International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
Vol:4, No:10, 2010

Evaluation of Electronic Payment Systems Using Fuzzy Multi-Criteria Decision Making Approach

Gülfem Alptekin, S. Emre Alptekin

***Abstract*—**Global competitiveness has recently become the biggest concern of both manufacturing and service companies. Electronic commerce, as a key technology enables the firms to reach all the potential consumers from all over the world. In this study, we have presented commonly used electronic payment systems, and then we have shown the evaluation of these systems in respect to different criteria. The payment systems which are included in this research are the credit card, the virtual credit card, the electronic money, the mobile payment, the credit transfer and the debit instruments. We have realized a systematic comparison of these systems in respect to three main criteria: Technical, economical and social. We have conducted a fuzzy multi-criteria decision making procedure to deal with the multi-attribute nature of the problem. The subjectiveness and imprecision of the evaluation process are modeled using triangular fuzzy numbers.

***Keywords*—**Electronic payment systems, fuzzy multi-criteria decision making, analytical hierarchy process.

I. INTRODUCTION

THE severe competition has recently been one of the greatest concerns of the manufacturing and service companies. The competition takes place on the electronic business (e-business) environments also. The e-business allows companies to reach potential customers from all over the world. Hence, one of the greatest problems is the lack of a global finance system in an open electronic market, such as Internet. Payment systems play a major part in the conduct of a country's monetary policy, financial sector and economic development [1] [2]. They improve macroeconomic management, release funds from the clearing and settlement functions for more productive use, and reduce float levels, improving the control of monetary aggregates. Moreover, firms in different economic sectors use payment system to transfer funds and to provide competitive financial services [3]. Electronic commerce (e-commerce) has rapidly flourished because of the openness, speed, anonymity, digitization, and global accessibility characteristics of the Internet, which facilitated real-time business activities, including advertising, querying, sourcing, negotiation, auction, ordering, and paying for merchandise [4]. The main concern with electronic payment is the level of security in each step of the transaction; because money and merchandise are transferred while there is no direct contact between the two sides involved in the transaction. If there is even the slightest possibility that the e-payment system may not be secure, trust and confidence in this system term will begin to erode, destroying the infrastructure needed for electronic term commerce [4]. To deal with these problems, many organizations have developed their own financial systems on the Internet, which is generally called the electronic payment systems (e-payment).

In this paper, we do not focus on the security of the payment systems; instead we aim at evaluating them according to various criteria. The e-payment systems that we evaluate are the credit card, the virtual credit card, the electronic money (e-money), the mobile payment, the credit transfer and the debit instruments.

It is certain that the credit card is the most commonly used payment system for e-commerce today; in spite of its online usage vulnerability. The virtual credit card is a form of payment that provides security in situations where a credit card number and expiry date are the only verification needed, such as when making purchases over the Internet or by telephone. The card is called virtual, because it doesn't physically exist. A virtual credit card has a spending limit that you determine yourself. E-money (CyberCash) was an e-payment service for e-commerce. The company initially provided an electronic wallet software to customers and provided software to merchants to accept credit card payments. Later, they also offered “CyberCoin”, a micropayment system modeled after the NetBill research project at Carnegie Mellon University, which they later licensed. In mobile payment, instead of paying with cash, check or credit cards, a customer can use a mobile phone to pay for wide range of services and digital or hard goods such as music, videos, online game subscription, books, tickets, etc. A credit transfer corresponds to an order of the debtor addressed to his bank, to transfer on request, of the deposits of a certain value, towards the account of the recipient. The debit instrument corresponds to a card, code, or other device by

G. Alptekin (corresponding author), Department of Computer Engineering, Galatasaray University, Çırağan Cad. No: 36, Ortaköy, Istanbul, Turkey (e-mail: gisiklar@gsu.edu.tr).

S.E. Alptekin, Department of Industrial Engineering, Galatasaray University, Çırağan Cad. No: 36, Ortaköy, Istanbul, Turkey (e-mail: ealptekin@gsu.edu.tr).

which a person may initiate an EFT.

The evaluation of these payment systems are realized by using the Analytical Hierarchy Process (AHP) tool. AHP is a structured technique for dealing with complex decisions. In AHP, we first decompose the decision problem into a hierarchy of more easily comprehended sub-problems and we analyze each of them independently. We have used the pairwise comparisons of the AHP in order to calculate the importance weights of the criteria. As the pairwise comparisons are realized by consumers, some subjectiveness and imprecision exist in the results. We have made use of the fuzzy set theory and triangular fuzzy numbers to deal with this subjectiveness. We have used the utility theory and calculated the highest and lowest degree of approximations of each alternative. Then, we have compared the alternatives by calculating their distance to positive and negative ideal solutions.

II. Model Description

The application of fuzzy set theory on the multi-criteria decision making problems enables dealing with the imprecision of linguistic data. A typical decision making problem consist of [5]:

1. A set of alternatives: A_j, $\left(j = 1, 2, .., n\right)$,
2. A set of independent evaluation criteria: C_i, $\left(i = 1, 2, .., m\right)$
3. Subjective assessements which represent the performance of each alternative (A_j) in terms of each criterion (C_i): $x_{ij}\,(i = 1, 2, .., m;\ j = 1, 2, ..., n)$. This gives us the decision matrix for m criteria and n alternatives :

$$X = \begin{bmatrix} x_{11} & x_{12} & ... & x_{1n} \\ x_{21} & x_{22} & ... & x_{2n} \\ ... & ... & ... & ... \\ x_{m1} & x_{m2} & ... & x_{mn} \end{bmatrix} \qquad (1)$$

4. The weight vector (weight of each criterion): $W = (w_1, w_2, ..., w_m)$ which represents the relative importance of evaluation criteria.

If sub-criteria C_{ik} (k = 1,2,…, p_j) are used for criterion C_i, a lower-level decision matrix is to be given y_{ik} are the decision maker's linguistic assessments of the performance rating of alternative A_i with respect to sub-criteria C_{ik} of criterion C_i:

$$Y_{C_i} = \begin{bmatrix} y_{11} & y_{12} & ... & y_{1n} \\ y_{21} & y_{22} & ... & y_{2n} \\ ... & ... & ... & ... \\ y_{p_i1} & y_{p_i2} & ... & y_{p_in} \end{bmatrix} \qquad (2)$$

The weight vectors (W) is expressed by the linguistic terms which are defined in Table 1.

TABLE I
FUZZY NUMBERS

Fuzzy number	Membership function
$\bar{1}$	(1, 1, 3)
$\bar{x}$	(x – 2, x, x + 2)
$\bar{9}$	(7, 9, 9)

The linguistic terms are represented by the fuzzy triangular numbers ranging between 1 and 9. They are noted as (a_1, a_2, a_3), where $1 \le a_1$, $1 \le a_2 \le a_3 \le 9$. a_2 is the most possible value of the lingusitic term, whereas a_1 is the lower bound and a_3 is the upper bound value for the fuzzy number.

The lingusitic terms and corresponding triangular fuzzy number which are utilized for the evaluation of alternatives and for the decision matrix are given in Table 2 and Table 3, respectively.

TABLE II
LINGUISTIC TERMS USED FOR THE EVALUATION OF CRITERIA

Lingusitic term	Equal imp.	Moderate imp.	Strong imp.	Very strong imp.	Extreme imp.
Tri. fuzzy number	(1,1,3)	(1,3,5)	(3,5,7)	(5,7,9)	(7,9,9)

TABLE III
LINGUISTIC TERMS USED FOR THE DECISION MATRIX

Lingusitic term	Very poor	Poor	Fair	Good	Very good
Tri. fuzzy number	(1,1,3)	(1,3,5)	(3,5,7)	(5,7,9)	(7,9,9)

The main problem with traditional fuzzy multi-criteria decision making models lies in the fact that the comparison of fuzzy numbers is not always straightforward and reliable. To ensure an effective ranking outcome is always achieved, we use the concept of the degree of optimality [5] [6] [7] for transforming the weighted fuzzy decision matrix (referred to as *the performance matrix*) into a fuzzy singleton matrix [8]. The performance matrix represents the weighted fuzzy assessments of all alternatives with respect to each criterion at the highest level. With this transformation process, the approach can incorporate the decision maker's attitude towards risk into the ranking procedure.

The ranking procedure of the approach is based on the generation of the fuzzy performance matrix, which is the multiplication of the criteria weighting vector with the decision matrix. If criterion C_i consists of sub-criteria C_{ik}, the decision vector is determined by:

$$(x_{11},\ x_{12},\ ......, x_{1n}) = \frac{W_i * Y_{C_i}}{\sum_{k=1}^{p_i} w_{ik}} \qquad (3)$$

Given the fuzzy vector of the performance matrix for criterion C_j, a fuzzy maximum ($M_{\max}^j$) and a fuzzy minimum ($M_{\min}^j$) can be determined on the real line R to respectively represent the best and the worst fuzzy performance ratings among all the alternatives with respect to criterion C_i [5]. Their membership functions are given respectively by:

$$\mu_{M^i_{\max}}(x) = \begin{cases} \dfrac{x - x^i_{\min}}{x^i_{\max} - x^i_{\min}}, & x^i_{\min} \le x \le x^i_{\max} \\ 0 & , \text{ otherwise} \end{cases} \quad (4)$$

$$\mu_{M^i_{\min}}(x) = \begin{cases} \dfrac{x^i_{\max} - x}{x^i_{\max} - x^i_{\min}}, & x^i_{\min} \le x \le x^i_{\max} \\ 0 & , \text{ otherwise} \end{cases} \quad (5)$$

where $i = 1, 2, ..., m$; $j = 1, 2, ..., n$.

$$x^i_{\max} = \sup \bigcup_{j=1}^{n} \{ x, x \in \Re \quad \text{and} \quad 0 < \mu_{w_i x_{ij}}(x) < 1 \}$$

(6)

$$x^i_{\min} = \inf \bigcup_{j=1}^{n} \{ x, x \in \Re \quad \text{and} \quad 0 < \mu_{w_i x_{ij}}(x) < 1 \}$$

(7)

$u_{Ri}(j)$ represents the highest degree of approximation of alternative A_j's weighted performance on criterion C_i to the fuzzy maximum. Therefore, it reflects the decision maker's optimistic view:

$$u_{Ri}(j) = \sup_{x \in \Re}(w_i x_{ij} \bigcap M^i_{\max}), \ i = 1, 2, ..., m, \ j = 1, 2, ..., n \quad (8)$$

Similarly, the decision maker's pessimistic view can be represented by the degree to which the alternative A_j is not the worst alternative with respect to criterion C_i:

$$u_{Li}(j) = 1 - \sup_{x \in \Re}(w_i x_{ij} \bigcap M^i_{\min}), \ i = 1, 2, ..., m, \ \ j = 1, 2, ..., n$$

(9)

Let f_{ij} be a fuzzy function which defines the performance of an alternative A_j in respect to the criterion C_i. The corresponding triangular number can be expressed as (a_{ij}, b_{ij}, c_{ij}):

$$f_{ij} = \begin{cases} (x - a_{ij}) / (b_{ij} - a_{ij}) & a_{ij} \le x \le b_{ij} \\ (x - c_{ij}) / (b_{ij} - c_{ij}) & b_{ij} \le x \le c_{ij} \end{cases} \quad (10)$$

$$\frac{x - a_{ij}}{b_{ij} - a_{ij}} = \frac{x^i_{\max} - x}{x^i_{\max} - x^i_{\min}} \qquad \Rightarrow x = \frac{(a_{ij} - b_{ij}) x_{\max} - (x_{\max} - x_{\min})}{(a_{ij} - b_{ij}) - (x_{\max} - x_{\min})}$$

(11)

where $$u_{Li}(j) = 1 - \frac{(a_{ij} - b_{ij}) x_{\max} - (x_{\max} - x_{\min}) a_{ij}}{(a_{ij} - b_{ij}) - (x_{\max} - x_{\min})} \quad (12)$$

Similarly, we can calculate $u_{Ri}(j)$:

$$u_{Ri}(j) = \frac{(b_{ij} - c_{ij}) x_{\min} - (x_{\max} - x_{\min}) c_{ij}}{(b_{ij} - c_{ij}) - (x_{\max} - x_{\min})}$$

(13)

In actual decision settings, the decision maker's attitude is not necessarily to be absolutely optimistic or pessimistic; but somewhere in between. An optimism index λ in the range of 0–1 is thus used to indicate the relative preference between $u_{Rj}(i)$ and $u_{Lj}(i)$ [5]. In line with this concept, the degree of optimality of alternative A_j with respect to criterion C_i is determined by:

$$r_{ij} = \frac{\lambda u_{Ri}(j) + (1 - \lambda) u_{Li}(j)}{2}, \ i = 1, 2, ..., m, \ j = 1, 2, ..., n \quad (14)$$

where r_{ij} indicates the degree of preferability of alternative A_j over all other alternatives in regard to criterion C_i. A fuzzy singleton matrix is obtained from the fuzzy performance matrix, given as:

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} \quad (15)$$

To rank alternatives based on the fuzzy singleton matrix or a weighted decision matrix, the concept of the positive and negative ideal solutions (alternatives) is used. The positive (or negative) ideal solution consists of the best (or worst) criteria values attainable from all the alternatives, if each criterion takes monotonically increasing or decreasing values [9]. The most preferred alternative should not only have the shortest distance from the positive ideal solution; but also have the longest distance from the negative ideal solution.

The positive ideal solution A^+ and the negative ideal solution A^-, can be determined by:

$$r^+ = (r^+_1, r^+_2, ..., r^+_m) \text{ and } r^- = (r^-_1, r^-_2, ..., r^-_m) \quad (16)$$

where $r^+_i = \sup(r_{i1}, r_{i2}, ..., r_{in})$, $r^-_i = \inf(r_{i1}, r_{i2}, ..., r_{in})$, $i = 1, 2, ..., m$.

It is possible to use different distance formulations. In this paper, we have utilized the Hamming and the Euclidian distances and have compared them. The Hamming distance between alternative A_j and the positive ideal solution and the negative ideal solution can be calculated, respectively, by:

$$s^+_j = \sum_{i=1}^{m} (r^+_i - r_{ij}), \ s^-_j = \sum_{i=1}^{m} (r_{ij} - r^-_i), \ j = 1, 2, ..., n \quad (17)$$

The Euclidian distance between alternative A_j and the positive ideal solution and the negative ideal solution can be calculated, respectively, by:

International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
Vol:4, No:10, 2010

$$s_j^+ = \sqrt{\sum (r_{ij} - r_i^+)^2}\ , s_j^- = \sqrt{\sum (r_{ij} - r_i^-)^2}\ , j = 1, 2, ..., n \quad (18)$$

A crisp overall performance index for alternative A_j across all the criteria can be determined by:

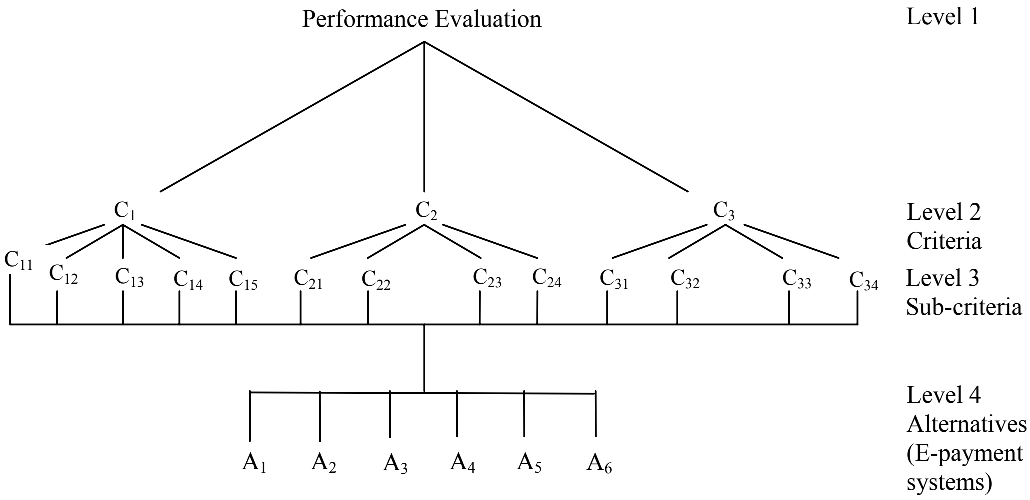

Fig. 1 The hierarchic structure of the problem

$$P_j = \frac{s_j^-}{s_j^+ + s_j^-}, \qquad j = 1, 2, ..., n \qquad (19)$$

The larger the performance index, the more preferred the alternative.

III. Evaluation Of Payment Systems

We have realized an interview with two experts in the technology and security department of the biggest bank of Turkey. Accordingly, we have defined three criteria and their sub-criteria for evaluating six e-payment systems (Figure 1, Table 4 and Table 5).

TABLE IV
CRITERIA AND SUB-CRITERIA

C_1: Technical factors	C_2: Economical factors	C_3 : Social factors
C_{11}: Authentication	C_{21} : Acceptability	C_{31} : Anonymity
C_{12} : Globality	C_{22} : Fixed fee	C_{32} : User friendliness
C_{13} : Portability	C_{23}: Transaction fee	C_{33} : Confidentiality
C_{14} : Comptability	C_{24}: Chargeback	C_{34} : Integrity
C_{15} : Security		

TABLE V
ALTERNATIVES

A_1 : Credit card	A_2 :Virtual credit card	A_3 : Mobile payment
A_4 : E-money	A_5 : Credit transfer	A_6 : Debit instruments

The importance weights of criteria and sub-criteria are calculated by utilizing the pairwise comparisions of AHP. Before calculating the weight of the criteria, the decision matrices have to be checked to see if they are consistant. The consistency ratio of the comparison matrices for each criteria are found as 0.063, 0.045 and 0.020, respectively. Hence, the decision matrices are consistant.

TABLE VI
IMPORTANCE WEIGHTS

Technical factors	W	**Technical factors**	W_{norm}
Authentication	(1.264, 1.838, 3.725)	Authentication	(0.107, 0.284, 0.898)
Globality	(0.779, 1.147, 2.452)	Globality	(0.066, 0.177, 0.591)
Portability	(0.512, 0.784, 1.412)	Portability	(0.043, 0.121, 0.340)
Comptability	(0.201, 0.247, 0.432)	Comptability	(0.017, 0.038, 0.104)
Security	(0.393, 2.450, 3.821)	Securtiy	(0.118, 0.379, 0.921)
Economical factors		**Economical factors**	
Acceptability	(2.106, 2.981, 5.107)	Acceptability	(0.220, 0.547, 1.349)
Fixed fee	(0.398, 0.493, 1.052)	Fixed fee	(0.042, 0.090, 0.278)
Transaction fee	(0.949, 1.531, 2.604)	Transaction fee	(0.099, 0.281, 0.688)
Chargeback	(0.333, 0.445, 0.811)	Chargeback	(0.035, 0.082, 0.214)
Social factors		**Social factors**	
Anonymity	(1.342, 1.957, 3.850)	Anonymity	(0.142, 0.380, 1.134)
User friendliness	(0.456, 0.586, 1.437)	User friendliness	(0.048, 0.114, 0.423)
Confidentiality	(1.315, 2.213, 3.519)	Confidentiality	(0.139, 0.430, 1.037)
Integrity	(0.282, 0.394, 0.679)	Integrity	(0.030, 0.077, 0.200)
Technical factors	(0.352, 0.435, 1.134)	Technical factors	(0.047, 0.115, 0.463)
Economical factors	(1.494, 2.403, 4.519)	Economical factors	(0.199, 0.633, 1.847)
Social factors	(0.600, 0.957, 1.856)	Social factors	(0.080, 0.252, 0.758)

The pairwise comparisons have been realized by the lingusitic comparisons of 31 interviewers. Then, we have taken the average of their assessments (Table 6).

The fuzzy decision matrix which represents the fuzzy weights of each alternative in terms of each criterion is calculated by multiplying the importance weight vector with the final decision matrix (Table 7):

TABLE VII
THE FINAL DECISION MATRIX

	X_1	X_2	X_3
Credit card	(0.039, 0.165, 0.724)	(0.049, 0.207, 0.845)	(0.031, 0.171, 1.034)
Virtual credit card	(0.042, 0.181, 0.729)	(0.041, 0.181, 0.845)	(0.027, 0.158, 1.021)
E-money	(0.036, 0.160, 0.671)	(0.036, 0.170, 0.763)	(0.030, 0.167, 1.034)
Mobile payment	(0.036, 0.159, 0.739)	(0.019, 0.112, 0.603)	(0.028, 0.162, 1.034)
Credit transfer	(0.039, 0.167, 0.782)	(0.023, 0.123, 0.662)	(0.031, 0.176, 1.007)
Debit instruments	(0.039, 0.167, 0.782)	(0.049, 0.208, 0.902)	(0.029, 0.165, 1.034)

TABLE VIII
THE FUZZY PERFORMANCE MATRIX

	$W*X_1$	$W*X_2$	$W*X_3$
Credit card	(0.002, 0.019, 0.336)	(0.010, 0.131, 1.561)	(0.002, 0.043, 0.784)
Virtual credit card	(0.002, 0.021, 0.338)	(0.008, 0.114, 1.561)	(0.002, 0.040, 0.775)
E-money	(0.002, 0.018, 0.311)	(0.007, 0.108, 1.410)	(0.002, 0.042, 0.784)
Mobile payment	(0.002, 0.018, 0.343)	(0.004, 0.071, 1.114)	(0.002, 0.041, 0.784)
Credit transfer	(0.002, 0.019, 0.362)	(0.005, 0.078, 1.223)	(0.003, 0.044, 0.764)
Debit instruments	(0.002, 0.019, 0.362)	(0.010, 0.132, 1.662)	(0.002, 0.042, 0.784)

TABLE IX
RELATIVE PERFORMANCE VALUES

	C_1		C_2		C_3	
	$u_{Li}(j)$	$u_{R_i}(j)$	$u_{Li}(j)$	$u_{R_i}(j)$	$u_{Li}(j)$	$u_{R_i}(j)$
Credit card	0.982	0.179	0.878	0.841	0.959	0.404
Virtual credit card	0.980	0.181	0.892	0.837	0.962	0.400
E-money	0.982	0.172	0.898	0.792	0.960	0.403
Mobile payment	0.983	0.181	0.932	0.686	0.961	0.403
Credit transfer	0.982	0.186	0.925	0.726	0.958	0.399
Debit instruments	0.982	0.186	0.877	0.399	0.960	0.403

TABLE X
FUZZY SINGLETON MATRICES

$\lambda = 1$

	Credit card	Virtual credit card	E-money	Mobile payment	Credit transfer	Debit instruments
C_1	0.090	0.090	0.086	0.091	0.093	0.093
C_2	0.421	0.418	0.396	0.343	0.363	0.434
C_3	0.202	0.200	0.202	0.202	0.199	0.202

$\lambda = 0.5$

C_1	0.290	0.290	0.289	0.291	0.292	0.292
C_2	0.430	0.432	0.423	0.404	0.413	0.436
C_3	0.341	0.341	0.341	0.341	0.339	0.341

$\lambda = 0$

C_1	0.491	0.490	0.491	0.491	0.491	0.491
C_2	0.439	0.446	0.449	0.466	0.463	0.439
C_3	0.479	0.481	0.480	0.480	0.479	0.480

Then, we obtain the vectors of the fuzzy performance matrix by multiplying the decision vectors by the weight of each criterion (Table 8).

With the help of the fuzzy maximum and fuzzy minimum, we determine the relative performances of each alternative for the criterion C_i. The $u_{Ri}(j)$ and $u_{Li}(j)$ values are given below (Table 9). The values of λ is taken as 1, 0.5 and 0 for reflecting the performance of an optimist, moderated and pessimist decision maker, respectively (Table 10).

The positive and negative ideal solutions are:

$$r^{+} = (0.434,\ 0.436,\ 0.491)$$

$$r^{-} = (0.086,\ 0.289,\ 0.439)$$

The distances among alternatives and the positive and negative ideal solutions are calculated using two different distances (Table 11). The obtained performance indices are given in Table 12. Therefore, the e-payment systems can be ordered as (Table 13).

TABLE XI
DISTANCES FOR THREE DIFFERENT TYPES OF DECISION MAKERS

$\lambda = 1$

	Credit card	Virtual credit card	E-money	Mobile payment	Credit transfer	Debit instruments
S^{+}_{Euc}	0.014	0.016	0.039	0.091	0.071	0.000
S^{-}_{Euc}	0.078	0.075	0.053	0.005	0.021	0.092
S^{+}_{Ham}	0.017	0.021	0.045	0.094	0.074	0.000
S^{-}_{Ham}	0.083	0.080	0.056	0.006	0.027	0.101

$\lambda = 0.5$

S^{+}_{Euc}	0.007	0.005	0.014	0.032	0.024	0.000
S^{-}_{Euc}	0.025	0.028	0.018	0.003	0.009	0.032
S^{+}_{Ham}	0.009	0.006	0.017	0.033	0.026	0.000
S^{-}_{Ham}	0.028	0.031	0.020	0.004	0.012	0.037

$\lambda = 0$

S^{+}_{Euc}	0.027	0.020	0.017	0.000	0.004	0.027
S^{-}_{Euc}	0.001	0.008	0.011	0.027	0.024	0.001
S^{+}_{Ham}	0.029	0.021	0.018	0.000	0.006	0.029
S^{-}_{Ham}	0.002	0.010	0.013	0.030	0.025	0.002

TABLE XII
PERFORMANCE INDICES FOR THREE DIFFERENT TYPES OF DECISION MAKERS

	$\lambda = 1$		$\lambda = 0.5$		$\lambda = 0$	
	$P_{i(Euc)}$	$P_{i(Ham)}$	$P_{i(Euc)}$	$P_{i(Ham)}$	$P_{i(Euc)}$	$P_{i(Ham)}$
Credit card	0.8457	0.8289	0.7840	0.7630	0.0373	0.0546
Virtual credit card	0.8222	0.7963	0.8577	0.8253	0.2823	0.3135
E-money	0.5794	0.5512	0.5624	0.5334	0.3840	0.4110
Mobile payment	0.0502	0.0638	0.0831	0.1099	0.9856	0.9869
Credit transfer	0.2283	0.2676	0.2731	0.3125	0.8585	0.8080
Debit instruments	0.9981	0.9983	0.9956	0.9962	0.0495	0.0634

TABLE XIII
RANKING OF THE ALTERNATIVES

	$\lambda = 1$		$\lambda = 0.5$		$\lambda = 0$	
	$P_{i(Euc)}$	$P_{i(Ham)}$	$P_{i(Euc)}$	$P_{i(Ham)}$	$P_{i(Euc)}$	$P_{i(Ham)}$
1.	Debit inst.	Debit inst.	Debit inst.	Debit inst.	Mobile payment	Mobile payment
2.	Credit card	Credit card	Vir. credit card	Vir. credit card	Credit transfer	Credit transfer
3.	Vir. credit card	Vir. credit card	Credit card	Credit card	E-money	E-money
4.	E-money	E-money	E-money	E-money	Vir. credit card	Vir. credit card
5.	Credit transfer	Credit transfer	Credit transfer	Credit transfer	Debit inst.	Debit inst.
6.	Mobile payment	Mobile payment	Mobile payment	Mobile payment	Credit card	Credit card

IV. Discussion

We can observe that the ranking of the alternatives are the same in both types of distance; Hamming and Euclidian. The results show that the most preferable payment system varies with the perspective of decision maker. The ranking of the alteratives is almost the same for the optimist and moderated decision makers. However, the ranking is totally different when the decision maker is pessimist.

The most preferable payment systems for the optimist and moderated decision makers are found as the debit instruments, the credit card and the virtual credit card, which are the least preferable alternatives for the pessimists. The pessimist decision makers prefer to use the mobile payment and the credit transfer.

These results prove that the choice of e-payment system depends on the attitude of the decision maker; since it has a direct impact on its performance evaluation.

Acknowledgment

The authors acknowledge the financial support of the Galatasaray University Research Fund.

References

[1] O.E.G. Johnson, *Payment systems monetary policy, and the role of the central bank.* International Monetary Fund, 1998, Washington, DC.
[2] World Bank, *Financial systems and development*. World Bank Policy and Research Series No. 15, 1990, Washington, DC.
[3] T. Khiaonarong, "Electronic payment systems development in Thailand", International Journal of Information Management, vol. 20 (1), 2000, pp. 59-72.
[4] H.C. Yu, K.H. Hsia and P.J. Kuob, "Electronic payment systems: an analysis and comparison of types", *Technology in Society*, vol. 24 (3), 2002, pp. 331-347.
[5] C.H. Yeh, H. Deng and Y.H. Chang, "Fuzzy multicriteria analysis for performance evaluation of bus companies", *European Journal of Operational Research*, vol.126, 2000, pp. 459 – 473.
[6] M. Zeleny, Multiple Criteria Decision Making. McGraw-Hill, 1982, New York.
[7] M. Zeleny, "Multiple criteria decision making: Eight concepts of optimality", *Human Systems Management*, vol. 17 (2), pp. 97–107.
[8] L.A. Zadeh, "Outline of a new approach to the analysis of complex system and decision process", *IEEE Transactions on Systems Man and Cybernetics*, vol. 2, 1973, pp. 28–44.
[9] C.L Hwang and K.S. Yoon, Multiple Attribute Decision Making: Methods and Applications, Springer, 1981, Berlin.