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EVALUATION AND ANALYSIS OF MOBILE COMMERCE TECHNOLOGIES USING A CHOQUET INTEGRAL-BASED APPROACH*

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ABSTRACT

Mobile Commerce is any transaction that involves the transfer of ownership or rights to use goods and services, which is initiated and/or completed by using mobile access to computer-mediated networks via an electronic device. Selection among m-commerce technologies is a multi-criteria evaluation problem having many conflicting and interactive criteria. In this study, 4 main criteria, which are economic trends, social trends, technological possibilities and data security and IT security, and 14 sub-criteria are determined to evaluate m-commerce standards and technologies. Choquet integral is used to evaluate mobile commerce technologies with multiple criteria. The accuracy of the obtained results is examined through a sensitivity analysis.

Keywords: *Multi-Criteria Decision Making, M-Commerce, Choquet Integral, Sensitivity Analysis.*

Tufan DEMİREL

CHOQUET İNTEGRAL TABANLI BİR YAKLAŞIM KULLANILARAK MOBİL TİCARET TEKNOLOJİLERİNİN DEĞERLENDİRİLMESİ VE ANALİZİ

ÖZ

Mobil Ticaret, elektronik bir cihaz yardımıyla bilgisayar aracılı ağlara mobil erişim kullanılarak başlatılan ve/veya tamamlanan mal ve hizmetlerin mülkiyet veya kullanım haklarının devredilmesini içeren herhangi bir işlemdir. Mobil ticaret teknolojileri arasından seçim, birçok çelişkili ve etkileşimli kriteri olan çok kriterli bir değerlendirme problemidir. Bu çalışmada, m-ticaret standartlarını ve teknolojilerini değerlendirmek için ekonomik trendler, sosyal trendler, teknolojik olanaklar ve veri güvenliği ve BT güvenliği olmak üzere 4 ana kriter ve 14 alt kriter belirlendi. Mobil ticaret teknolojilerini çok kriterli olarak değerlendirmek için Choquet integrali kullanıldı. Elde edilen sonuçların sağlamlığı bir duyarlılık analizi ile incelendi.

Anahtar Kelimeler: *Çok Kriterli Karar Verme, M-Ticaret, Choquet İntegral, Duyarlılık Analizi.*

1. INTRODUCTION

Referring the practice of conducting financial and promotional activities, mobile commerce (m-commerce) is about the services accessible using a handheld device. Despite being based on electronic commerce (e-commerce), it is quite different than the traditional way. Involving new services, technologies and business models; it is more advanced in making interaction available in a more personalized way to a wider audience. Handheld devices have different structures than computers, providing new opportunities as well as new constraints. It also gives the ability to exchange information by connecting with objects in a more direct way which was not possible until now. Being an emerging market, m-commerce has significant opportunities and significant risks.

It is impossible to conduct m-commerce without certain technologies. The interaction between embedded technologies, such as communicating wireless information with other devices and the combination of camera and image recognition, is vital for achieving the full potential of the mobile phones. In order to satisfy user experience; high quality information display, state of art technologies and secure structure are essential. Mobile networks should be able to deal with large amounts of traffic provided by high-speed connections to improve user comfort and reactivity (GS1, 2008). Success of m-commerce is mainly based on, the availability of technologies. M-commerce is built on several key technologies. Among alternatives, we can count GSM, 3G and upper versions, Wireless Networks (Bluetooth/Wi-Fi), SMS, and MMS.

The selection among m-commerce technologies is a multiple criteria selection problem with many conflicting main and sub-criteria. Among the main criteria, we can count *Economic Trends* with its sub-criteria: prices for mobile devices, prices of the mobile services and demand factors; *Social Trends* with its sub-criteria: this the need for increased mobility, market liberalization, and increasing demand for comfort; *Technological Possibilities* with its sub-criteria: the technologies of mobile devices, interface software development, transmission rate, user-friendliness, and personalization; *Data Security and IT Security* with its sub-criteria: data protection, data security technologies and international laws and standards.

The objective of our paper is to apply Choquet integral to the multi-criteria selection among mobile commerce technologies and standards. To the best of our knowledge, this is the first paper, which applies Choquet integral to this problem. Firstly, the main and sub-criteria are decide by using the experiences of experts and academic studies in the literature and are obtained by means of a hierarchical model. Then, using the joint judgments of the experts who work in IT, E-Commerce and GSM Sector, we calculate the priorities of the main and sub-criteria of the hierarchical model with Choquet integral. After that, sensitivity analyses are conducted so as to observe the behavior of any alternative technology by changing the weights of the main criteria. Finally, the results obtained by applying the method were evaluated and interpreted.

Choquet integral, used to solve MCDM problems, is a way of measuring the expected utility of an uncertain event. Marichal et al. (2005) constructed a freeware from this method to analyze an ordinal sorting procedure to assign alternatives to graded classes. Meyer and Roubens (2006) present a multiple criteria decision support approach using a fuzzy extension of choquet integral to provide a ranking of alternatives. The Choquet integral is a flexible aggregation operator being introduced by Sugeno (1974) and it is the generalization of the max-min and ordered weighted average operators, and weighted average method (Grabisch et al., 2000). In 2012, Yang and Chen proposed new aggregation operators to reflect the correlations among the elements better (2012). Choquet integral are being used to different areas recently; such as to evaluate intensity of knowledge work in jobs (Dahooie and Arsalan, 2013), and to select supply chain partners and configuration (Ashayeri et al., 2012). Apart from Choquet Integral, various fuzzy integral approaches are being proposed (Afshari et al., 2013).

The remaining sections of this paper are organized in the following fashion: Section 2 presents general approaches about mobile commerce. The evaluation criteria of mobile commerce Technologies and Standard are defined in Section 3. Section 4 introduces some definitions and formulations related to Choquet integral. In addition, the steps of the methodology are defined in the same section. The application can be found in Section 5. The last section provides a summary of the findings, making suggestions for further research.

2. MOBILE COMMERCE: A LITERATURE REVIEW

It is clear that, the Internet and related technologies will affect peoples' lives in ways we cannot imagine (Barnes, 2002). Although the use of mobile technologies for business activities was a minor in the past, it is rapidly growing nowadays.

Having the highest accessibility rate of all IT devices, mobile phones make it possible to reach the customer anytime and anywhere (Pousttchi et al., 2002). They are already in the center of most people's lives in developed countries. Although mobile phones will continue to be used to communicate with others, as it becomes easier and cheaper to transfer larger amounts of data, they will become a device that enables users to connect, transact and innovate. Mobile phones are connective devices, enabling individuals to connect to a large variety of sources of data whenever they want, wherever they want. Mobile phones are also transactional devices that prove ideal for payments and transactions. Besides, mobile phones are intelligent devices, by means of which multiple applications can meet and fuse (GS1, 2008).

In the first decade of this millennium, mobile communications have changed from 2G/2.5G to 3G/3.5G. In consequence, according to an analysis from the University of St. Andrews, the data transfer speed has increased from 56 Kbps in 2.5G/GPRS to 384 Kbps in 3G/UMTS (2014). Today, the most widely used technology is 3.5G/HSDPA, and it has data transfer rate between 3.5 Mbps and 21 Mbps, which is similar to that of the wired Internet. Recent developments lead to an increase in the use of mobile devices, to conduct m-commerce on the mobile Web (Venkatesh et al., 2003; Ngai and Gunasekaran, 2007; Liu and Liou, 2011).

M-commerce is a subset of electronic commerce that is at least one side uses mobile communication techniques during the procurement of service (Pousttchi et al., 2002). Ngai and Gunasekaran (2007) categorize the literature on m-commerce research and present an extensive review of these studies. Earlier studies are focused on understanding m-commerce and adapting it to businesses. Mahatanankoon et al. (2005) aims to provide empirical data on consumer perception of mobile applications during the first years of m-commerce to provide useful information about the future of m-commerce to companies. Since m-commerce is all about mobility, it has a

linear relationship with the improvements in mobile phones. In 2009, Chang et al. has conducted a study about smartphone characteristics that are beneficial for m-commerce. In the recent years, with the increase of smartphone and tablet usage, m-commerce has become a priority. Therefore, studies about m-commerce have evaluated from introduction to improvement and broaden of m-commerce usage, such as analyzing the key factors for a successful adoption to different regions and different business sectors (Al Hosni et al., 2010; Christou and Kassianidis, 2010; Chong et al., 2012). Also there are studies using MCDM methods, especially fuzzy analytic approaches in customer oriented research (Buyukozkan, 2009; Kabir and Hasin, 2011). In 2015, Cai et al. proposed an entropy-robust optimization model for m-commerce systems.

O'Donnell et al. (2007) conducts a research on the challenges and issues, arisen mainly from regulations and legal issues, in wireless-based projects with multiple organizations. Liu and Liou (2011) explain a hybrid multiple channel method in addressing the knowledge scarcity about the new channel users' consumption behavior.

One of the main problems in mobile commerce is the user's trust to the service provided. Varnali and Toker stated that in adopting mobile services, trust issue is a major barrier which should be dealt with (2010). These issues have motivated researchers to focus on the trust factor in the mobile context. Trust's importance in m-commerce has been supported in the study of Karjaluoto et al., stating that it has positive influence on both the impulsion to receive messages and the opinion toward mobile advertising (2008). In addition, Zhang and Mao found that predicted by psychological disposition and perceived ease of use, trust increases behavioral tendency to accept advertisement both directly and indirectly through the usage of SMS advertising (2008). According to Wang et al. (2015), in order rates per year rise owing to mobile devices since more and more customers are adopting mobile shopping. Omar et al. (2021), state that global m-commerce sales were £1.76 trillion in 2019 and are estimated to reach £2.21 trillion in 2020 according to Statista (2020).

3. MOBILE COMMERCE TECHNOLOGIES AND EVALUATION CRITERIA

In the following, the alternative m-commerce technologies and the evaluation criteria are explained. These alternatives and criteria will be used in the application section.

3.1. Alternative Technologies

Several standards held communication of mobile devices with the supporting network. The most influential standards are (GS1, 2008; Barnes, 2002):

GSM (A_1): The most used standard for mobile phones in the world is Global System for Mobile communication, which is estimated that 82% of the global mobile market. General Packet Data Service (GPRS) is a GSM standard wireless protocol offering continuous access to data networks. The speed can rise to a maximum of 56 kbit/s (GS1, 2008). It allows end users to access mobile Internet services even in the lack of 3G networks. In the recent years, Enhanced GPRS (EGPRS) or Enhanced Data rates for Global Evolution (EDGE), which is a higher bandwidth version of GPRS and an evolution of GSM, are still being widely used in the regions where 3G is not operating efficiently. EDGE meets the requirements for a 3G network but is named as 2.75G due to its limited capacity.

3G and Upper Versions (A_2): 3G, the third generation of mobile phone standards and technology, offers users a wider range of services by providing greater and more efficient network capacity. The high speeds will provide multimedia applications with high bandwidth usage. Universal Mobile Telecommunications System (UMTS) is one of the third-generation (3G) mobile phone technologies. High-Speed Packet Access (HSPA) extends and improves the performance of existing UMTS protocols, with collecting various mobile protocols. Fourth generation (4G), which is already being used in some regions of the world, is planned to have higher transmission rates (at least 100 Mbits/sec).

Wireless Networks (Bluetooth/Wi-Fi) (A_3): Wireless networks, i.e. Bluetooth or Wi-Fi, are an alternative communication technology since mobile phones support several technologies at once.

SMS (A_4): Using standardized communication protocols, Short Message Service is a text messaging service which allows mobile phones to exchange short text messages.

MMS (A_5): Multimedia Messaging Service (MMS) is an extension of SMS, including multimedia content over a cellular network. It extends SMS capability, allowing text messages greater than 160 characters. MMS can also deliver a variety of media such as video, image, or audio.

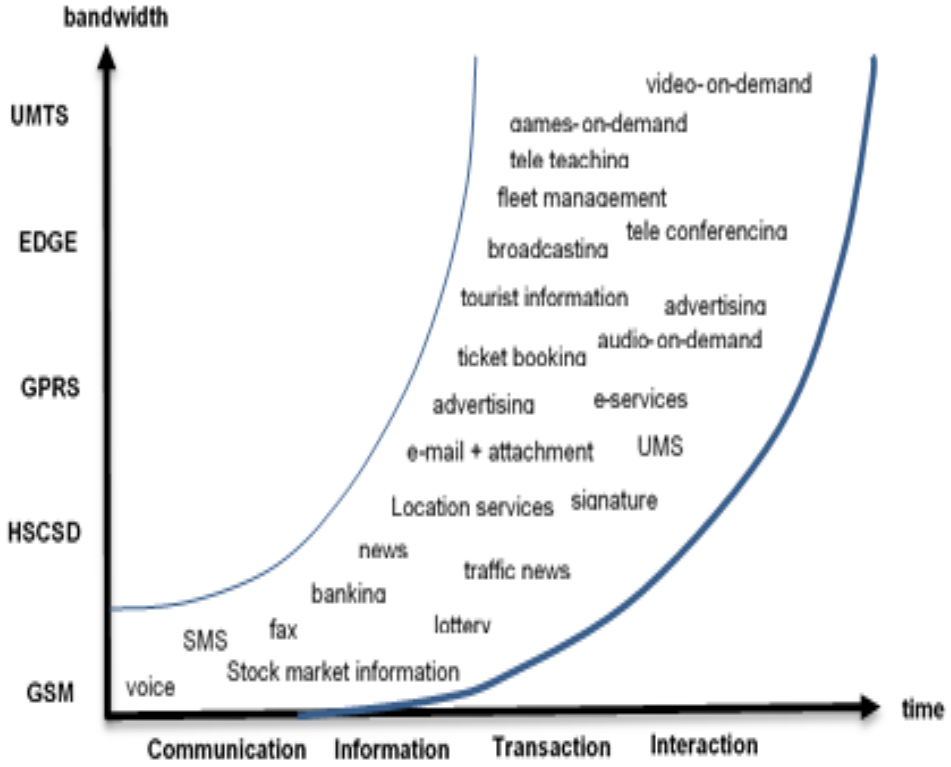

Figure 1. Diffusion of mobile services.

Figure 1 shows the relationships among network technologies and mobile applications, depending on time and bandwidth (Buellingen and Woerter, 2004).

3.2. Main and Sub-Criteria for the Evaluation of M-commerce Technologies

4 main criteria and 14 sub-criteria are used for evaluating m-commerce standards and Technologies in this paper. These criteria were selected from the studies of Buellingen and Woerter (2004), Anckar and D'Incau (2002), Abdelkarim and Nasereddin (2010), and Alturaigi and Altameem (2015). In addition, the opinions of experts in the e-commerce sector are also taken into account. The main and sub-criteria are explained below:

Economic Trends (ET): Under the economic trend criterion, four sub-criteria are defined: prices for mobile devices (ET_1), prices of the mobile services (ET_2) and demand factors (ET_3). Both prices of mobile devices and prices of mobile services are separate price-based criteria. The demand factor is a criterion that expresses the need for mobile commerce and mobile services.

Social Trends (ST): This main criterion defines the need for increased mobility (ST_1), market liberalization (ST_2) and increasing demand for comfort (SC_3). The demand for mobility is a leading force behind mobile banking, entertainment and marketing, and supported by the uniting world of computers and mobile devices. Comfort is the ability to access business activities anytime anywhere.

Technological Possibilities (TP): It is a main criterion defining the technologies of mobile devices (TP_1), interface software development (TP_2), transmission rate (TP_3), user-friendliness (TP_4) and personalization (TP_5). The first criterion refers to the compliance between the mobile device technologies and mobile commerce. Interface software development allows an interaction between users, and mobile commerce and device. The transmission rate is an important factor for mobile communication. User-friendliness explains the ability to access business activities and communication services with ease of use. Personalization provides time saving, comfort, and timeliness of information, flexibility and reduced search cost in the mobile commerce (Buellingen and Woerter 2004). It can be said that mobile devices could become the primary e-commerce tool for delivering personalized information, products, and services; even though

consumer personalization applications on mobile devices are still limited (Abdelkarim and Nasereddin, 2010).

Data Security and IT Security (ITS): It is a main criterion that defines data protection (ITS_1), data security technologies (ITS_2) and international laws and standards (ITS_3). Data protection is a vital condition in perfecting mobile business processes. Data security technologies contain data masking, backups, and hardware-based mechanisms for protecting data, disk encryption and data erasure.

A hierarchical structure for m-commerce technologies and standards is illustrated in Figure 2, employing the main and sub-criteria explained above.

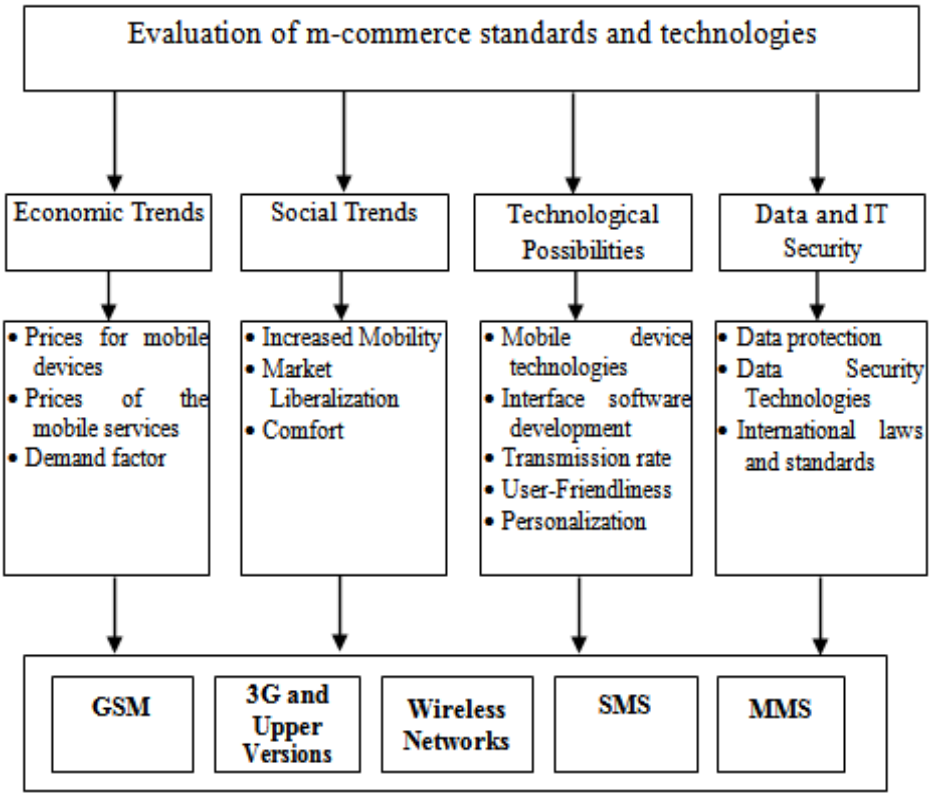

Figure 2. The hierarchy of the mobile commerce technologies and standards.

4. CHOQUET INTEGRAL METHOD

One of the methods used to solve MCDM problems is the Choquet integral. With this method, the expected benefit of an uncertain event can be measured. Academicians have developed many techniques for MCDM problems and solved problems in many different areas with these methods (Chang, 1996; Mikhailov, 2002; Kahraman et al., 2004; Gu and Zhu, 2006; Wang et al., 2008; Deveci et al., 2018; Khan et al., 2021). Our methodology follows Tsai and Lu's (2006) approach to Auephanwiriyakul et al. 2002).

The methodology is as follows (Tsai and Lu, 2006; Demirel et al., 2010; Çetin Demirel et al., 2017):

Step 1. Conducting a survey to obtain linguistic preferences. To quantify all linguistic terms for tolerance range, perceived performance levels of alternative m-commerce technologies and degree of importance; trapezoidal fuzzy numbers are used.

Linguistic terms given by respondent t for criteria i is identified as $\tilde{A}_i^t = (a_{i1}^t, a_{i2}^t, a_{i3}^t, a_{i4}^t)$, perceived performance levels by $\tilde{P}_i^t = (p_{i1}^t, p_{i2}^t, p_{i3}^t, p_{i4}^t)$, and the tolerance zone by $\tilde{e}_i^t = (e_{i1}^t, e_{i2}^t, e_{i3}^t, e_{i4}^t)$.

The average of the values obtained from more than one expert is calculated by Eq.(1).

$$\widetilde{A}_i = \frac{\sum_{t=1}^{k} \widetilde{A}_i^t}{k} = \left(\frac{\sum_{t=1}^{k} a_{i1}^t}{k}, \frac{\sum_{t=1}^{k} a_{i2}^t}{k}, \frac{\sum_{t=1}^{k} a_{i3}^t}{k}, \frac{\sum_{t=1}^{k} a_{i4}^t}{k} \right) \quad \textbf{(1)}$$

Step 2. Normalize the alternative technology value for each criterion using Eq. (2).

$$\widetilde{f}_i = \bigcup_{\alpha \in [0,1]} \bar{f}_i^{\alpha} = \bigcup_{\alpha \in [0,1]} [f_{i,\alpha}^{-}, f_{i,\alpha}^{+}] \quad \textbf{(2)}$$

Where $f_i \in F(s)$ is a fuzzy-valued function, $\tilde{F}(S)$ is the set of all fuzzy-valued functions and $f, f_i^{\alpha} = [f_{i,\alpha}^{-}, f_{i,\alpha}^{+}] = \frac{\bar{p}_i^{\alpha} - \bar{e}_i^{\propto} + [1,1]}{2}$, $\bar{p}_i^{\propto}, \bar{e}_i^{\propto}$ are α-level cuts of $\bar{p}_i^{\propto}$ and $\bar{e}_i^{\propto}$ for all $\propto = [0,1]$.

Step 3. Use Eq.(3) to calculate the alternative technology value of dimension *j*.

$$(C)\int \tilde{f} d\tilde{g} = \bigcup_{\alpha=[0,1]} \left[(C)\int f_{\alpha}^{-} dg_{\alpha}^{-}, (C)\int f_{\alpha}^{+} dg_{\alpha}^{+}, \right] \quad \textbf{(3)}$$

Where $\bar{g}_i : P(S) \to I(R^{+}), \bar{g}_i = [g_i^{-}, g_i^{+}], \quad \bar{g}_i^{\alpha} = [g_{i,\alpha}^{-}, g_{i,\alpha}^{+}]$,

$\bar{f}_i : S \to I(R^{+}),$ and $f_i = [f_i^{-}, f_i^{+}]$ for i=1, 2, 3, ..., n_j.

For this alternative technology value to be calculated, a λ value and the fuzzy measures *g(A(i)), i*=1,2,...,n, are needed. These can be obtained from the following Eqs. (4), (5), and (6) (Sugeno 1974; Ishii and Sugeno 1985):

$$g(A_{(n)}) = g(\{s_{(n)}\}) = g_n \quad \textbf{(4)}$$

$$g(A_{(i)}) = g_i + g(A_{(i+1)}) + \lambda g_i g(A_{(i+1)}), \qquad \text{where } 1 \le i < n \quad \textbf{(5)}$$

$$1 = g(S) = \begin{cases} 1/\lambda \left\{ \prod_{i=1}^{n} [1 + \lambda g(A_i)] - 1 \right\} & \text{if } \lambda \neq 0 \\ \sum_{i=1}^{n} g(A_i) & \text{if } \lambda = 0 \end{cases} \quad \textbf{(6)}$$

Where, $A_i \cap A_j = \emptyset$ for all *i, j* = 1,2,3,…,n and $i \neq j$, and $\lambda \epsilon (-1, \infty]$.
Let μ be a fuzzy measure on $(I, P(I))$ and an application $f: I \to \Re^{+}$.

The Choquet integral of f with regard to μ is defined by:

$$(C)\int_I f d\mu = \sum_{i=1}^{n}\left(f\left(\sigma(i)\right) - f\left(\sigma(i-1)\right)\right)\mu\left(A_{(i)}\right) \quad \textbf{(7)}$$

Where σ is a permutation of the indices in order to have $f\left(\sigma(1)\right) \leq \cdots \leq f\sigma(n)), A_{(i)} = \{\sigma(i), \ldots, \sigma(n)\}$ and $f\left(\sigma(0)\right) = 0$ by convention.

Step 4. Use a hierarchical process to aggregate all dimensional performance levels of the technology alternatives into overall performance levels, applying the two-stage aggregation process of the generalized Choquet integral. This is represented in Eq. (8). The overall performance levels yield a fuzzy number, $\widetilde{V}$.

$$\left.\begin{array}{lll} sub\ criteria: \begin{Bmatrix} ET1 \\ ET2 \\ ET3 \end{Bmatrix} \rightarrow & main\ criterion_1: & ET = (C)\int f_1 dg \\ \vdots & \vdots & \\ sub\ criteria: \begin{Bmatrix} ITS1 \\ ITS2 \\ ITS3 \end{Bmatrix} \rightarrow & main\ criterion_4: & ITS = (C)\int f_4 dg \end{array}\right\rangle Overall\ Value_1: A_1 = (C)\int f dg \quad \textbf{(8)}$$

Step 5. Assuming the membership of $\widetilde{V}$ is $\mu_{\tilde{v}}(x)$; the fuzzy number $\widetilde{V}$ is defuzzified into a crisp value *v* by using Eq. (9), and a comparison of the overall performance levels of alternative m-commerce technologies is made. Finally, weak and advantageous criteria among the technology alternatives are compared using Eq.(1).

$$F\left(\widetilde{A}\right) = \frac{a_1 + a_2 + a_3 + a_4}{4} \quad \textbf{(9)}$$

5. APPLICATION

This study aims to evaluate the alternatives of m-commerce technologies with regard to some conflicting criteria. The hierarchy in Section 3 was established by experts from IT (3 experts), E-Commerce (2 experts), and GSM (3 experts). These eight experts confirmed the criteria and sub-criteria and decided to use the evaluation scale in Table 1 (Delgado et al., 1998). Considering the experiences and positions of the field experts, it was accepted that all of them were of equal importance. Arithmetic mean was used in calculating the mean of the mathematical equivalents of the linguistic expressions obtained from the experts (Tsai and Lu, 2006).

Table 1. A nine-linguistic-term scale representing the relationship between trapezoidal fuzzy numbers and degrees of linguistic importance.

Low/High Levels		The degrees of importance		Trapezoidal
Label	Linguistic terms	Label	Linguistic terms	fuzzy numbers
EL	Extra Low	EU	Extra Unimportant	(0,0,0,0)
VL	Very Low	VU	Very Unimportant	(0,0.01,0.02,0.07)
L	Low	U	Unimportant	(0.04,0.1,0.18,0.23)
SL	Slightly Low	SU	Slightly Unimportant	(0.17,0.22,0.36,0.42)
M	Middle	M	Middle	(0.32,0.41,0.58,0.65)
SH	Slightly High	SI	Slightly Important	(0.58,0.63,0.8,0.86)
H	High	HI	High Important	(0.72,0.78,0.92,0.97)
VH	Very High	VI	Very Important	(0.93,0.98,0.98,1.0)
EH	Extra High	EI	Extra Important	(1,1,1,1)

The data are obtained that the individual importance of main and sub-criteria and their tolerance zones from the experts. While obtaining data from experts, experts make linguistic evaluations. Table 2 shows these data that were obtained from an expert.

Table 3 presents the average results that were evaluated by experts. Each expert's individual evaluations are combined by calculating the arithmetic mean of these numerical values by Eq.(1) in Step 1.

Table 2. Individual importance of criteria, tolerance zones, and an expert's linguistic evaluation of each m-commerce technology.

Main Criteria	Sub-Criteria	Individual importance of criteria	The Tolerance Zone	M-Commerce Technologies and Standards				
				GSM	3G and Upper Version	Wireless Networks	SMS	MMS
Economic Trends		H						
	Prices of mobile devices	H	[VL, H]	VL	M	M	VL	H
	Prices of the mobile services	VH	[M, SH]	H	H	SH	H	M
	Demand factors	M	[SL,VH]	M	VH	VH	SH	SL
Social Trends		M						
	Increased mobility	VH	[M,VH]	SH	VH	H	M	SH
	Market liberalization	SL	[M, EH]	H	EH	VH	M	M
	Comfort	M	[M, EH]	M	EH	L	M	SH
Technological Possibilities		VH						
	Technologies of mobile devices	EH	[M, EH]	M	EH	EH	M	SH
	Interface software development	VH	[M,VH]	SL	EH	VH	SL	M
	Transmission rate	M	[L, VH]	VL	EH	VH	L	VH
	User-friendliness	SH	[L,H]	M	H	SL	L	SL
	Personalization	H	[L, H]	L	H	L	H	H
Data and IT Security		EH						
	Data protection	H	[M, H]	M	SH	H	M	M
	Data security technologies	VH	[M, VH]	M	VH	H	H	H
	International laws and standards	VH	[M, H]	M	EH	H	M	M

The tolerance zones indicated in Table 3 have been obtained as follows: The first two numerical values of the lower linguistic value of a tolerance zone

in Table 3 are combined with the last two numerical values of the upper linguistic value of the same tolerance zone. If the tolerance zone is [(0.01,0.04,0.07,0.12), (0.59,0.66,0.81,0.86)], then the combined tolerance zone is (0.01, 0.04, 0.81, 0.86).

Table 3. The average results for Choquet Integral which are evaluated by eight experts.

Criteria	Individual importance	The Combined Tolerance Range	Perceived Performance Levels of Alternative Technologies				
			A_1	A_2	A_3	A_4	A_5
ET	(0.79,0.85,0.94,0.98)						
ET1	(0.4,0.47,0.62,0.68)	(0.01,0.04,0.81,0.86)	(0.07,0.11,0.19,0.24)	(0.27,0.35,0.51,0.57)	(0.36,0.42,0.58,0.64)	(0.01,0.04,0.07,0.12)	(0.59,0.66,0.81,0.86)
ET2	(0.61,0.67,0.79,0.84)	(0.27,0.35,0.84,0.9)	(0.63,0.68,0.84,0.9)	(0.63,0.68,0.84,0.9)	(0.41,0.48,0.65,0.72)	(0.4,0.47,0.62,0.68)	(0.41,0.48,0.65,0.72)
ET3	(0.77,0.8,0.86,0.88)	(0.27,0.35,0.99,1)	(0.66,0.72,0.83,0.87)	(0.95,0.99,0.99,1)	(0.61,0.67,0.79,0.84)	(0.49,0.56,0.73,0.79)	(0.49,0.54,0.69,0.75)
ST	(0.45,0.53,0.69,0.76)						
ST1	(0.95,0.99,0.99,1)	(0.27,0.35,0.94,0.98)	(0.49,0.56,0.73,0.79)	(0.79,0.85,0.94,0.98)	(0.4,0.47,0.62,0.68)	(0.41,0.48,0.65,0.72)	(0.49,0.56,0.73,0.79)
ST2	(0.13,0.18,0.3,0.36)	(0.27,0.35,0.99,1)	(0.72,0.78,0.92,0.97)	(0.95,0.99,0.99,1)	(0.74,0.8,0.9,0.94)	(0.27,0.35,0.51,0.57)	(0.49,0.56,0.73,0.79)
ST3	(0.45,0.53,0.69,0.76)	(0.31,0.38,0.99,1)	(0.54,0.61,0.77,0.83)	(0.95,0.99,0.99,1)	(0.36,0.43,0.56,0.62)	(0.41,0.48,0.65,0.72)	(0.49,0.56,0.73,0.79)
TP	(0.84,0.87,0.93,0.95)						
TP1	(0.98,0.99,0.99,1)	(0.27,0.35,0.99,1)	(0.27,0.35,0.51,0.57)	(0.98,0.99,0.99,1)	(0.88,0.92,0.97,0.99)	(0.54,0.61,0.77,0.83)	(0.61,0.67,0.79,0.84)
TP2	(0.95,0.99,0.99,1)	(0.31,0.36,0.99,1)	(0.35,0.41,0.55,0.6)	(0.95,0.99,0.99,1)	(0.79,0.85,0.94,0.98)	(0.36,0.42,0.58,0.64)	(0.54,0.61,0.77,0.83)
TP3	(0.52,0.6,0.71,0.77)	(0.06,0.08,0.97,0.99)	(0.07,0.11,0.19,0.24)	(0.77,0.8,0.91,0.94)	(0.88,0.92,0.97,0.99)	(0.12,0.17,0.26,0.32)	(0.73,0.79,0.85,0.88)
TP4	(0.63,0.68,0.84,0.9)	(0.18,0.24,0.96,0.99)	(0.49,0.56,0.73,0.79)	(0.86,0.91,0.96,0.99)	(0.36,0.42,0.58,0.64)	(0.18,0.24,0.37,0.43)	(0.27,0.35,0.51,0.57)
TP5	(0.79,0.85,0.94,0.98)	(0.07,0.11,0.96,0.99)	(0.31,0.38,0.52,0.58)	(0.79,0.85,0.94,0.98)	(0.07,0.11,0.19,0.24)	(0.86,0.91,0.96,0.99)	(0.74,0.8,0.9,0.94)
ITS	(0.88,0.92,0.97,0.99)						
ITS1	(0.67,0.73,0.88,0.93)	(0.27,0.35,0.88,0.93)	(0.27,0.35,0.51,0.57)	(0.49,0.56,0.73,0.79)	(0.67,0.73,0.88,0.93)	(0.27,0.35,0.51,0.57)	(0.32,0.41,0.58,0.65)
ITS2	(0.86,0.91,0.96,0.99)	(0.45,0.53,0.99,1)	(0.45,0.53,0.69,0.76)	(0.95,0.99,0.99,1)	(0.86,0.91,0.96,0.99)	(0.72,0.78,0.92,0.97)	(0.67,0.73,0.88,0.93)
ITS3	(0.95,0.99,0.99,1)	(0.54,0.61,0.99,1)	(0.54,0.61,0.77,0.83)	(0.95,0.99,0.99,1)	(0.86,0.91,0.96,0.99)	(0.54,0.61,0.77,0.83)	(0.54,0.61,0.77,0.83)

Table 4 and Table 5 illustrate the evaluation results by the generalized Choquet integral for α=0 and α=1. For the sub-criteria, Eq.(2) is used. Eq.(3) is used for the main criteria. In Table 4, for instance, the value [0.105, 0.615] of "alternative 1 and sub-criterion ET1" is obtained in this way:

$$f, f_i^{\alpha} = \left[f_{i,\alpha}^{-}, f_{i,\alpha}^{+}\right] = \frac{[0.07,0.24] - [0.01,0.86] + [1,1]}{2} = [0.105,0.615]$$

The aggregated Choquet integral values for the main criterion ET are calculated as follows. Tables 4 and 5 demonstrate the normalized discrepancies and alternative technology values (Choquet integrals).

$$(C)\int f^{-}_{\alpha=0} dg^{-}_{\alpha=0} \quad = 0.3401$$

$$(C)\int f^{+}_{\alpha=0} dg^{+}_{\alpha=0} \quad = 0.8108$$

That is,

$$(C)\int \tilde{f} d\tilde{g} = [0.3401, 0.8108]$$

Table 4. Evaluation results by the generalized Choquet Integral for α=0.

Criteria	**Individual importance of criteria** $[g_i^{-}, g_i^{+}]$	**The normalized discrepancy** $\bar{f}_i = [f_i^{-}, f_i^{+}]$ **and alternative technology value** $[(C)\int f^{-}\mathrm{d}g^{-}, (C)\int f^{+}\mathrm{d}g^{+}]$				
		A_1	**A_2**	**A_3**	**A_4**	**A_5**
ET		[0.3401, 0.8108]	[0.4417, 0.8586]	[0.2932, 0.8036]	[0.2396, 0.7519]	[0.2969, 0.8654]
ET_1	[0.4,0.68]	[0.105,0.615]	[0.205,0.78]	[0.25,0.815]	[0.075,0.555]	[0.365,0.925]
ET_2	[0.61,0.84]	[0.365,0.815]	[0.365,0.815]	[0.255,0.725]	[0.25,0.705]	[0.255,0.725]
ET_3	[0.77,0.88]	[0.33,0.8]	[0.475,0.865]	[0.305,0.785]	[0.245,0.76]	[0.245,0.74]
ST		[0.2745, 0.7924]	[0.4414, 0.8586]	[0.2296, 0.7518]	[0.2138, 0.725]	[0.2545, 0.76]
ST_1	[0.95,1]	[0.255,0.76]	[0.405,0.855]	[0.21,0.705]	[0.215,0.725]	[0.255,0.76]
ST_2	[0.13,0.36]	[0.36,0.85]	[0.475,0.865]	[0.37,0.835]	[0.135,0.65]	[0.245,0.76]
ST_3	[0.45,0.76]	[0.27,0.76]	[0.475,0.845]	[0.18,0.655]	[0.205,0.705]	[0.245,0.74]
TP		[0.222, 0.8]	[0.4897, 0.9547]	[0.4422, 0.9408]	[0.4004, 0.9564]	[0.3674, 0.9345]
TP_1	[0.98,1]	[0.135,0.65]	[0.49,0.865]	[0.44,0.86]	[0.27,0.78]	[0.305,0.785]
TP_2	[0.95,1]	[0.175,0.645]	[0.475,0.845]	[0.395,0.835]	[0.18,0.665]	[0.27,0.76]
TP_3	[0.52,0.77]	[0.04,0.59]	[0.39,0.94]	[0.445,0.965]	[0.065,0.63]	[0.37,0.91]
TP_4	[0.63,0.9]	[0.25,0.805]	[0.435,0.905]	[0.185,0.73]	[0.095,0.625]	[0.14,0.695]
TP_5	[0.79,0.98]	[0.16,0.755]	[0.4,0.955]	[0.04,0.585]	[0.435,0.96]	[0.375,0.935]
ITS		[0.2678, 0.655]	[0.475, 0.7748]	[0.43, 0.8258]	[0.3474, 0.7589]	[0.3259, 0.7395]
ITS_1	[0.67,0.93]	[0.17,0.65]	[0.28,0.76]	[0.37,0.83]	[0.17,0.65]	[0.195,0.69]
ITS_2	[0.86,0.99]	[0.225,0.655]	[0.475,0.775]	[0.43,0.77]	[0.36,0.76]	[0.335,0.74]
ITS_3	[0.95,1]	[0.27,0.645]	[0.475,0.73]	[0.43,0.725]	[0.27,0.645]	[0.27,0.645]

Table 5. Evaluation results by the generalized Choquet Integral for α=1.

Criteria	**Individual importance of criteria** $[g_i^-, g_i^+]$	**The normalized discrepancy** $\bar{f}_i = [f_i^-, f_i^+]$ **and alternative technology value** $[(C)\int f^- \mathrm{d}g^-, (C)\int f^+ \mathrm{d}g^+]$				
		A_1	**A_2**	**A_3**	**A_4**	**A_5**
ET		[0.3932, 0.7406]	[0.478, 0.8093]	[0.3354, 0.7475]	[0.2983, 0.6799]	[0.3622, 0.8023]
ET_1	[0.47,0.62]	[0.15,0.575]	[0.27,0.735]	[0.305,0.77]	[0.115,0.515]	[0.425,0.885]
ET_2	[0.67,0.79]	[0.42,0.745]	[0.42,0.745]	[0.32,0.65]	[0.315,0.635]	[0.32,0.65]
ET_3	[0.8,0.86]	[0.365,0.74]	[0.5,0.82]	[0.34,0.72]	[0.285,0.69]	[0.275,0.67]
ST		[0.3253, 0.7209]	[0.4829, 0.8073]	[0.2898, 0.6766]	[0.2698, 0.6498]	[0.3097, 0.6898]
ST_1	[0.99,0.99]	[0.31,0.69]	[0.455,0.795]	[0.265,0.635]	[0.27,0.65]	[0.31,0.69]
ST_2	[0.18,0.3]	[0.395,0.785]	[0.5,0.82]	[0.405,0.775]	[0.18,0.58]	[0.285,0.69]
ST_3	[0.53,0.69]	[0.31,0.695]	[0.5,0.805]	[0.22,0.59]	[0.245,0.635]	[0.285,0.675]
TP		[0.2712, 0.7375]	[0.5, 0.9139]	[0.471, 0.9058]	[0.4502, 0.9121]	[0.4143, 0.8911]
TP_1	[0.99,0.99]	[0.18,0.58]	[0.5,0.82]	[0.465,0.81]	[0.31,0.71]	[0.34,0.72]
TP_2	[0.99,0.99]	[0.21,0.595]	[0.5,0.815]	[0.43,0.79]	[0.215,0.61]	[0.31,0.705]
TP_3	[0.6,0.71]	[0.07,0.555]	[0.415,0.915]	[0.475,0.945]	[0.1,0.59]	[0.41,0.885]
TP_4	[0.68,0.84]	[0.3,0.745]	[0.475,0.86]	[0.23,0.67]	[0.14,0.565]	[0.195,0.635]
TP_5	[0.85,0.94]	[0.21,0.705]	[0.445,0.915]	[0.075,0.54]	[0.475,0.925]	[0.42,0.895]
ITS		[0.3096, 0.58]	[0.5, 0.7284]	[0.46, 0.759]	[0.3874, 0.6904]	[0.3646, 0.6726]
ITS_1	[0.73,0.88]	[0.235,0.58]	[0.34,0.69]	[0.425,0.765]	[0.235,0.58]	[0.265,0.615]
ITS_2	[0.91,0.96]	[0.27,0.58]	[0.5,0.73]	[0.46,0.715]	[0.395,0.695]	[0.37,0.675]
ITS_3	[0.99,0.99]	[0.31,0.58]	[0.5,0.69]	[0.46,0.675]	[0.31,0.58]	[0.31,0.58]

In Table 6, using the calculation for Choquet integral just above, the overall m-commerce technology values are obtained. In this table, all trapezoidal fuzzy numbers are also given as crisp numbers.

Table 6. Defuzzified overall values of alternative m-commerce technologies using generalized Chouqet Integral.

Criteria	$(C)\int \tilde{f} d\tilde{g}$					Defuzzified $(C)\int \tilde{f} d\tilde{g}$				
	A_1	A_2	A_3	A_4	A_5	A1	A2	A3	A4	A5
Overall tech. value	**(0.3251, 0.3768, 0.5816, 0.6564)**	**(0.4867, 0.4996, 0.7303, 0.7766)**	**(0.4375, 0.4667, 0.7605, 0.827)**	**(0.3898, 0.4384, 0.6926, 0.7609)**	**(0.3602, 0.4063, 0.6748, 0.7415)**	0.485	**0.623**	0.622	0.570	0.545
ET	**(0.340. 0.393. 0.740. 0.810)**	**(0.441. 0.47. 0.809. 0.858)**	**(0.293, 0.335, 0.747, 0.803)**	**(0.239. 0.298. 0.679. 0.751)**	**(0.296. 0.362. 0.802. 0.865)**	0.571	**0.646**	0.544	0.492	0.581
ET_1	(0.105. 0.15. 0.575. 0.615)	(0.205. 0.27. 0.735. 0.78)	(0.25. 0.305. 0.77. 0.815)	(0.075. 0.115. 0.515. 0.555)	(0.365. 0.425. 0.885. 0.925)	0.361	0.497	0.535	0.315	**0.65**
ET_2	(0.365. 0.42. 0.745. 0.815)	(0.365. 0.42. 0.745. 0.815)	(0.255. 0.32. 0.65. 0.725)	(0.25. 0.315. 0.635. 0.705)	(0.255. 0.32. 0.65. 0.725)	0.586	**0.586**	0.487	0.476	0.487
ET_3	(0.33. 0.365. 0.74. 0.8)	(0.475. 0.5. 0.82. 0.865)	(0.305. 0.34. 0.72. 0.785)	(0.245. 0.285. 0.69. 0.76)	(0.245. 0.275. 0.67. 0.74)	0.558	**0.665**	0.537	0.495	0.482
ST	**(0.2745. 0.3253. 0.7209. 0.7924)**	**(0.4414. 0.4829. 0.8073. 0.8586)**	**(0.2296. 0.2898. 0.6766. 0.7518)**	**(0.2138. 0.2698. 0.6498. 0.725)**	**(0.2545. 0.3097. 0.6898. 0.76)**	0.528	**0.647**	0.487	0.464	0.503
ST_1	(0.255. 0.31. 0.69. 0.76)	(0.405. 0.455. 0.795. 0.855)	(0.21. 0.265. 0.635. 0.705)	(0.215. 0.27. 0.65. 0.725)	(0.255. 0.31. 0.69. 0.76)	0.503	**0.627**	0.453	0.465	0.503
ST_2	(0.36. 0.395. 0.785. 0.85)	(0.475. 0.5. 0.82. 0.865)	(0.37. 0.405. 0.775. 0.835)	(0.135. 0.18. 0.58. 0.65)	(0.245. 0.285. 0.69. 0.76)	0.597	**0.665**	0.596	0.386	0.495
ST_3	(0.27. 0.31. 0.695. 0.76)	(0.475. 0.5. 0.805. 0.845)	(0.18. 0.22. 0.59. 0.655)	(0.205. 0.245. 0.635. 0.705)	(0.245. 0.285. 0.675. 0.74)	0.508	**0.656**	0.411	0.447	0.486
TP	**(0.222. 0.2712. 0.7375. 0.8)**	**(0.4897. 0.5. 0.9139. 0.9547)**	**(0.4422. 0.471. 0.9058. 0.9408)**	**(0.4004. 0.4502. 0.9121. 0.9564)**	**(0.3674. 0.4143. 0.8911. 0.9345)**	0.507	**0.714**	0.69	0.679	0.651
TP_1	(0.135. 0.18. 0.58. 0.65)	(0.49. 0.5. 0.82. 0.865)	(0.44. 0.465. 0.81. 0.86)	(0.27. 0.31. 0.71. 0.78)	(0.305. 0.34. 0.72. 0.785)	0.386	**0.668**	0.643	0.517	0.537
TP_2	(0.175. 0.21. 0.595. 0.645)	(0.475. 0.5. 0.815. 0.845)	(0.395. 0.43. 0.79. 0.835)	(0.18. 0.215. 0.61. 0.665)	(0.27. 0.31. 0.705. 0.76)	0.406	**0.658**	0.612	0.417	0.511
TP_3	(0.04. 0.07. 0.555. 0.59)	(0.39. 0.415. 0.915. 0.94)	(0.445. 0.475. 0.945. 0.965)	(0.065. 0.1. 0.59. 0.63)	(0.37. 0.41. 0.885. 0.91)	0.313	**0.665**	0.707	0.346	0.643
TP_4	(0.25. 0.3. 0.745. 0.805)	(0.435. 0.475. 0.86. 0.905)	(0.185. 0.23. 0.67. 0.73)	(0.095. 0.14. 0.565. 0.625)	(0.14. 0.195. 0.635. 0.695)	0.525	**0.668**	0.453	0.356	0.416
TP_5	(0.16. 0.21. 0.705. 0.755)	(0.4. 0.445. 0.915. 0.955)	(0.04. 0.075. 0.54. 0.585)	(0.435. 0.475. 0.925. 0.96)	(0.375. 0.42. 0.895. 0.935)	0.457	0.678	0.31	**0.698**	0.656
ITS	**(0.2678. 0.3096. 0.58. 0.655)**	**(0.475. 0.5. 0.7284. 0.7748)**	**(0.43. 0.46. 0.759. 0.8258)**	**(0.3474. 0.3874. 0.6904. 0.7589)**	**(0.3259. 0.3646. 0.6726. 0.7395)**	0.453	**0.619**	0.618	0.546	0.525
ITS_1	(0.17. 0.235. 0.58. 0.65)	(0.28. 0.34. 0.69. 0.76)	(0.37. 0.425. 0.765. 0.83)	(0.17. 0.235. 0.58. 0.65)	(0.195. 0.265. 0.615. 0.69)	0.4088	0.517	**0.597**	0.408	0.441
ITS_2	(0.225. 0.27. 0.58. 0.655)	(0.475. 0.5. 0.73. 0.775)	(0.43. 0.46. 0.715. 0.77)	(0.36. 0.395. 0.695. 0.76)	(0.335. 0.37. 0.675. 0.74)	0.4325	**0.62**	0.593	0.552	0.53
ITS_3	(0.27. 0.31. 0.58. 0.645)	(0.475. 0.5. 0.69. 0.73)	(0.43. 0.46. 0.675. 0.725)	(0.27. 0.31. 0.58. 0.645)	(0.27. 0.31. 0.58. 0.645)	0.4512	**0.598**	0.572	0.451	0.451

As Table 6 indicates, Alternative 2 is generally better than the other alternatives. This alternative is the best option in terms of all criteria except three criteria. It is not the best at ET_1, TP_5, and ITS_1. Alternative 5 is the

best at ET_1, Alternative 4 is the best at TP_5, and Alternative 3 is the best at ITS_1.

Figure 3 illustrates the main criteria for the sensitivity analysis. In this analysis, only one criterion is taken each time and these criteria are given (0,0,0,0) and (1,1,1,1) values, respectively. Then the new values of alternatives are obtained by solving the problem again with the new value of this criterion.

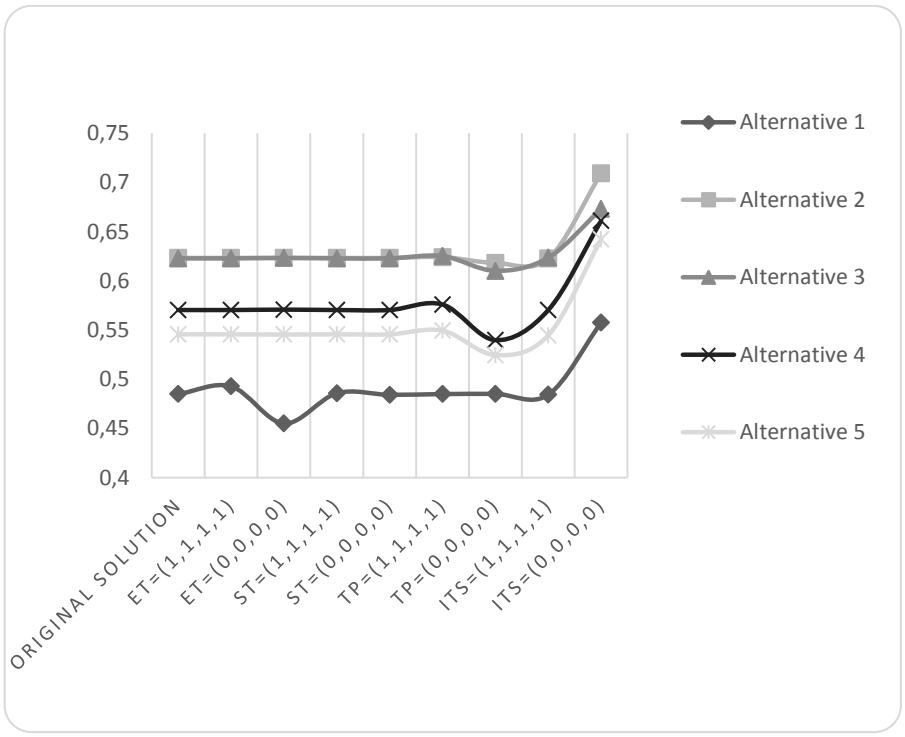

Figure 3. Sensitivity analysis.

From Figure 3, it is seen that Alternative 2 is almost insensitive to the changes in the values of the considered criteria. Alternative 1 is also insensitive and it is the worst among all.

An analysis of the results sets 3G and Upper Version as the best alternative. Wireless Networks is the second best; SMS and MMS, having similar

results, are slightly worse than Wireless Networks. GSM is in the last place by being the worst alternative in each case. It can be seen from the sensitivity analysis study carried out that the best alternative maintains its first position in different criterion weights.

6. CONCLUSION

Constructed from the concept of fuzzy measure, Choquet integral is capable of taking into account the interaction between criteria. When criteria are independent, it identifies with the weighted arithmetic mean. M-commerce makes it possible for users to access the Internet without having to find a place to plug in. M-commerce evaluation criteria have many interactions. So the m-commerce technologies is evaluated by using Choquet integral. The sensitivity analysis shows that m-commerce technologies have low sensitivity. An alternative saves its position in all the cases of sensitivity analysis. For further research, I suggest different MCDM techniques to be used and the obtained results be compared with this paper's. Furthermore, the output of this paper can be taken into account and the weak points of suggested technologies can be eliminated for improvement.

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