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Evaluation of B2C website based on the usability factors by using fuzzy AHP & hierarchical fuzzy TOPSIS

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Abstract. In today's technology, electronic trading transaction via internet has been utilized properly with rapid growth. This paper intends to evaluate related to B2C e-commerce website in order to find out the one which meets the usability factors better than another. The influential factors to B2C e-commerce website are determined for two big retailer websites. The factors are investigated based on the consideration of several studies and conformed to the website characteristics. The evaluation is conducted by using different methods namely fuzzy AHP and hierarchical fuzzy TOPSIS so that the final evaluation can be compared. Fuzzy triangular number is adopted to deal with imprecise judgment under fuzzy environment.

1. Introduction

The global trading compels industry in some sectors such which engaged in electronic product, part/component, textile, etc. to enhance marketing strategy particularly for transaction of customer's purchase mode. E-commerce such application on B2C website plays a key role in the success of expanding the promotion and sale in the global trading. B2C e-commerce aims to get a special offer for a specific product by increasing the demand through integrating the potential customer whose interest. For world-wide trading company, the transaction method is the foremost considered to confronting the different local time which may vary. So it will be a flexible time for customers who are willing to purchase in their current time. Website design is needed to enable online purchasing. It is not easy to create a website convincing the intention of customers because internet purchase transaction needs an authenticity of the official website which impresses to the customers that it can certify the privacy.

Trust assurance can be figured out such one of them is trust-assuring argument. Trust assurance might be enforced in various manners by impressing direct or indirect hint, such, trust-assuring argument is the way to reveal the assurance clearly and directly to the customer. As mentioned before, trust factor is not a sole key of the success of e-commerce instead another factors are also important to be focused on the e-commerce particularly for B2C website design. Ling and Salvendy (2013) investigate 19 factors for usability consideration for B2C website design based on the past literature. The important web design features in B2C website design have been determined through past research. It examined the influence between web design and success and simulated by the empirical study between significance of usability to B2C web design success.

Website design features may vary based on the customer perception due to different customer character and desire. Customer character and desire differ from one customer to another customer can

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be affected by gender, age, occupation, ethnic, geography, and etc. Such a review from Liao et al. (2008), it compared customer behavior regarding ethnic character between American and Chinese by looking at cognitive ability, culture and cognitive models, infrastructural and economic development rapport of e-commerce consumer behavior. In this study, first we would like to delve into the criteria in terms of usability factors influencing the B2C website design and then we would like to evaluate B2C website of amazon.com and hepsiburada.com based on those factors.

2. Usability Heuristics and Guidelines

There are so many studies proposed to generalize usability of B2C website design. Such a study which is proposed by Ling and Salvendy (2013), it delves into several past studies and literatures to conclude 19 factors of usability measurement for B2C web design. They attempt to construct the priority of 19 usability factors. In their study, they conduct survey among 287 respondents to derive the priority based on the mean of importance rating. The priority can be summarized in table 1. In addition, they tempted to sort 19 factors according to relevant category and determine the category associating the importance by using post-hoc Tukey's test.

Table 1. Importance rating of usability factors

No	Usability factors	Mean	Standard Deviation
1	Security & privacy	6.7	0.78
2	Confirmation	6.3	1.00
3	Feedback	6.2	0.79
4	Easy-to-follow shop and checkout links	6.2	0.71
5	Content organization	6.1	0.87
6	Loading time	6.0	1.01
7	Constructive error message	5.9	0.86
8	Clear link description	5.9	1.02
9	Instructions & help	5.8	0.97
10	Robust search	5.7	1.22
11	Easy Navigation	5.7	0.96
12	Clear layout	5.6	0.95
13	Not using jargon	5.5	1.28
14	Consistent term & design	5.5	1.18
15	Uncluttered page	5.3	1.17
16	Contextual navigation information	5.1	1.21
17	Interesting to explore	5.1	1.24
18	Visually attractive	5.0	1.25
19	Personalize	4.1	1.53

El Sofany et al., (2012) in the study entitled Impact of Trust Factors in Improvement and Development of E-commerce in Saudi Arabia, introduced trust factors which are influential to e-commerce transaction. They divided trust factors into 4 categories which can be summarized as follows:

1) Human interaction factors: easiness, attractiveness, obviousness, encouragement, availability, competitively, generation gap.
2) E-commerce factors: transaction processing, buying and selling facilities, rewards and loyalty, scalability, e-commerce infrastructure, financial services.
3) Marketing factors: targeting the right audience, providing service' centers, customizability
4) Knowledge factors: richness of the site, incorporating multi customer characters and their needs, knowledge publishing support.
5) Security factors:

a. Trust: consists of site legality, stability of company information, identification and certification of the products.
b. e-Payment support: consist of the method for online payment, (e.g. credit cards, charge cards, e-Cash, e-Wallet, and smart cards)
c. Safety: includes guidance (auto notification) to save user from unintentional error or mistake during transaction (e.g. lists and choices),
d. Privacy: includes assuring user's private data
e. Measures policies, laws and incentives: includes spreading trust publicly and confidence among e-commerce participants.

3. Method

Two kinds of methods are used to evaluate B2C website design in order to find out the best online store website between amazon.com and hepsiburada.com. Those methods deal with Fuzzy AHP and Hierarchical Fuzzy TOPSIS and the comparison is performed between both methods. The decision maker's opinion is under uncertainty in terms of perceiving the alternatives. Hence, fuzzy is applied on AHP and TOPSIS to incorporating the decision maker's opinion. The whole steps of fuzzy AHP and Hierarchical fuzzy TOPSIS for B2C website evaluation can be described as follows. The pre-evaluation of alternatives' website with respect to the sub criteria is conducted before constructing pair wise comparison matrix.

3.1 Fuzzy AHP

In this study, Fuzzy AHP steps can be briefly explained by using this following approach:
Step 1. Define the problem. Problem should be generalized clearly through defining what the main problem with respect to the objective, identifying criteria (i= 1,2,…,n), sub-criteria (l=1,2,…,L), and alternatives (m=1,2,…M) related to the problem. The decision maker should be determined whether it is single or multi decision maker. On the other hand, set the number of k-decision maker (k=1,2,.., K).
Step 2. Construct problem into hierarchy. This step defines the problem into level of hierarchical structure including in order respectively objective, criteria, sub-criteria, and alternatives.
Step 3. For each k-decision maker, construct pair wise comparison matrix for criteria, sub-criteria, and alternatives with respect to each sub-criterion by using Saaty's importance scale 1-9.
Step 4. Perform consistency test for each pair wise comparison matrix. Saaty (1980) suggested the maximal eigenvalue (λ_{max}) used to evaluate the effectiveness of measurements. Let C denotes an n-dimensional column vector indexing the sum of the weight values for the importance scale of criteria and it can be determined by using formula bellow:

$$C = [C_i]_{nx1} = A.W^T = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} [w_1, w_2, \ldots, w_n] = \begin{bmatrix} c_1 \\ c_2 \\ \ldots \\ c_3 \end{bmatrix}, i = 1,2,\ldots,n$$

Finally, λ_{max} can be determined by dropping those values into formula below:

$$\lambda_{max} = \frac{\sum_{i=1}^{n} \frac{c_i}{w_i}}{n}, i = 1,2,\ldots,n \quad (1)$$

To check the consistency between pairwise comparison matrices, the consistency index (CI) and consistency ratio (CR) are estimated using the equations:

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (2)$$

$$CR = \frac{CI}{RC} \leq 0.1 \quad (3)$$

where RI is a random index with a value obtained by different orders of pairwise comparison matrices. If the value of the CR is below 0.1, it indicates that the comparison judgment in performing the importance scale doesn't consist of randomness and finally the evaluation of the importance degrees is acceptable and reasonable.

Step 5. Transform pair wise comparison matrix into triangular fuzzy number.

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\tilde{a}_{n1} & 1/\tilde{a}_{n2} & \cdots & 1 \end{bmatrix}$$

where $\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij})$; $\forall i,j = 1,2,\ldots,n$

and $\tilde{a}_{ij} = \begin{cases} 1 \; if \; i = j \\ \tilde{9}, \tilde{8}, \tilde{7}, \tilde{6}, \tilde{5}, \tilde{4}, \tilde{3}, \tilde{2} \; or \; its \; reciprocal \; if \; i \neq j \end{cases}$

By applying Saaty's scales, the importance rating for pair wise comparison matrix shown in table 2 is converted into triangular fuzzy number developed by (Nuhodzic et al., 2010).

Table 2. Triangular fuzzy numbers based on the Saaty's scale

Fuzzy Number	Fuzzy Triangular Number (l.m.u)	Reciprocal Fuzzy Number	Reciprocal Fuzzy Triangular Number
$\tilde{1}$	(1,1, 1)	$1/\tilde{1}$	(1,1, 1)
$\tilde{2}$	(1, 2, 3)	$1/\tilde{2}$	(1/3, 1.2, 1)
$\tilde{3}$	(1, 3, 5)	$1/\tilde{3}$	(1/5, 1/3, 1)
$\tilde{4}$	(2, 4, 6)	$1/\tilde{4}$	(1/6, 1/4, 1/2)
$\tilde{5}$	(3, 5, 7)	$1/\tilde{5}$	(1/7, 1/5, 1/3)
$\tilde{6}$	(4, 6, 8)	$1/\tilde{6}$	(1/8, 1/6, 1/4)
$\tilde{7}$	(5, 7, 9)	$1/\tilde{7}$	(1/9, 1/7, 1/5)
$\tilde{8}$	(6, 8, 9)	$1/\tilde{8}$	(1/9, 1/8, 1/6)
$\tilde{9}$	(7, 9, 9)	$1/\tilde{9}$	(1/9, 1/9, 1/7)

Step 6. Aggregate the elements of synthetic fuzzy pairwise comparison matrix for criteria ($\tilde{a}_{ij}$), sub-criteria ($\tilde{a}_{lj}$), and alternatives ($\tilde{a}_{mj}$) judged by K-decision maker by using the geometric mean method suggested by Buckley (1985).

$\tilde{a}_{ij} = (\tilde{a}_{ijk} \otimes \ldots \otimes \tilde{a}_{ij2} \otimes \ldots \otimes \tilde{a}_{ijK})^{1/K}$

$\tilde{a}_{lj} = (\tilde{a}_{lk} \otimes \ldots \otimes \tilde{a}_{lj2} \otimes \ldots \otimes \tilde{a}_{ljK})^{1/K}$

$\tilde{a}_{mj} = (\tilde{a}_{mjk} \otimes \ldots \otimes \tilde{a}_{lj2} \otimes \ldots \otimes \tilde{a}_{mjK})^{1/K}$

Step 7. Calculate fuzzy weight for each criterion ($\tilde{w}_i$), sub-criterion ($\tilde{w}_l$), and alternative ($\tilde{w}_m$),

$\tilde{w}_i = \tilde{r}_i \otimes [\tilde{r}_1 \oplus \ldots \oplus \tilde{r}_i \oplus \ldots \oplus \tilde{r}_n]^{-1}$

$\tilde{w}_l = \tilde{r}_l \otimes [\tilde{r}_1 \oplus \ldots \oplus \tilde{r}_l \oplus \ldots \oplus \tilde{r}_L]^{-1}$

$\tilde{w}_m = \tilde{r}_m \otimes [\tilde{r}_1 \oplus \ldots \oplus \tilde{r}_m \oplus \ldots \oplus \tilde{r}_M]^{-1}$

where:

$\tilde{r}_i = (\tilde{a}_{i1} \otimes \ldots \otimes \tilde{a}_{ij} \otimes \ldots \otimes \tilde{a}_{in})^{1/n}$

$\tilde{r}_l = (\tilde{a}_{l1} \otimes \ldots \otimes \tilde{a}_{lj} \otimes \ldots \otimes \tilde{a}_{lL})^{1/L}$

$\tilde{r}_m = (\tilde{a}_{m1} \otimes \ldots \otimes \tilde{a}_{mj} \otimes \ldots \otimes \tilde{a}_{mM})^{1/M}$

Step 8. Compute global fuzzy weight of each sub-criterion ($\widetilde{W}_{il}$)

$\widetilde{W}_{il} = \tilde{w}_i \otimes \tilde{w}_l$; l= 1,2,…, L; i=1,2,…,n

Step 9. Calculate the overall weights of the alternatives incorporating global weight of sub-criteria ($\widetilde{W}_m$)

$$\sum_{i=1,2,\ldots n, l=1}^{L} \tilde{w}_{m,il} \otimes \widetilde{W}_{il}$$

$\widetilde{W}_m$= ; l= 1,2,…, L; i=1,2,…,n, m= 1,2,.., M (4)

Step 10. Obtain crisp weight of alternatives in order to determine the priority and rank alternatives based on the order of crisp value from high to small. COG (Center Of Gravity) is introduced to derive a crisp value in view of simplicity and efficiency (Pan, 2008). COG formula can be expressed as follows:

$Z^* = \frac{\int \mu(Z).Z\, dz}{\int \mu(Z) dz}$ (5)

where μ(Z) is the membership value; Z^* is the weighted average

3.2 Hierarchical Fuzzy TOPSIS

The steps of hierarchical fuzzy TOPSIS algorithm can be constructed in details as follows:

Step 1. Generating feasible alternatives, determining the evaluation criteria, and setting a group of decision makers. Assume that there are m alternative, n evaluation criterion, and k decision maker.

Step 2. Obtain global weight of sub criteria ($\widetilde{W}_l = \widetilde{w}_j$)(under the corresponding l^{th} criterion) by using fuzzy AHP.

Step 3. Choose the appropriate linguistic ratings for alternatives with respect to criteria ($\tilde{x}_{ij}$) as TFN.

Step 4. Obtain the aggregated fuzzy rating $\tilde{x}_{ij}$ of alternative A_i under sub-criterion C_j (under the corresponding l^{th} criterion) evaluated by k expert.

$\tilde{x}_{ij} = \frac{1}{k}[\, \tilde{x}_{ij}^1 + \tilde{x}_{ij}^2 + \ldots + \tilde{x}_{ij}^k \,]$; i = 1,2, …, m; j = 1,2, …, n (6)

Step 5. Construct the fuzzy decision matrix.

$$\widetilde{D} = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix} \end{array} ; \text{i = 1,2, …, m ; j = 1,2, …, n}$$

Step 6. Normalize fuzzy decision matrix.

The normalized fuzzy decision matrix denoted by $\tilde{R}$ is obtained by formula as follows:

$\widetilde{\mathbf{R}} = [\tilde{r}_{ij}]_{mxn}$, i = 1,2,…, m ; j = 1,2,…, n

The formula above can be calculated as details:

$\tilde{r}_{ij} = \left(\frac{l_{ij}}{U_j^*}, \frac{m_{ij}}{U_j^*}, \frac{u_{ij}}{U_j^*}\right)$, where $U_j^* = \max u_{ij}$ (7)

Step 7. Construct the weighted normalized fuzzy decision matrix.

In order to the different importance of each criterion, we can construct the weighted normalized fuzzy decision matrix as:

$\widetilde{\mathbf{V}} = [\tilde{v}_{ij}]_{mxn}$, i = 1,2,…, m ; j = 1,2,…, n (8)

Where $\tilde{v}_{ij} = \tilde{r}_{ij} \otimes \tilde{w}_j$, i = 1,2,…, m ; j = 1,2,…, n

and $\tilde{w}_j$ is the global weight of sub-criterion obtained from fuzzy AHP ($\tilde{w}_j = \widetilde{W}_l = \tilde{w}_i \otimes \tilde{w}_l$)

Step 8. Determine the fuzzy positive-ideal solution (FPIS) S^+ and fuzzy negative-ideal solution (FNIS) S^-. The calculation can be obtained as follows:

$S^+ = (\tilde{v}_1^+, \tilde{v}_2^+, \ldots, \tilde{v}_n^+)$

$S^- = (\tilde{v}_1^-, \tilde{v}_2^-, \ldots, \tilde{v}_n^-)$

where $\tilde{v}_j^+ = \max\{v_{ij3}\}$ and $\tilde{v}_j^- = \min\{v_{ij1}\}$ since $\tilde{v}_j$ is weighted normalized TFNs

i = 1,2,…, m ; j = 1,2,…, n

Step 9. Calculate the distance of each alternative from FPIS (d^+) and FNIS (d^-) .

According to the vertex method, the distance between two triangular fuzzy numbers A_1 (l_1, m_1, u_1) and A_2 (l_2, m_2, u_2) is calculated as:

$$d(A_1, A_2) = \sqrt{\frac{1}{3}\left[(l_1 - l_2)^2 + (m_1 - m_2)^2 + (u_1 - u_2)^2\right]}$$

$$d_i^+ = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^+\right) \quad , i = 1,2,\ldots, m$$

$$d_i^- = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^-\right) \quad , i = 1,2,\ldots, m$$

Step 10. Calculate the closeness coefficient (CC_i) and rank the order of alternatives according to the coefficient. After we obtain the distance d^+ and d^-, we calculate the closeness coefficient of each alternative using the formula bellow:

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-} \quad , i = 1,2,\ldots, m \qquad (9)$$

Based on the value of closeness coefficient of each alternative, we determine the ranking order of all alternatives from the highest closeness coefficient to the lowest. The alternative with the highest closeness coefficient is obviously considerable.

This study uses Fuzzy AHP and Fuzzy TOPSIS to evaluate the B2C website of two online stores: Amazon.com and Hebsiburada.com in term of the usability factors. The criteria and sub criteria are selected according to prior literature and then selected respondents are required to give response in pair wise comparison. The pair wise data matrix are then used as an input for fussy AHP and fuzzy TOPSIS to determine the best B2C website design based on the selected criteria.

4. Results and Discussions

We know that amazon.com is American well-known online store selling several kinds of products such as book, electronic, furniture, food, toys, jewelry and many others. Initially, amazon started as an online bookstore and soon diversified selling various products (http://en.wikipedia.org/wiki/Amazon.com). It currently expands the branch office by collaborating with other countries across North America, Latin America, Europe, Africa, and Asia. Whereas, hepsiburada.com is the biggest online store which domains in Turkey. It has similar marketing operation as amazon.com, but its scope is specifically in region of Turkey.

This study intends to evaluate B2C website between amazon.com and hepsiburada.com. As one of the largest online store, amazon establishes business process properly either in fulfillment, customer service center or warehousing and determines marketing strategy comprehensively indeed. But, an aspect such website usability may be comparable because this aspect sensitively links to the customer perspective judgment. The ones whose an appropriate website usability to emerge the purchase intention indicates that it represents the customer preference. By focusing on usability factors of website, the evaluation is conducted in this paper in order to find out which one has the best B2C website design.

Based on the literatures, finally 5 criteria which consist of Trustworthiness (C1), Shopping support (C2), Information access efficiency (C3), Ease of comprehension (C4), and Hedonic quality (C5), and 15 sub criteria which consist of Security & privacy (C11), Confirmation (C12), e-Payment support (C13), Trust (C14), Feedback (C21), Easy-to-follow shop and checkout links (C22), Constructive error message (C23), Instruction & help (C24), Easy transaction (C25), Loading time (C31), Robust search (C32), Content organization (C33), Clear link description (C34), Uncluttered page (C35), Clear layout (C41) are selected.

Two different methods are applied and compared. Based on the results, both methods give same priority regarding B2C website evaluation in which the 1st priority belong to hepsiburada.com and the second one goes to amazon.com. By using fuzzy AHP, hepsiburada.com is on the ranking 1 with overall weight 1.30659, whereas by using hierarchical fuzzy TOPSIS, Hepsiburada.com achieves overall weight 0.4277. For amazon.com, overall weight is 1.23731 obtained by using fuzzy AHP and 0.4074 obtained by using hierarchical fuzzy TOPSIS. Hepsiburada.com has a 5.60% of advantages over amazon.com based on the overall weight obtained from fuzzy AHP and has a 4.98% of advantages based on the overall weight obtained from hierarchical fuzzy TOPSIS.

The consistency of an expert is examined in the evaluation of websites when perceiving the opinion in two different judgment approaches. The expert must carry out the judgment in the same viewpoint either by pair wise or order preference in order to obtain a reliable decision making. Triangular fuzzy number utilization in both methods can incorporate the vagueness of decision maker's opinion.

Based on the usability factors of B2C website, hepsiburada.com overall meets and incorporates those factors better than amazon.com. Although Amazon is well-known as one of the biggest online retailers for global trade, but the superiority doesn't always link to it. Amazon may leads on the business process related to the warehousing & logistic, fulfillment and branch office world widely. One thing could be considered on hepsiburada.com when we think of usability factors of B2C website. Moreover, the criteria for B2C website determination also influence the perspective of evaluation toward the alternatives and priority of alternatives may change which rely on what criteria we think of. An example, Yu et al. (2011) evaluated B2C e-commerce website in e-alliance based on the website quality. They considered 5 factors influencing the website quality such as product, design, technology, service quality and logistic company. The study tends to engage both inner and outer aspect influencing the website quality as well as aspects influencing business process. In this study, by contrast, it focuses on the inner aspect as well as usability of the B2C website.

The result of fuzzy AHP related to the weight of sub-criteria shows that security& privacy is the most important one and the following orders are respectively trust, loading time, easy transaction, and e-payment support. In this session, there are some noticeable findings regarding the most critical criteria on B2C website. The first one, trust is the problematic and dilemmatic factor of e-commerce issue in any country, for the countries which distrust attach to the justification, it will be a serious obstacle to e-commerce growth (Anigan, 1999). Second, high speed internet access for non-business users receives less attention and it is unallocated in almost all developing countries (Hawk, 2004). Hence, B2C e-commerce website should be designed by considering the loading time of the web page in order to enable the operation in the low bandwidth environment used by potential customers (Domeisen, 2001). Third one, payment method (easy transaction) in terms of lack credit card penetration is one of two most widely problems besides delivery systems particularly in developing countries (Bingi et al., 2000, Cohen, 2001, Palumbo and Herbig, 1998).

5. Conclusion

By using either fuzzy AHP or hierarchical fuzzy TOPSIS, the decision making problem under fuzzy environment for evaluation of B2C website particularly can be solved and the final alternative for consideration can be observed. Fuzzy AHP applies fuzzy pairwise comparison matrix to deal with the judgment. Hierarchical fuzzy TOPSIS is an appropriate approach for evaluation problem dealing with hierarchical decision making. The imprecise judgment can be conveyed with fuzzy triangular number. The alternatives evaluation has been obtained and the alternative's priorities derived from both fuzzy AHP and hierarchical fuzzy TOPSIS offer same indication.

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