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A Fuzzy Model Approach for Selecting IP Carriers: A Case Study of Greek ISP

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Abstract: Modern global market has totally changed abandoning old fashion orientation strategies similar to production and sales ones. Gradually markets adopted well-developed marketing orientation strategies in order to assist companies to survive. Taking into account the world's financial situation and the recent crisis, most of the companies try to minimize the risks but in the mean time try to retain their competitive advantage. With the aid of Supply Chain Management (SCM) individual functions of companies are being integrated so as to form the supply chain network. This study illustrates a case study of IP carriers selection and evaluation for supplier management. More specifically with the use of a fuzzy model and the combination of quantitative and qualitative models IP carriers selection is made.

Key words: Triangular Fuzzy Numbers (TFN), Internet Providers (IP), vendor evaluation, supply chain management, old fashion, network

INTRODUCTION

Supply Chain Management (SCM) has attracted the interest by researchers and managers. The successful operation of SCM is a changing management process under which several individual functions are managed and integrated/combined to form a supply chain network. Harland (1996) identified Supply Chain Management (SCM) as the management of a network of interconnected businesses involved in the ultimate provision of product and service packages required by end customers. Nevertheless, the process of evaluation and supplier's selection in many cases might be proven problematic and rather complicated. Consequently, the evaluation and supplier selection might solely based on operational metrics, simple weight scoring methods or even subjective criteria. Lambert (2008) illustrated that key supply chain process involves customer relationship management, customer service management, demand management, order fulfillment, manufacturing flow management, supplier relationship management, product development and returns management.

Over the last years, several studies discuss the selection of a supplier in the context of purchasing a product which effectively can be used in a manufacturing envriroment. As far as the selection techniques are concerned, these can be described for example in terms but not limited to: Data Envelompment Analysis (DEA), Linear Weignting (LW), Data Mining (DM), Activity Based Costing (ABC), even Quality Function Deployment (QFD) and Meural Networks (NN). Other carrier selection ones can be mixed integer programming, Analytic Hierarchy Process (AHP), Goal Programming (GP), Mathematical Programming (MP), Generic Algorithm (GA), Case-Based Reasoning (CBR), Multi-Objective Programming (MOP) and Total Cost of Owenership (TCO). Taking into account the literature review findings, most of researchers combined two or more of the above mentioned techniques together. However, only few of these studies examine specifically the telecommunications sector. Van de Klundert *et al*. (2005) illustrated their model, the main purpose of which was to select international telecommunication carriers for a major telecommunication service provider. Based on their model, volume discounts were accounted and more over showed that a special case of their model resulted in a minimum cost flow model. Bottani and Rizzi (2006) had a totally different approach, actually a multi-attribute approach which had a result, the ranking and selection of the most suitable third party service provider. Amin and Razmi (2009) have introduced an integrated fuzzy model for the selection and evaluation of ISP in the region of Iran. The proposed model is divided into two phases. The qualititave metrics are evaluated with the Quality Function Deployment (QFD) and rank the best ISPs and the quantitative ones are evaluated with linearity. Then, the researchers combine

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the two models and rank the best ISP. Their proposed model, evaluates the ISPs from three perspectives: performance, competition and customer experience.

In the telecommunication services sector, Sato and Kataoka (1995) have introduced a customer satisfaction study and analyzed customer perception. All customers were surveyed regarding service order reception, provisioning and repairs. Concerning the other issues such as telegrams, directory assistance, telephone directories, network performance, terminal equipment and public telephones customers, they were surveyed randomly. The inspection results were counted up each month for the first set of items and each quarter for the rest. They actually, projected two methods of assessing the data obtained from these surveys. AHP was used to inspect the customer's perception of the importance of the Quality of Service (QoS) and estimate the overall Customer Satisfaction (CS) measured by importance. In AHP, the importance weight is obtained from data rated by a pair-wise comparison. During the survey, the respondents subjectively rated the comparative importance for every pair of items by selecting one out of nine rankings. The other way, measures customer satisfaction by categorizing customer opinions into optimistic and pessimist comments. A probability model was made, in order that it could forecast the number of optimistic and pessimist comments and which can be used to design CS objectives. In any case and taking into consideration the researchers most recent and accurate knowledge, in literature there is no similar supplier's selection and evaluaiotn model for IP carrier.

In this study and taking into account that suppliers selection mainly involves subjective criteria being rather vague and imprecise assessments, fuzzy logic has been selected as the most appropriate for qualitative criteria. According to Chou and Chang, vague and imprecise assessments are by nature fuzzy and are expressd in linguistic terms. These terms are often intuitive and rather effective for decision makers during the assessment process. Moreover, a model for IP carriers selection and evaluation is proposed which can be applied for all the ISPs in the telecommunication sector. Additionally, the majority of the published models in this filed, emphasise only on the customer perspectives or in the supplier's performance and actually lack to pay attention in the above mentioned factors or combination among them. This study, proposes a decision model that consists of two phases. In the first phase, a fuzzy model will be evaluated based on the qualitative criteria. In the second phase, a quantitative model based on weighted linear program is presented and finally by combining these two models, the best IP wholesale carrier is selected. Meanwhile, a case study is presented to illustrate and validate the two models. The case study is based on the selection of IP Carriers from one Greek ISP which provides triple play services.

This study is organizes as follows: the fuzzy model is being used together with the explanation of the linguistic variables. The quantitative model is being illustrated with the aid of which ranking and identification of the most important IP carrier can be accomplished. Then the combination of the qualitative and quantitative models is explained which in turn provides the final score results. The above results are validated with an empirical case study where the IP interconnections carriers selection criteria are illustrated.

MATERIALS AND METHODS

In this study, the fuzzy model is applied to consider qualitative criteria in supplier selection process. Zadeh (1975) has introduced first the Fuzzy Set Theory (FST) for solving problems where the decisions, observations and judgments are vague and subjective. Kaufmann and Gupta (1985) and Van Laarhoven and Pedrycz (1983) have developed an extension from the fuzzy set theory to the triangular fuzzy numbers. A Triangular Fuzzy Number (TFN) is a set of elements denoted as M = (a, b, c) where $a \le b \le c$ is a special fuzzy number which is described by the membership function μ (x) valued in the real unit interval [0, 1]. The membership function is defined as the following:

$$\mu(x) = \begin{cases} \frac{x-a}{b-a}, a \le x \le b \\ \frac{c-x}{c-b}, b \le x \le c \\ 0, x \le a \text{ or } x \ge c \end{cases}$$

Fuzzy arithmetic operations are developed by Dubois and Prade (1980) and Zadeh (1975) and are similar with the traditional ones but there are a number of operations that are valid for fuzzy numbers only. Researchers briefly summarize the basic mathematical operations for TFNs. There is assume that M1 = (a1, b1, c1) and M2 = (a2, b2, c2) based on Dubois and Prade (1980) and Chen and Hwang (1992), researchers have the following operations:

- Addition of two fuzzy numbers
- $M1 \oplus M2 = (a1+a2, b1+b2, c1+c2)$
- Subtraction of two fuzzy numbers
  $M1 - M2 = (a1-c2, b1-b2, c1-a2)$
- Multiplication of any scalar number λ with a fuzzy number
  $\lambda \otimes M2 = (\lambda\, a2, \lambda\, b2, \lambda c2), \lambda > 0$

- Multiplication of two fuzzy numbers
  $M1 \otimes M2 = (a1xa2, b1xb2, c1xc2)$
- Division of two fuzzy numbers (Δ)
  $M1 \Delta M2 = (a1/c2, b1/b2, c1/a2)$
- Division by any real number k
  $M1 \Delta k = (a1/k, b1/k, c1/k)$
- Subtraction of any real k and a fuzzy number M1
  $M1\text{-}k = (a1\text{-}k, b1\text{-}k, c1\text{-}k)$

MODEL DEVELOPMENT

On telecoms is an Internet Service Provider (ISP) in Greece which funded in 2005 which the investment of the company has been estimated to 150 million Euros in 2004. Totally, 250 personnel work in the firm in two branches. The main POP-Data center is located in Athens. The company purchases internet wholesale services from well-established IP wholesale carriers however, recently new technical problems in connections were revealed. According to the importance of internet quality and taking into account customer satisfaction especially in Business and SMEs companies, high level management decided to select multiple IP carriers and dictate for the design of a formal performance assessment process. The project is controlled and supervised by the Network Director (DMU1) in the technology division. Furthermore, procurement manager (DMU2) and wholesale marketing manager (DMU3) contribute in decision-making process. They carefully reviewed the four IP carriers (IP carrier 1, IP carrier 2, IP carrier 3 and IP carrier 4) and in this empirical study we present the process of selecting IP carrier. The aim of the decision maker is to select the best IP carrier which meets the requirements of the company (Fig. 1). The decision makers are necessary to answer in the following two questions:

- Which are the criteria that should be used to measure an IP carrier's performance?
- Which are the techniques that should be used so as to assess an IP carrier in terms of management process and by taking into account qualitative and quantitative criteria?

Considering the existing literature review findings, the majority of the researchers have presented the supplier evaluation and selection separately. But in the real cases the combined supplier management models are required. The decisions makers have decided to organize meetings in order to determine the required

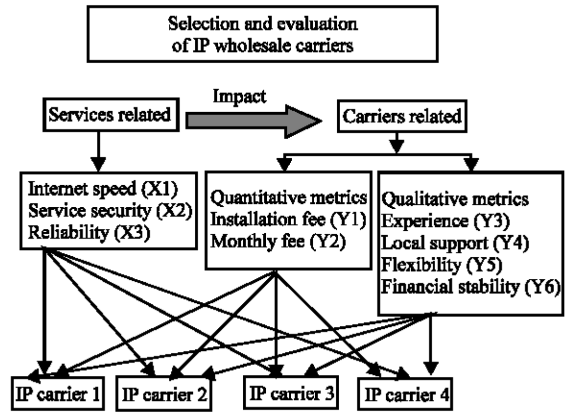

Fig. 1: Decision making model for IP carrier criteria

criteria. Criteria are organized in two groups: service related and carrier (supplier) related. Besides, carrier related group criteria are categorized to qualitative and quantitative ones shown in the Fig. 1.

SOLUTION OF THE MODEL

Kahraman *et al.* (2003) have proposed a mathematical model fos solving uncertainly and subjective problems. The fuzzy model is presented in the following steps:

Calculation of qualitative metrics

Step 1: Assume that Ω = {L, ML, M, MH, H} is the linguistic set used to present the group of criteria. The linguistic variables of Ω can be quantified using triangular fuzzy numbers as shown in the Fig. 2. However, each linguistic variable (Ω) is associated with a fuzzy numbers as shown in Table 1. Each of the three decision-makers presents the opinions in terms of linguist variable and shows the weights of each of service related criteria. The results are shown in Table 2.

Step 2: According to Chou and Chang the experience qualitative metric (Y3) is not equal for all Decision Makers (DMUs) and it is supposed that a DMU has more experience than the others. According to the Hellenic National Regulatory Authority which supervises and regulates the telecommunications, the deregulation of the telecommunication is starting the last 11 years so in the case study a decision maker is considered good in the telecom area if he has at least 10 years of experience. For this reason it is necessary to determine the weights of DMUs and assume that the weight of DMU_n is r_n. This experience qualitative metric index can be presented as linguistic variables as the shown in Fig. 3. From the Fig. 3, the linguistics variables poor, good and expert are presented as poor = (0, 0, 10); good = (5, 10, 15) and expert = (10, 20, 20). However, in the case, the decision makers DMU1 has expert experience and DMU2, DMU3 have good experience so the weights are r_1 = (10, 20, 20), r_2 = (5, 10, 15), r_3 = (5,10,15), respectively.

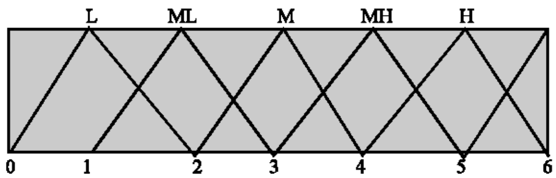

Fig. 2: Linguistic scale

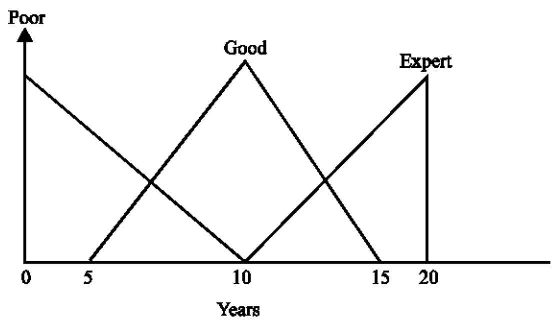

Fig. 3: Experience index

Table 1: Linguistic variable to fuzzy number association

Linguistic variables	Symbols	Fuzzy numbers
Low	L	0, 1, 2
Medium Low	ML	1, 2, 3
Medium	M	2, 3, 4
Medium High	MH	3, 4, 5
High	H	4, 5, 6

Table 2: Weigths related to service criteria

Service related criteria weights (wi)	DMU1 (w_{i1})	DMU2 (w_{i2})	DMU3 (w_{i3})
Internet speed (X1)	H (4, 5, 6)	MH (3, 4, 5)	M (2, 3, 4)
Security (X2)	H (4, 5, 6)	H (4, 5, 6)	H (4, 5, 6)
Reliability(X3)	H (4, 5, 6)	M (2, 3, 4)	H (4, 5, 6)

Table 3: Aggregated weights

Services related	r_1*w_{i1}	r_2*w_{i2}	r_3*w_{i3}	Aggregated weights (w_i)
Internet speed (X1)	40,100,120	30,80,100	20,60,80	90,240,300
Security (X2)	20,50,90	20,50,90	20,50,90	60,150,270
Reliability (X3)	20,50,90	15,40,75	20,50,90	55,140,255

Step 3: The aggregated weights (w_i) assigned by the Decision Makers (DMUs) is calculated by Eq. 1:

$$w_i = \sum_{n=1}^{N} r_n \otimes w_{in} \qquad (1)$$

where, i is the number of services relates (i = 1, 2, . . ., I) and (n) is the number of decision-makers (n = 1, 2, . . ., N). In the case study I = 3 and N = 3. Then the aggregated weights are shown in Table 3.

Step 4: Each Decision Makers (DMU) by using linguistic variables express the personal opinion for each IP carriers-suppliers in relation with the services metrics provided. The impact of each service related with the IP carriers metrics are shown in Table 4.

Step 5: The Eq. 2:

$$a_{ij} = \sum_{n=1}^{N} r_n \otimes a_{ijn} \qquad (2)$$

The Eq. 2 represents the aggregated weight (α_{ij}) between services and carriers-suppliers metrics and the results are shown in Table 5.

Step 6: The fuzzy model can be completed by calculating the weights averaging the aggregated weight for services related metrics (w_i) with the aggregated weight for carriers-suppliers metrics (α_{ij}) between them according to the Eq. 3:

$$f_j = \frac{1}{I} \otimes \sum_{i=1}^{I} w_i \otimes a_{ij} \qquad (3)$$

The fuzzy values are shown in the Table 6.

Step 7: For each IP carrier, the next step is to assess and rank. The assessment is based on the criterion in

Table 4: Impact of each services metric on each carriers-suppliers metrics

Impact of services with carriers related	Experience (Y3)			Support (Y4)			Flexibility (Y5)			Financial (Y6)		
	DMU1	DMU2	DMU3	DMU1	DMU2	DMU3	DMU1	DMU2	DMU3	DMU1	DMU2	DMU3
Speed (X1)	H	MH	ML	H	ML	MH	ML	H	H	MH	H	M
Security (X2)	H	H	H	H	MH	H	H	MH	MH	H	MH	H
Reliability (X3)	H	ML	H	H	H	M	ML	H	H	ML	H	H

Table 5: Aggregated weights between services and carriers metrics

Aggregated weights (α_{ij})	Experience (Y3)	Support (Y4)	Flexibility (Y5)	Financial (Y6)
Speed (X1)	(60, 140, 240)	(50, 140, 210)	(50, 140, 240)	(70, 180, 280)
Security (X2)	(80, 120, 300)	(80, 200, 300)	(70, 180, 270)	(75, 190, 285)
Reliability (X3)	(65, 170, 255)	(70, 180, 270)	(50, 140, 240)	(50, 140, 240)

Table 6: Fuzzy averaged carriers metrics

Metrics	Values
Aggregated weights for carriers metrics (α_{ij})	(60, 140, 240), (80, 120, 300), (65, 170, 255), (50, 140, 210), (80, 200, 300), (70, 180, 270) (50, 140, 240), (70, 180, 270), (50, 140, 240), (70, 180, 280), (75, 190, 285), (50, 140, 240)
Aggregated weights for services metrics (w_i)	(90, 240, 300), (60, 150, 270), (55, 140, 255)
Fuzzy values averaged carriers metrics (f_j)	(1531, 9711, 24255), (1550, 10022, 23250) (1289, 8978, 21800, (1250, 8778, 22417)

Table 7: Impact of each IP carriers on the suplliers related metrics

Impact of each IP carrier on the suppliers related metrics	Experience (Y3)			Support (Y4)			Flexibility (Y5)			Financial (Y6)		
	DMU 1	DMU2	DMU3	DMU1	DMU2	DMU3	DMU1	DMU2	DMU3	DMU1	DMU2	DMU3
IP carrier #1	H	H	H	MH	H	L	MH	H	ML	H	MH	M
IP carrier #2	H	L	L	L	L	ML	ML	MH	L	ML	L	MH
IP Carrier #3	H	H	H	H	MH	H	MH	H	H	H	H	H
IP Carrier #4	L	ML	MH	ML	M	MH	L	ML	ML	L	ML	L

Table 8: Supplier-Carrier Rating (SR)

IP carriers	Experience (Y3)	Support (Y4)	Flexibility (Y5)	Financial (Y6)
IP Carrier #1	(80, 200, 300)	(50, 140, 220)	(55, 150, 235)	(65, 170, 255)
IP Carrier #2	(40, 120, 180)	(5, 50, 115)	(25, 90, 165)	(25, 90, 165)
IP Carrier #3	(80, 200, 300)	(75, 190, 285)	(70, 180, 280)	(80, 200, 300)
IP Carrier #4	(20, 80, 160)	(35, 110, 195)	(10, 60, 130)	(5, 50, 115)

Table 9: FSI index for IP carriers

IP carriers	FSI index	Results
IP carrier #1	FSI_1	7, 439, 514
IP carrier #2	FSI_2	4, 431, 772
IP carrier #3	FSI_3	8, 592, 417
IP carrier #14	FSI_4	4, 195, 639

Table 10: IP carriers ranking

IP carriers	FSI_n	FSI index	Score (q_u)	Rank
IP carrier #1	FSI_1	7, 439, 514	0.7378	2
IP carrier #2	FSI_2	4, 431, 772	0.0537	3
IP carrier #3	FSI_3	8, 592, 417	1.0000	1
IP carrier #4	FSI_4	4, 195, 639	0.0000	4

question and combines it with the weight or each criterion. Same as before, linguistic variables are being used for quantification. Table 7 shows the decision makers opinions on the various IPs in relation to each carrier-supplier metrics. Consequently, for the quantification the triangular fuzzy number are used. The Supplier Rating (SR) is aggregated based on the following formula:

$$SR_{uj} = \sum_{i=1}^{N} r_i \otimes sr_{uji} \qquad (4)$$

where, j = 1, 2, . . ., J and u = 1, 2, . . ., U. Meaning, U is the number of IP carriers. The results of carrier-supllier ranking as shown in the Table 8.

Step 8: The FSI index presents the degree to which each IP carrier-supplier satisfies a given requirement. The FSI index is calculated using the Eq. 5 which it is a triangular fuzzy number (Table 9):

$$FSI_u = \frac{1}{J} * \sum_{j=1}^{J} SR_{uj} \otimes f_j \qquad (5)$$

Step 9: The scores are normalized in a 0-1 scale using the Eq. 6:

$$q_u = \frac{FSI_u - \min\{FSI_u\}}{\max_{u=1,2,\ldots,U}\{FSI_u\} - \min_{u=1,2,3,\ldots U}\{FSI_u\}} \qquad (6)$$

Finally, the scores can be ranked. Ultimate ranks and scores based on qualitative criteria are shown Table 10.

Calculation of quantitative metrics: In this study, explanation of the quantitative model which is based on weighted linear programming proposed by Ng (2008) is provided. In general the quantitative metrics such as price have high impact on decisions. According to Ferrell and Hartline (2008) views, they summarized five pricing strategies singularly critical for telecom operator's success.

More specifically, an operator can set a high price relative to the competition thereby skimming the profits off the top of the market. In penetration strategy operator set relative low prices in order to maximize sales and gain market share in a short period. Further operators focus on matching competitor's prices at the same level. Alternative, operators can offer free service to gain market share, in the expectation that other revenue sources will fund their access. Finally operators can focus on keeping the benchmark prices low while earning their profits on other services. The proposed model consists of the following steps:

Step 1: List all IP carriers which measure the two quantitative metrics such as installation and monthly fee. In the Table 11, the values of the variables are being shown.

Table 11: IP carriers quantitative metrics

IP Carriers	Installation fee (Y1, €)	Monthly fee (Y2, €)
IP carrier #1	10,000	5,125
IP carrier #2	5,000	8,600
IP carrier #3	12,555	6,500
IP carrier #4	7,000	2,800

Table 12: Normalized measures for IP carriers

Normalized measures IP carriers	Installation fee (Y1)	Monthly fee (Y2)
IP carrier #1	0.6618	0.4008
IP carrier #2	0.0000	1.0000
IP carrier #3	1.0000	0.6379
IP carrier #4	0.2646	0.0000

Table 13: Partial average results

	Partial averages with k criteria	
IP carriers	k = 1	k = 2
IP carrier #1	0.6618	0.5313
IP carrier #2	0.0000	0.5000
IP carrier #3	1.0000	1.0000
IP carrier #4	0.2647	0.1323

Table 14: Ranking scores

	Ranking scores	
IP carriers	Score	Rank
IP carrier #1	0.6618	2
IP carrier #2	0.5000	3
IP carrier #3	1.0000	1
IP carrier #4	0.2647	4

Step 2: Normalize all the quantitative variable values in a 0-1 scale of Table 11. A set of U IP carriers are available and the scope is to select them according to K quantitative criteria. The metric of IP_u under criterion k is denoted as x_{uk} (u = 1, 2,. . .,U, k = 1, 2,. . ., K). Next, there is normalize all measures x_{uk} into a 0-1 scale by the Eq. 7 and denote them as y_{uk}.

$$y_{uk} = \frac{x_{uk} - \min\{x_{uk}\}}{\max_{u=1,2,\ldots,U}\{x_{uk}\} - \min_{u=1,2,3,\ldots U}\{x_{uk}\}} \quad (7)$$

In the Table 12 the normalized results for IP carriers are presented:

Step 3: Then, all partial averages are being calculated by the Eq. 8:

$$\frac{1}{k} * \sum_{g=1}^{k} y_{ug},\ k=1,2,\ldots,K \quad (8)$$

Step 4: From the Table 13, a comparison and selection is being made taking into account the maximum score among these partial averages. The maximum value is the score of each IP carrier. Then researchers rank the scores and identify the most important IP carrier. Table 14 shows the scores and the rank.

COMBINATION OF MODELS

In two previous studies, the scores of IP carriers based on qualitative and quantitative criteria were calculated. However, in order to obtain the final scores, a combination between them is necessary. Suppose that q_u is the score of IP_u carrier that is obtained from qualitative model (Table 10) and z_u is the score of IP_u carrier which is calculated by quantitative model (Table 14). Furthermore, λ_1 and λ_2 are the weights of the qualitative model and the quantitative model respectively which $\lambda_1+\lambda_2 = 1$. These parameters are determined by Decision Makers (DMUs) of the organization. After organizing meeting the members of committee decide that: $\lambda_1 = 0.6$ and $\lambda_2 = 0.4$. Effectively, the final score of each IP_u carriers SC_u is calculated by using the Eq. 9:

$$\lambda_1 q_u + \lambda_2 z_u = SC_u \quad (9)$$

Table 15: Final ranking scores

IP carriers	Qualitative score (q_u)	Quantitative score (Z_u)	Final score (Sc_u)	Final rank
IP carrier #1	0.7378	0,6618	0,7074	2
IP carrier #2	0.0537	0,5000	0,2322	3
IP carrier #3	1.0000	1,0000	1,0000	1
IP carrier #4	0.0000	0,2647	0,1058	4

The results of the Eq. 9 are shown in the Table 15. From Table 15 it is observed that IP carrier #3 and IP carrier #1 are selected with final scores 1.0000 and 0.7074, respectively.

CONCLUSION

This study illustrated a case study of IP carriers selection and evaluation for supplier management. Most operators mainly due to the global financial crisis have slow growth and pricing pressures start to arise due to heavy competition. This has as aftereffects mergers and acquisitions. Nevertheless, for the executive board, strategic decisions have to be made in order to minimize risks, understand customer and the market as a whole. The fuzzy modeling has proven to be useful for the decision makers from the macroeconomic point of view and also the fuzzy logic addresses the ambiquities associated with the personal criteria of the decision makers in best possible way. The contribution of this study is three-fold:

- Researchers provide a compreshensive model base on fuzzy methodology for the qualitative criteria
- Researchers provide a weighted linear model for the quantitative criteria
- Researchers use a real case study and demonstrated the applicability of the models

There are many research areas for future works in this field. A fuzzy ahp model can be developed to produce some results for the qualitative criteria or a fuzzy dea model can be used for produced efficiencies for quantitative criteria. Both these methodoligies are an important area for future research.

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