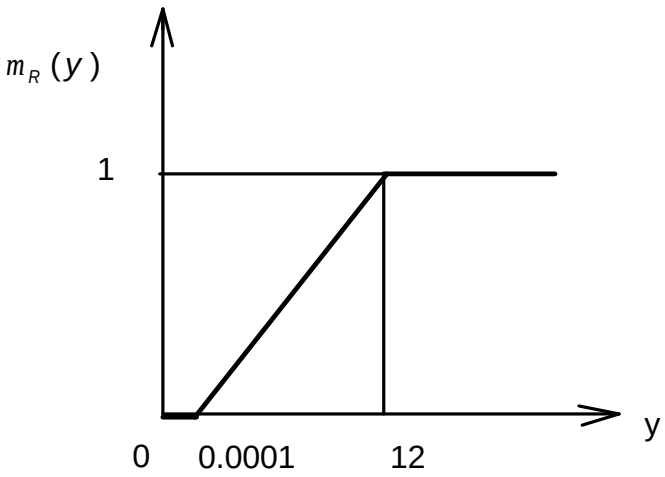

Fig.2.membership function for facet R

The membership function of the fuzzy set, purchase decision time (T), is defined as follows

$$m_T(y) = \begin{cases} 0 & y \le 0.001 \\ y - 0.001 \,/\, 0.989 & 0.001 < y < 0.99 \\ 1 & y \ge 0.99 \end{cases} \qquad (5)$$

where

y = the average value of purchase decision time of total subjects of a product from the questionnaire.

0.989 = 0.99-0.001.

0.001 = the threshold value of the membership function given by respondents and computed by Shin's (1993) and Smithson's (1982) method.

0.99 = the starting of maximum involvement of purchase decision time given by respondents and computed by Shin's (1993) and Smithson's (1982) method.

$m_T(y)$ = the membership function of the fuzzy set T.

The membership function $m_T(y)$ is depicted in Fig 3.

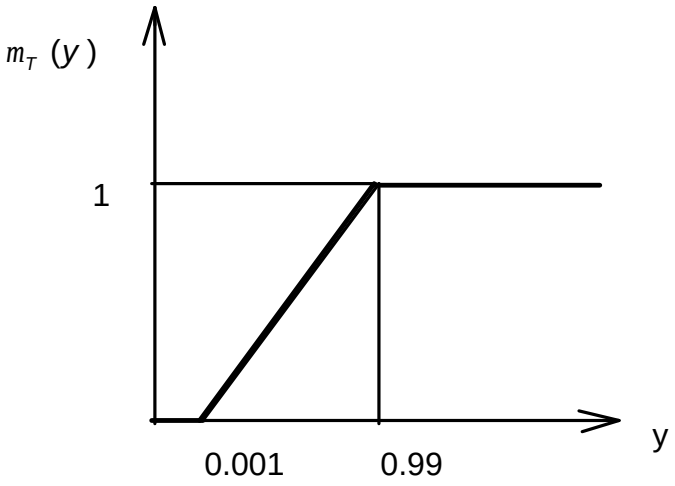

Fig.3. membership function for facet T

Various rules (Dempster 1967; Oblow 1987a,b) have been established to combine respondent's opinions. In this paper, we adopt the newly published method given by Shin (1993). Shin's method is intuitive and much easier to perform than the other methods. Shin's method of calculating weight l_{A_i} for fuzzy facet A_i can be described as follows :

(1). Suppose there are p experts taking part in the evaluation of the weight l_{A_i} of A_i.

(2). Each expert is to mark three to five points on interval [0,1] showing the importance of A_i to the subject related to evaluation.

(3). Each point is to be marked on the interval [0,1] in separate sheet and without reference to the previous marked points.

(4). Let a_{ki} be the minimum value and b_{ki} be the maximum value of the three or five points marked by expert k and,

$$\overline{W_i} = \frac{1}{P}\sum_{k=1}^{P}\frac{a_{ki}+b_{ki}}{2} \qquad , 1\le k\le p, \qquad (6)$$

$$M_i = \frac{1}{P}\sum_{k=1}^{P}\frac{b_{ki}-a_{ki}}{2} \qquad (7)$$

$$W_i = \overline{W_i}(1-M_i) \Big/ \sum_{i=1}^{n}(1-M_i) \qquad (8)$$

where

n = total number of the facets.

M_i : blind degree, the smaller the value ,the greater the reliability is.

By formulas (6), (7), and (8) we get the weight l_{A_i} of A_i in formula (2),

$$l_{A_i} = W_i \Big/ \sum_{i=1}^{n} W_i \qquad (9)$$

Numerical Example

We now present an example application of our appraoch measuring the multi-facet consumer involvement of students to four products. The products used were sport shoes, personal computer, ball-point pen, and watch are chosen for the reason that most of our students are familiar with them. 72 undergraduate students who answered the questionnaire consisting of 16-items with six measuring facets (these items are presented in the Appendix). A multi-item scale with 5-point Likert-type response format (fully disagree to fully agree) was applied to measure the facets. Cronbach's alpha reliability measure was used to evaluate internal consistency and showed a highly satisfactory result of 0.951. The assessment facets of consumer involvement applied were composed of those indicated in Laurent and Kapferer (1985) and Ratchford (1987). They are product interest (*I*), hedonic value (*H*), sign value (*S*), and risk probability (*P*) risk importance (*R*), and purchase decision time (*T*). Therefore, the synthetic index of consumer involvement can be calculated as formula (10).

$$m_{\text{involvement}}(y) = \left\{\prod_{i=1}^{6}(m_{A_i}(y))^{l_{A_i}}\right\}^{1-g}\left\{1-\prod_{i=1}^{6}(1-m_{A_i}(y))^{l_{A_i}}\right\}^{g} \qquad (10)$$

After comparing the results obtained from the fuzzy mathematical method shown in Table 2, and the crisp method shown in Table 1, we find the two results are quite compatible.

Table 1. The averaging value of the six facets

	Risk Importance	*Decision Time*	*Risk Probability*	*Product Interest*	*Hedonic Value*	*Sign Value*
Shoes	0.0048	0.0068	0.3843	0.5683	0.4889	0.5637
Computer	0.3529	0.0701	0.6412	0.7361	0.5269	0.4444
Ball-Pen	0.0010	0.0004	0.2072	0.4294	0.2843	0.4132
Watch	0.0138	0.0093	0.4630	0.7384	0.5731	0.7049

Table 2. The synthetic index of consumer involvement of the six fuzzy facets

	Risk Importance	*Decision Time*	*Risk Probability*	*Product Interest*	*Hedonic Value*	*Sign Value*
Shoes	0.0100	0.2049	0.4316	0.6015	0.6410	0.5972
Computer	0.7353	1.0000	0.6688	0.7521	0.6848	0.4872
Ball-Pen	0.0021	0.0121	0.2682	0.4733	0.4049	0.4583
Watch	0.0288	0.2815	0.5043	0.7585	0.7382	0.7276

Regardless of what methods we have applied, the orders showing the consumer involvement of the products are the same. On the third row of Table 2, the ball-pen has the smallest membership degree in six facets. It indicates that students are less concerned with the ball-pen. To a college student, buying a personal computer is a necessary and considerable expense, therefore he must make a careful choice in purchasing one. This is the reason why the membership degrees of risk importance (0.7353), decision time (1) and risk probability (0.6688) shown on the second row of Table 2 are obviously higher compared to the other products. Especially, the degree of membership in decision time equals to 1. It indicates that the student is deeply involved in purchasing a personal computer. The product interest (0.7585), hedonic value (0.7382), and sign value (0.7276) are high on the fourth row of Table 2. The results suggest that watches are a product imbued with symbolic value and are lifestyle purchases for students. The crisp result shown on the Table 1 gives the same information but with less distinction which indicates that the fuzzy mathematical method is more suitable for measuring the consumer involvement.

According to Shin (1993), we aggregate opinions from all respondents to get weights l_R =0.168, l_T =0.193, l_P =0.121, l_I =0.22, l_H =0.182, and l_S =0.116 for the fuzzy sets, risk importance, decision time, risk probability, product interest, hedonic value, and sign value respectively. And then we use equation (10) to calculate the membership degree of involvement for the fuzzy set – involvement and show the results in Table 3. In Table 3, personal computer attains the highest involvement of 0.8541 and then the index of watch, shoes and ball-pen are ranked in sequence as 0.4436, 0.3298, 0.1575. Therefore by looking at Table 3, we can immediately tell that the college student's consumer involvement in a personal computer is high and his involvement in a ball-pen is low. In this way the synthetic index on Table 3 will give us an obvious and objective information about the consumer's involvement.

Table 3. The synthetic index of the degree of consumer involvement

	Shoe	***Computer***	***Ball-Pen***	***Watch***
£g Involvement	0.3298	0.8541	0.1575	0.4436

The performance of the membership degree of involvement is compared to the other available scales in terms of ability to predict some of the consequences of involvement used in previous studies: greater information search, perception of differences among brands, and preference for a particular brand (Zaichkowsky 1985, McQuarrie and Munson 1987). Three items are used to capture the first proposition: "I would be interested in reading about this product," "I would pay attention to an advertisement for this product," and "I would compare product characteristics among brands for this product." The last two consequences are assessed using one item for each: "I think there are great differences among brands of this product" and "I have a most preferred brand of this product" respectively. All five statements are rated on a five-point scale from strongly disagree (1) to strongly agree (5). The three statements for greater information search are highly inter-correlated (alpha = 0.83) and are therefore combined into a single scale. The results are summarized in Table 4. The predictive ability (adjusted R-squared) of the fuzzy mathematical method is seen to match the best of the earlier scales.

Table 4. Regression analysis: Various scales regressed on consequences of involvement

	Adjusted R-squared		
Consequence	**Laurent & Kapferer's scale (1985)**	**Zaichkowsky's scale (1985)**	**The synthetic index**
Information search	0.41	0.38	0.44
Perception of brand differences	0.28	0.19	0.31
Preference for a brand	0.25	0.21	0.27

Conclusion

The benefits of using fuzzy mathematics are :
(a) Membership function is deliberately designed in fuzzy theory to treat the vagueness caused by natural language. Therefore in using membership functions to assess the semantically defined measuring facets are more reliable and accurate than using the traditional statistical methods -- score points or scatter plot.

(b) Membership function standardizes the semantic meaning of assessment facets so that we can compare the degree of consumer involvement of a product regardless of the differences of timing and situation.

(c) Membership functions applied in this paper are continuous functions which are more accurate in measuring the assessment facets than the traditional discrete methods.

(d) The fuzzy mathematical method presented in this paper is easier to perform than the traditional method, once the membership functions of assessment facets are defined.

(e) The synthetic index of the degree of consumer involvement of a product obtained from formula (2) is automatically in the closed interval [0,1] which is obviously acceptable and easier to distinguish than those scales that have been used in measuring consumer involvement.

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Appendix

English Translations of the items of consumer involvement profile

Product interest
I attach great importance to _____. (2)
I'm really very interested in _____. (7)
*For me _____ does not matter. (12)
Hedonic value
It would give me pleasure to purchase _____ for myself. (3)
Whenever I buy _____, it's like giving myself a present. (8)
Having _____ is a pleasure for me. (13)
Sign value
You can tell a lot about a person from the _____ he or she picks out. (4)
The _____ you buy tell something about you. (9)
The _____ you buy shows the sort of man or woman you are. (14)
Risk probability
When I purchase _____, I'm never certain I made the right choice. (1)
When I'm in front of the _____ section, I always feel rather unsure about what to pick. (6)
Choosing _____ is rather complicated. (11)
Risk importance
*When I choose a _____, it is not a big deal if I make a mistake. (5)
It certainly is annoying to purchase _____ that doesn't meet my needs. (10)
I would be really upset if, after I bought some _____ I found I had made a poor choice. (15)
Decision time
When I choose a _____, the decision requires a lot of thought. (16)

Note. The numbers in parentheses indicate the order in which items are presented in our study. The star sign (*) indicates an item which is negatively worded and, hence needs to be reverse scored. All items are measured with 5-point Likert scales (from fully disagree to fully agree). The spaces in the items are corresponding to the products that are measured in the study.