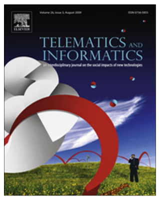
Telematics and Informatics xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Telematics and Informatics

journal homepage: www.elsevier.com/locate/tele



Analyzing customer preference and measuring relative efficiency in telecom sector: A hybrid fuzzy AHP/DEA study

Ajay Kumar [a,*], Roma Mitra Debnath [b], Ravi Shankar [c], Jaideep Prabhu [d]

[a] *Bharti School of Telecommunication Technology and Management, Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110016, India*
[b] *Indian Institute of Public Administration, Indraprastha Estate, Mahatma Gandhi Marg, New Delhi 110002, India*
[c] *Bharti School of Telecommunication Technology, Department of Management Studies, Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110016, India*
[d] *Judge Business School, University of Cambridge, Trumpington Street, Cambridge CB2 1AG, UK*

ARTICLE INFO

Article history:
Received 31 July 2014
Accepted 29 October 2014
Available online xxxx

Keywords:
Fuzzy set theory
Data envelopment analysis
Indian telecom industry
Policy requirements
Revenue efficiency
Benchmarking

ABSTRACT

The purpose of this research paper is to develop a framework to understand the consumer's preference affecting variables and consumer's perception choice in telecommunication service providers in India. The present study use a hybrid approach to access the relative efficiency based on fuzzy AHP and DEA model. The fuzzy AHP is used to determine weights of the consumer's preference as criteria and DEA method is used to identify the inefficient service providers in terms of efficiency. Findings of the study suggest that the most preferred value that determines consumer's preference by mobile subscribers is network parameters, followed by low tariff scheme. Our results also show that technical efficiency and technical progress indicator are the main factors of resources allocation of Indian telecom industry. Most of the work on this hybrid FAHP–DEA is dedicated to either vendor selection, facility layout problem or supplier selection. A study of this kind, in the context of mobile subscriber's preference is an original contribution to the literature of Indian telecom sector. This research paper identifies the different variables and then a model is prepared for benchmarking of the mobile service providers in India. Based on the efficiency analysis decision makers can develop strategy to improve their performance according to efficient service providers as their role model. The other advantage of this hybrid AHP/DEA method is that by using inputs and outputs data we can derive mathematically all pair wise comparisons in fuzzy AHP and DEA models and there is no any form of subjective analysis engaged within the methodology.

1. Introduction

Telecommunication is one of the fastest growing sectors across globe with excellent potential for the future. Telecommunication sector has played an important role for rapid growth for different sectors of the economy over the last decades. Telecom service sector made remarkable progress by allowing big amount of cross-boundary information flows, stimulating customer demand for top class brands, products, solution and services by reducing transaction costs. Telecom sector is playing very important role for growth in economy of all countries. Bohlin et al. (2007) have shown the different telecom technology and regulation implications for growth and competitiveness in European telecom market like spectrum policy, licensing scheme and network rollout. Investment in improving communication infrastructure does not imply the increase

* Corresponding author. Mobile: +91 9582618207.
E-mail address: ajay.tomar@dmsiitd.org (A. Kumar).

http://dx.doi.org/10.1016/j.tele.2014.10.003
0736-5853/© 2014 Published by Elsevier Ltd.

customer satisfaction and loyalty. If telecom service providers can understand the relation among the customer satisfaction, customer loyalty and the performance of operators then they may give the new dimensions in this sector toward the management. Benchmarking is a popular choice for this purpose. By benchmarking of different mobile service provider companies we can evaluate their efficiency and this study will be very helpful for measuring the differences in customer satisfaction and loyalty efficiency and will help telecom experts for making proper policies and regulations for customers. The question is how mobile operators benchmark the best practice. Madden et al. (2004) have also studied the growth of mobile network and economic factors by using dynamic demand model based on 56 countries telecommunication panel data. Improvement in telecom services can be a cause of socio-economic development of any country. More recently Moreno et al. (2013) have also applied DEA approach to evaluate LECs' performance from year 1997 to 2007 and regression analysis approach has been come out to construct the effect of regulation schemes upon efficiency. Sung (2012) have used MPI method to compute the productivity and calculated the impacts of competitive pressure, strategies and regulation schemes on downturn in production growth by TFP-type of level regression analysis. Some attempts have been carried out for the purpose of calculating technical efficiency in U.S. telecom services market (Banker et al., 2010). A Window analysis approach was used by Yang and Chang (2009) to measure the telecom firms' efficiencies in Taiwan over the 2001–2005 period. The impact of the deregulatory environment on the effectiveness of Incumbent Local Exchange Carriers from 1988 to 2000 had been examined to some level by Resende (2008) by Data Envelopment Analysis. Sastry (2009) additionally utilized DEA to study the links between these major modifications in competition and the overall performance features of telecomm service providers, focusing on the service quality. In the last few years progress in telecommunication are changing the world economy but policy makers and public are criticizing the mobile service providers for keeping call rate much lower but with improved quality of service (Debnath and Shankar, 2008).

The objective of this paper is to measuring the relative efficiencies using data envelopment analysis based on performance and customer's preferences for benchmarking the quality of service in Indian mobile sector. In this paper we use the fuzzy AHP for shortlisting the variables which are affecting the customer's preference and these variables will be used as inputs for DEA analysis. The paper is organized in this following way. The next section reviews the Indian mobile sector and also discusses the teledensity and robust growth over the years in India. Section 2 discusses the performance parameters and variables affecting the consumer's preference based on literature review. Section 3 provides the detailed methods of fuzzy AHP and data envelopment analysis for measuring the relative efficiency. Section 4 presents the result of fuzzy AHP analysis and DEA approach. The final section summarizes or findings and discuss the implications of this study for telecom policy makers and provides concluding remarks.

1.1. Indian telecom market

Indian mobile service market is facing a tough competition by reforming government policies and entry of new companies. Objectives of these new policies are increasing the number of customers with lower tariffs rates. Indian telecom network is the second largest in the world after China based on the number of mobile and landline phones. Indian telecom sector has one of the lowest call tariffs and third-largest Internet users in the world. This sector has marked an impressive growth during this 2011–12 year in Indian market by increasing telephone subscriptions from 846.32 million to 951.34 million with 12.41% growth. As per (TRAI annual Report 2011–12), the mobile user base increased by 107.58 million and landline base recorded a decline of 2.56 million. The mobile segment continued to register 919.17 million connections. The rural teledensity increased from 33.79 to 39.22 and urban teledensity from 157.32 to 169.55. Overall teledensity in the India increased from 70.89 to 78.66. The gross income of Indian telecom services has increase from Rs. 1,71,719 crore to Rs. 1,95,442 crore during this 2011–12 year with 13.82% growth. All telecom service providers are going to improve their service for increasing the profit due to global competition. In Indian telecom market Bharti Airtel, Idea, Vodafone India, BSNL, Tata Indicom and Reliance are the leading players in the mobile service area. In Indian mobile telephony sector Vodafone and Idea's overall performance is additionally shown in their sales revenue growth. Vodafone sales expanded 21.3% and Idea grew 26.4% during 2011–12 in comparison to the financial growth of 14.8%. Airtel, nevertheless, saw just a 10.7% growth in sales in 2012, and along with Reliance and BSNL-both recorded the negative rate of growth during this period.

2. Literature review

DEA has been widely used for benchmarking and evaluation of performance in different sectors. In telecommunication sector DEA has been applied for calculating relative efficiency of different companies. Zeithaml et al. (1996) have established a relationship between customer satisfaction, loyalty, customer profitability and service quality. Majumdar (1997) used the DEA for modularity and obtained the patterns of resources in US Telecom companies. Madden and Savage (1999) used the DEA approach for calculating the productivity index and told how the developing countries can improve efficiency using technological catch-up. Giokas and Pentzaropoulos (2000) used this data envelopment analysis for measuring the efficiency of telecom companies in Greece and investigated how much units were efficient and How much were inefficient. Zhu (2003) has been used DEA for evaluation the relative efficiency in Korean telecom industries with strong ordinal input/output. Resende (2008) used the DEA model for efficiency measurement in US telecom market and compare the result with stochastic frontier analysis for obtaining moderate consistency in these approaches for making new regulation in telecom industries.

Debnath and Shankar (2008) used the DEA model for identify the inefficient service providers in a few states of India not for national level.

Yang and Chang (2009) used the Data Envelopment Analysis window analysis to calculate the efficiency of Taiwan telecom companies after pre and post-privatization. Bayraktar et al. (2012) used the DEA for measuring the customer satisfaction and loyalty efficiency for mobile sector in Turkey and prove CS&L can play an important role for attract the market share and profitability. Analytic Hierarchy Process (AHP) used to solve the complex problem which has multiple conflicting criteria. Most application are economic planning, location, selection, production, investment selection and ranking of different projects (Satty, 1980; Liberatore and Nydick, 2008; Zahedi, 1986). But use of AHP in telecommunication area have found very
Q3 less in the literature. Malladi and Min (2005) used the AHP to select internet access technology with integer programming based on cost, quality and speed. Kuo and Chen (2006) used the AHP for selection and ranking the values added services in different mobile service provider companies. Alkahtani, Woodward and Al-Begain (2006) have applied AHP for giving priority in communication network with four qualities of service metrics. Fu, Yang and Tzeng (2007) have analyzed the strategies to open mobile virtual network services for location selection and economic planning in Taiwan. Giokas and Pentzaropoulos (2008) have applied first time AHP and DEA both approaches for efficiency ranking the Economic Co-operation and development (OECD) members state and pair wise country performance evaluation There are just one paper in telecommunication sector Giokas and Pentzaropoulos (2008) which use the DEA and AHP approaches for measuring the efficiency and ranking the states after pair wise country performance evaluation. This paper makes an attempt to benchmark the service of Indian mobile service provider companies and ranking of telecom service providers under different criteria of consumer's preference which comes from fuzzy AHP approach and used as input/output for DEA analysis. We use the DEA analysis because regression analysis uses multiple inputs or outputs but not both. Regression provides only average relationships and requires a functional relationship between input/outputs. Regression predicted average behavior but DEA gives best practice frontier. That is the reason we applied DEA for measuring the efficiency in telecom sector with fuzzy AHP.

3. Methods (fuzzy AHP and DEA approach)

3.1. Fuzzy AHP

Analytic hierarchy process is introduced by Satty (1980) which is a very useful tool for allocating the relative importance or ranking based on weights of criteria. It incorporates qualitative as well as quantitative factors or variables in the process of decision making. AHP are generally criticized by the expert's for capturing knowledge of a discrete scale which can not reflect human thoughts with uncertainty in choosing the priorities of preferences differently. Fuzzy-AHP applied for the research to solve the hierarchical fuzzy decision maker's thinking problems for taking linguistic vagueness. Fuzzy-Analytic hierarchy process has been commonly used to deal with multi-criteria fuzzy decision making problems in many fields, for example vendor selection problem in supply chain by Haq and Kannan (2006) R&D project selection by Huang et al. (2008). AHP is used for developed tools for knowledge portal by Kreng and Wu (2007), bridge construction selection method by Pan (2008), Global supplier selection by Chan et al. (2008), maintenance policy selection by Ilangkumaran and Kumanan (2009) and selection the personnel problems by Güngör, Serhadlio and Kesen (2009).

Zadeh (1965) proposed fuzzy set theory for capturing the reflect of vagueness in human thoughts. Fuzzy set is special class of objects and it is defined by a membership function. In fuzzy AHP membership functions allocate to each object a membership grade between 0 and 1 range. A tilde '∼' is used above a letter in the function if the letter presents fuzzy set. We use triangular fuzzy number (TFN) in fuzzy AHP to explain the fuzzy event which is represented as (l, m, n) shown in figure. The parameters l, m and n denote smallest, most promising and the largest possible value respectively for any fuzzy event (see Fig. 1).

These are a number of definitions of fuzzy sets discussed:

Definition 1. If $\tilde{A}_1 = (l_1, m_1, n_1)$ and $\tilde{A}_2 = (l_2, m_2, n_2)$ and then the operational laws of addition, subtraction, multiplication, reciprocal and division for these two TFN can be presented as follows by Zadeh (1965):

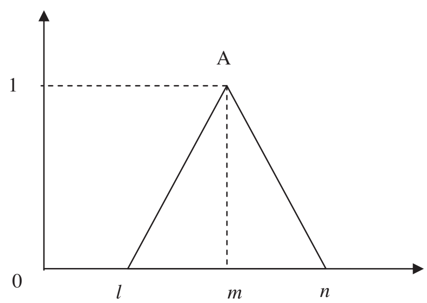


Fig. 1. Triangular fuzzy number.

$$\tilde{A}_1 \ominus \tilde{A}_2 = (l_1, m_1, n_1) \ominus (l_2, m_2, n_2) = (l_1 - n_2, m_1 - m_2, n_1 - l_2)$$

$$\tilde{A}_1 \oplus \tilde{A}_2 = (l_1, m_1, n_1) \oplus (l_2, m_2, n_2) = (l_1 + l_2, m_1 + m_2, n_1 + n_2)$$

$$\tilde{A}_1 \otimes \tilde{A}_2 = (l_1, m_1, n_1) \otimes (l_2, m_2, n_2) = (l_1 l_2, m_1 m_2, n_1 n_2)$$

$$\tilde{A}_1 \oslash \tilde{A}_2 = (l_1, m_1, n_1) \oslash (l_2, m_2, n_2) = (l_1/n_2, m_1/m_2, n_1/l_2)$$

$$\lambda \otimes \tilde{A}_1 = (\lambda l_1, \lambda m_1, \lambda n_1) \quad \text{where} \quad \lambda > 0$$

$$\tilde{A}_1^{-1} = (l_1, m_1, n_1)^{-1} = \left(\frac{1}{n_1}, \frac{1}{m_1}, \frac{1}{l_1}\right)$$

In the fuzzy-AHP method (TFNs) are applied to give the interval assessment for preferences and then pairwise comparison is calculated.

Definition 2. Fuzzy set $\tilde{A}$ in X is defined by membership function $\mu_{\tilde{A}}(x) \in (0, 1)$. It is used to present the membership grade of x to $\tilde{A}$. Nearer is value of $\mu_{\tilde{A}}(x)$ to unity and the higher is membership grade of x to $\tilde{A}$ by Zadeh (1965).

Definition 3. Membership function of a (TFN) $\tilde{A}$, represented by (l, m, n), is defined as

$$\mu_{\tilde{A}}(x) = \begin{cases} \frac{x-l}{m-l}, & l \leqslant x \leqslant m, \\ \frac{n-x}{n-m}, & m \leqslant x \leqslant n, \\ 0, & \text{otherwise} \end{cases}$$

And the degree of membership for any fuzzy number is:

$$\tilde{A} = (A^{L(y)}, A^{R(y)})$$

$$\tilde{A} = (l + (m - l)y, n + (n - m)y), y \in [0, 1]$$

The fuzzy-AHP process is described as follows:

Step 1: By using Fuzzy numbers calculate the fuzzy synthetic extent value for pairwise comparisons of attributes:

Let $X = \{x_1, x_2, \ldots, x_n\}$ and $U = \{u_1, u_2, \ldots, u_m\}$ be object set and goal set respectively. Using Chang's extent analysis approach m extent analysis values for each object can be calculated and denoted as:

$$A^1_{g_i}, A^2_{g_i}, \ldots, A^m_{g_i} \qquad i = 1, 2, \ldots, n,$$

where $A^j_{g_i} (j = 1, 2, \ldots, m)$ are triangular fuzzy numbers.

$$Si = \sum_{j=1}^{m} Mij \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} Mij\right]^{-1}$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{ij} = \quad \sum_{i=1}^{n}\sum_{j=1}^{m} l_{ij}, \sum_{i=1}^{n}\sum_{j=1}^{m} m_{ij}, \sum_{i=1}^{n}\sum_{j=1}^{m} u_{ij}\Bigg)$$

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} Mij\right]^{-1} = \quad \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} u_{ij}}, \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} m_{ij}}, \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} l_{ij}}\Bigg)$$

with the respect to ith object, value or cost of fuzzy extent :

$$S_i = \sum_{j=1}^{m} A^j_{g_i} \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} A^j_{g_i}\right]^{-1}$$

Step 2: Compare the fuzzy values and calculate the degree of possibility by Chang (1996):
Degree of possibility $\tilde{A}_2 = (l_2, m_2, n_2) \geq \tilde{A}_1 = (l_1, m_1, n_1)$ is defined as:

$$V(A_2 \geqslant A_1) = \underbrace{SUP}_{x \geq y} \left[\min\left(\mu_{A_1}(x), \mu_{A_2}(y)\right)\right]$$

when (x, y) exists such that $x > y$ and $\mu_{A_1}(x) = \mu_{A_2}(y) = 1$, then we have $V(A_2 \geq A_1) = 1$.
A_1 and A_2 are convex fuzzy numbers expressed as follows:

$$V(A_2 \geq A_1) = hgt(A_1 \cap A_2) = \mu_{A_2}(d)$$

when $\tilde{A}_1 = (l_1, m_1, n_1)and\tilde{A}_2 = (l_2, m_2, n_2)$ and $V(A_1 \geq A_2)$ and $V(A_2 \geq A_1)$ then $\mu_{A_2}(d)$ expression is as follows:

$$\mu_{A_2}(d) = \begin{cases} 1, & m_2 \geq m_1, \\ 0, & l_1 \geqslant n_2, \\ \frac{l_1 - n_2}{(m_2 - n_2) - (m_1 - l_1)}, & \text{otherwise}. \end{cases}$$

Step 3: Calculate the Priority weight by Gumus (2009):
Degree possibility of fuzzy number A_i ($i = 1, 2,\ldots, k$) can be defined by:

$$V(A \geq A_1, A_2, \ldots, A_k) = V[(A \geq A_1) \text{ and } (A \geq A_2) \text{ and} \ldots \text{ and } (A \geq A_k)]$$

$$= \min V(A \geq A_i) \; i = 1, 2, \ldots, k$$

If

$$m(P_i) = \min V(S_i \geq S_k) \quad \text{for} \quad k = 1, 2, \ldots, n; \quad k \neq i.$$

Weight vector is defined by:

$$W_p = (m(P_1), m(P_2), \ldots, m(P_n))^T$$

where $P_i (i = 1, 2, \ldots, n)$ are n elements.

Step 4: We calculate and normalize the weight vectors as follows:
After normalization of Wp taking W as a non fuzzy number we can calculate the normalized weight vectors

$$W = (w(P_1), w(P_2), \ldots, w(P_n))^T$$

3.2. Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) is a data oriented approach which is used for measuring the performance of a set of Decision Making Units (DMUs). Decision Making Units (DMUs) is used for convert the multiple inputs into multiple outputs. Charnes, Cooper, and Rhodes (1978) described DEA as a 'mathematical programming model which is applied to observational data for measuring the relative efficiency. DEA model deals with multiple inputs and outputs in a single integrated model and provides targets for improvement over time. In DEA Linear programming (LP) used to construct a non-parametric surface over the data and we have to solve one LP for each DMU. If we are reducing the inputs proportionally with fixed outputs then this type of model is called Input-orientated model. In output-orientated model, outputs can be proportionally expanded with fixed inputs. DEA model can be applied under the assumption of constant returns to scale (CRS) and variable returns to scale (VRS). Mathematical formulation of Data Envelopment Analysis (DEA) model is (Charnes et al., 1978):

$$\text{Max} h_0 = \frac{\sum_{r=1}^{s} u_r y_{rj0}}{\sum_{i=1}^{m} v_r x_{ij0}}$$

Subject to:

$$h_0 = \frac{\sum_{r=1}^{s} u_r y_{rj0}}{\sum_{i=1}^{m} v_r x_{ij0}} \leqslant 1 \quad \text{for all j} = 1, 2, 3, \ldots, \text{n},$$

$$u_r v_i \geqslant 0; \quad \text{r} = 1, 2, 3, \ldots \text{s and i} = 1, 2, 3, \ldots, \text{m}$$

u_r and v_i are weights given to output r and input i. y_{rj} and x_{ij} are the amounts of output r and input i produced by DMU_j. DEA provides efficiency score for each DMU and it gives target for all inefficient DMUs. DEA provides information on how much inputs can be decreased or outputs increased to make the unit efficient. DEA creates a efficient frontier consisting of the best performing DMUs and tells to policy makers and DMU managers to "what to do" by the identification of the peer group, which is a reasonable argument why this comparison is fair and it is indication of how important a particular DMU can be a role model for others DMUs. We can understand How DEA works in a simple way. In Fig. 2 there are five branches B1, B2, B3, B4 and B5. Three branches B1, B2 and B3 are efficient and the line connecting them is called the "envelopment surface" because it envelops all the cases. B1, B2 and B3 are efficient because they lie on efficient frontier and B4 and B5 are not on the envelopment surface and they lie below the efficient frontier so they are inefficient.

Please cite this article in press as: Kumar, A., et al. Analyzing customer preference and measuring relative efficiency in telecom sector: A hybrid fuzzy AHP/DEA study. Telemat. Informat. (2014), http://dx.doi.org/10.1016/j.tele.2014.10.003

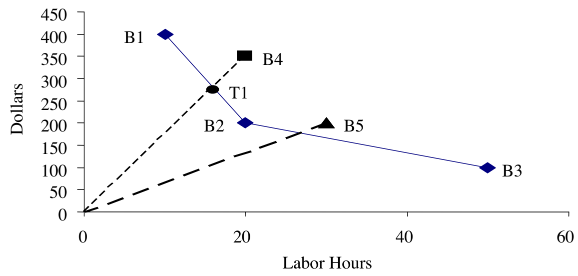


Fig. 2. Input oriented model.

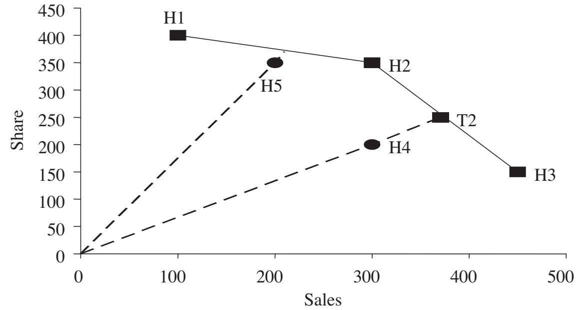


Fig. 3. Output oriented model.

In Fig. 3 H4 and H5 are not on the envelopment surface so they are evaluated as inefficient by DEA analysis. There are two way to explain these analysis. One is to say that target for B4 is to decrease the input at T1 and target for B4 is decrease the output at T2 for obtaining the envelopment surface or efficiency frontier.

CCR and BCC are the two useful models in DEA. The CCR model estimates the global technical efficiency and BCC model measures pure technical efficiency of a DMU. The difference between these CCR and BCC models is based on returns – to-scale (Charnes et al., 1978). Scale efficiency (SE) measures the firm's success in choosing a set of input with a given set of input–output costs. CRS assumption is only appropriate when all firms are operating at an optimal scale if all the firms are not operating at the optimal scale then we measures technical efficiency (TE) which are baffled by scale efficiencies (SE). By evaluating VRS and CRS models we can calculate the SE by keeping in mind difference in their score.

4. Proposed hybrid fuzzy AHP-DEA model development

4.1. Framework of this research

This framework use a hybrid approach to access relative efficiency based on fuzzy set theory, AHP and DEA. Fuzzy AHP is utilized to model the vagueness or we can say uncertainty in real world data. In the first phase, fuzzy AHP is used for ranking of variables, which are affecting the consumer's preference under different criteria in Indian mobile sector because it deals with vagueness in human thought for modeling linear uncertainty. On the second phase data envelopment analysis (DEA) is used to identify the strongest & weakest service providers and compare their relative efficiency under allocated the relative weight criteria of consumer's preference comes from fuzzy AHP approach. This result will help to develop a strategic based plan for telecom companies for measuring the customer satisfaction based on consumer's preference affecting factors and they will able to identify the inefficient telecom service providers based on efficiency so that decision and policy makers can develop the strategy to improve their performance according to efficient service providers as their role model (See Fig. 4).

4.2. Selection of inputs and outputs

To validate the ranking of variables, that are affecting the consumer's preference, a research study has been conducted for telecom companies in India. A group survey has been conducted for telecom policy experts and managers who have more than fifteen years experience in this domain. Due to some reasons, the identities of telecom experts have not been disclosed so they have been referred to as Expert 1, Expert 2, Expert 3, Expert 4, Expert 5, and Expert 6. For applying fuzzy AHP approach, a request has been made for all experts to express their opinion in a questionnaire following a linguistic scale. TRAI publish key performance indicator reports of mobile service providers. On basic of this report and available literature we

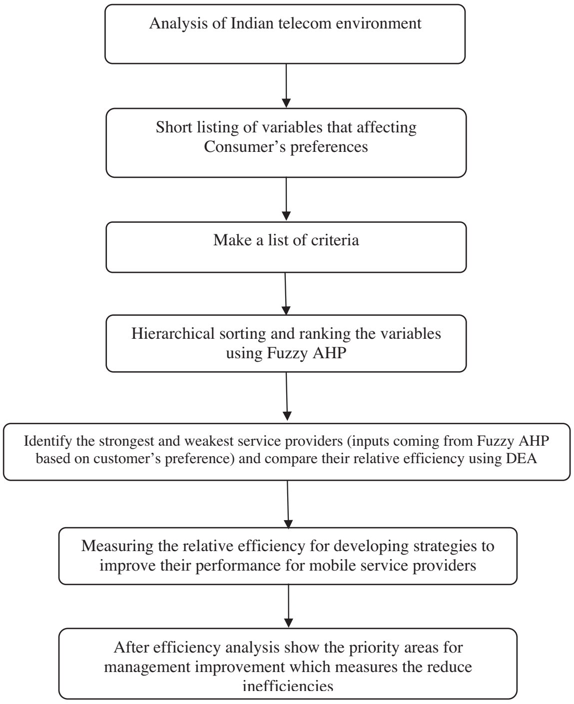


Fig. 4. Framework of research.

identified the total eight variables which are affecting the customer's preference. Network parameters, low tariff scheme, good voice quality, call charge, billing credibility, customer care approach, value added services and brand image are the total eight variables which have used in this studies for fuzzy AHP analysis. For measuring the performance and identifying the weakest and strongest service providers using DEA selection of inputs and outputs are the most important task. This study based on DEA analysis uses the latest published data for year 2011–12 compiled by TRAI (www.trai.gov.in).The selection of input and outputs for this study based on those variables that affecting the consumer's preference in mobile sector. Findings of the Fuzzy AHP study suggest that the most preferred value that determines consumer's preference by mobile subscribers is network parameters (BTS downtime, call success rate and call drop rate), followed by billing credibility. Based on this input which is coming from Fuzzy AHP we will identify the strongest and weakest service providers and compare their relative efficiency using DEA.

Facanha and Resende (2004) have done a study for choice of variables based on literature in international experience. The
316 Q4 variables' choice is based on latest published study of available literature Nigam et al. (2012). As per availability and accessibility of data eight parameters have chosen for inputs and outputs. Good voice quality, call drop rate, BTS downtime and call success rate have chosen as the inputs. Numbers of subscribers, billing credibility, accessibility of call center and percentage of call answered by operators (within 60 s) have chosen as outputs for this study based on available literature review. First of all we make the hierarchy of fuzzy AHP based on these inputs and identify and ranking the variables that are affecting the customer's preference and these inputs and outputs will use for DEA analysis. For DEA analysis we make three different clusters of Indian telecom mobile data. The first cluster consist all DMUs that have subscribers up to 5 million. The second cluster has the DMUs that have mobile subscribers between 5 and 9 million. The third cluster has more than 9 million subscribers in each DMUs. By the rule of DEA, the DMUs number should be a minimum of double the total of the amounts of outputs and inputs. In our study there are four inputs and four outputs which require a total of 16 DMUs. But in present study we have more than 16 DMUs in all three different clusters. This indicates that we have a satisfactory sample size for our study.

4.3. Extent analysis method: AHP

Using Chang's analysis approach extent analysis values (m), each object is taken and extent analysis value for each goal
330 Q5 performed. So in this method, the fuzzy conversion scale is as in Tables 1–3.

Now we will obtain the Fuzzy evaluation matrix with respect to the goal.

The fuzzy extent values of these six criteria with the respect to goal are calculated by using Eq. (9).

$$S_{NP} = (14.332, 17.315, 20.227) \times (1/100.67, 1/85.167, 1/72.700)$$

Please cite this article in press as: Kumar, A., et al. Analyzing customer preference and measuring relative efficiency in telecom sector: A hybrid fuzzy AHP/DEA study. Telemat. Informat. (2014), http://dx.doi.org/10.1016/j.tele.2014.10.003

Table 1
Linguistic variables and their fuzzy representation.

Linguistic scale	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Equally important	(1,1,1)	(1,1,1)
Slightly more important	(1,3/2,2)	(1/2,2/3,1)
Strongly more important	(3/2,2,5/2)	(2/5,1/2,2/3)
Very strongly more important	(2,5/2,3)	(1/3,2/5,1/2)
Absolutely more important	(5/2,3,7/2)	(2/7,1/3,2/5)

$$S_{LTS} = (11.423, 13.460, 15.790) \times (1/100.67, 1/85.167, 1/72.700)$$

$$S_{GVQ} = (12.239, 14.574, 16.893) \times (1/100.67, 1/85.167, 1/72.700)$$

$$S_{CC} = (11.156, 12.856, 14.689) \times (1/100.67, 1/85.167, 1/72.700)$$

$$S_{BC} = (9.340, 11.091, 13.010) \times (1/100.67, 1/85.167, 1/72.700)$$

$$S_{CCA} = (7.047, 8.331, 9.747) \times (1/100.67, 1/85.167, 1/72.700)$$

$$S_{VAS} = (3.924, 4.843, 5.867) \times (1/100.67, 1/85.167, 1/72.700)$$

$$S_{BI} = (3.239, 3.697, 4.447) \times (1/100.67, 1/85.167, 1/72.700)$$

$$S_{NP} = (0.142, 0.203, 0.278)$$

$$S_{LTS} = (0.113, 0.158, 0.217)$$

$$S_{GVQ} = (0.121, 0.171, 0.232)$$

$$S_{CC} = (0.110, 0.150, 0.202)$$

$$S_{BC} = (0.092, 0.130, 0.178)$$

$$S_{CCA} = (0.070, 0.097, 0.134)$$

$$S_{VAS} = (0.038, 0.056, 0.080)$$

$$S_{BI} = (0.032, 0.043, 0.061)$$

Now we will compare the fuzzy values and calculate the degree of possibility. The next important step of Chang's analysis method is to calculate the degree of possibility. It is a method of calculating the priority based greatest fuzzy number by comparing among other fuzzy numbers.

Now we calculate the Priority weight by calculating domination flows and the weakness flows of all different alternatives. So weight vector is:

$W' = (1,0.625,0.737,0.530,0.330,0.081,0,0)$

After normalization of W' we get normalized weight vectors as

$W = (0.302,0.189,0.221,0.160,0.099,0.024,0,0)$

By applying fuzzy AHP we have identified a list of variable's ranking which are affecting the consumer's preference in Indian mobile sector. Network parameter have gained highest score (0.302) it means this element of service play an important role for customer satisfaction and selling of cell phones. Good voice quality plays second important role of affecting the customer's preference. Value added service and brand image play an equal important role for customer choice requirements that determine satisfaction.

4.4. AHP and DEA integration

The idea of integration AHP with DEA is not really new. There have been numerous attempts to combine AHP with DEA in real world business applications. Bowen (1990) has compared AHP and DEA methodologies for a problem of site selection for discussing their similarities. Seifert and Zhu (1998) examined deficits and excesses of industrial returns and productivity for (1953–1990) years in China by integrating DEA with AHP technique. Yang and Kuo (2003) solved the facility layout design problem using this integrated AHP/DEA method. They have applied the AHP for collecting the qualitative performance data and identified performance efficient frontiers using the DEA technique. Saen et al. (2005) have discussed a method of mea-

Table 2
The fuzzy comparison matrix of criteria.

Performance attributes	Network parameters	Low tariff scheme	Good voice quality	Call charge	Billing credibility	Customer care approach	Value added service	Brand image
Network parameters	(1,1,1)	(1.452,1.853,2.229)	(1.414,1.581,1.732)	(1.452,1.853,2.229)	(1.778,2.289,2.797)	(2.236,2.739,3.240)	(2.500,3.000,3.500)	(2.500,3.000,3.500)
Low tariff scheme	(0.449,0.540,0.689)	(1,1,1)	(0.502,0.618,0.816)	(0.891,1.070,1.414)	(1.581,1.732,1.871)	(2.500,3.000,3.500)	(2.000,2.500,3.000)	(2.500,3.000,3.500)
Good voice quality	(0.577,0.677,0.794)	(1.334,1.513,1.672)	(1,1,1)	1.165,1.201,1.232)	(1.427,1.944,2.455)	(2.000,2.500,3.000)	(2.500,3.000,3.500)	(2.236,2.739,3.240)
Call charge	(0.449,0.540,0.689)	(0.707,0.816,1.00)	(1.000,1.000,1.000)	(1,1,1)	(1.000,1.000,1.000)	(2.000,2.500,3.000)	(2.500,3.000,3.500)	(2.500,3.000,3.500)
Billing credibility	(0.358,0.437,0.562)	(0.535,0.577,0.632)	(0.447,0.577,0.816)	(1.000,1.000,1.000)	(1,1,1)	(2.000,2.500,3.000)	(1.500,2.000,2.500)	(2.500,3.000,3.500)
Customer care approach	(0.309,0.365,0.447)	(0.286,0.333,0.400)	(0.333,0.400,0.500)	(0.333,0.400,0.500)	(0.286,0.333,0.400)	(1,1,1)	(2.000,2.500,3.000)	(2.500,3.000,3.500)
Value added service	(0.286,0.333,0.400)	(0.333,0.444,0.500)	(0.286,0.333,0.400)	(0.286,0.333,0.400)	(0.400,0.500,0.667)	(0.333,0.400,0.500)	(1,1,1)	(1.000,1.500,2.000)
Brand image	(0.286,0.333,0.400	(0.286,0.333,0.400)	(0.309,0.365,0.447)	(0.286,0.333,0.400)	(0.286,0.333,0.400)	(0.286,0.333,0.400)	0.500,0.667,1.000)	(1,1,1)

Table 3
Degree of possibility.

$V(S_{NP} \geqslant S_{LTS}) = 1$	$V(S_{NP} \geqslant S_{G}V_{Q}) = 1$	$V(S_{NP} \geqslant S_{CC}) = 1$	$V(S_{NP} \geqslant S_{BC}) = 1$	$V(S_{NP} \geqslant S_{CCA}) = 1$	$V(S_{NP} \geqslant S_{VAS}) = 1$	$V(S_{NP} \geqslant S_{BI}) = 1$
$V(S_{LTS} \geqslant S_{NP}) = 0.625$	$V(S_{LTS} \geqslant S_{GVQ}) = 1$	$V(S_{LTS} \geqslant S_{CC}) = 1$	$V(S_{LTS} \geqslant S_{BC}) = 1$	$V(S_{LTS} \geqslant S_{CCA}) = 1$	$V(S_{LTS} \geqslant S_{VAS}) = 1$	$V(S_{LTS} \geqslant S_{BI}) = 1$
$V(S_{GVQ} \geqslant S_{NP}) = 0.737$	$V(S_{GVQ} \geqslant S_{LTS}) = 1$	$V(S_{GVQ} \geqslant S_{CC}) = 1$	$V(S_{GVQ} \geqslant S_{BC}) = 1$	$V(S_{GVQ} \geqslant S_{CCA}) = 1$	$V(S_{GVQ} \geqslant S_{VAS}) = 1$	$V(S_{GVQ} \geqslant S_{BI}) = 1$
$V(S_{CC} \geqslant S_{NP}) = 0.530$	$V(S_{CC} \geqslant S_{LTS}) = 0.917$	$V(S_{CC} \geqslant S_{GVQ}) = 0.794$	$V(S_{CC} \geqslant S_{BC}) = 1$	$V(S_{CC} \geqslant S_{CCA}) = 1$	$V(S_{CC} \geqslant S_{VAS}) = 1$	$V(S_{CC} \geqslant S_{BI}) = 1$
$V(S_{BC} \geqslant S_{NP}) = 0.330$	$V(S_{BC} \geqslant S_{LTS}) = 0.698$	$V(S_{BC} \geqslant S_{GVQ}) = 0.581$	$V(S_{BC} \geqslant S_{CC}) = 0.772$	$V(S_{BC} \geqslant S_{CCA}) = 1$	$V(S_{BC} \geqslant S_{VAS}) = 1$	$V(S_{BC} \geqslant S_{BI}) = 1$
$V(S_{CCA} \geqslant S_{NP}) = 0.081$	$V(S_{CCA} \geqslant S_{LTS}) = 0.256$	$V(S_{CCA} \geqslant S_{GVQ}) = 0.149$	$V(S_{CCA} \geqslant S_{CC}) = 0.311$	$V(S_{CCA} \geqslant S_{BC}) = 0.560$	$V(S_{CCA} \geqslant S_{VAS}) = 1$	$V(S_{CCA} \geqslant S_{BI}) = 1$
$V(S_{VAS} \geqslant S_{NP}) = 0$	$V(S_{VAS} \geqslant S_{LTS}) = 0$	$V(S_{VAS} \geqslant S_{GVQ}) = 0$	$V(S_{VAS} \geqslant S_{CC}) = 0$	$V(S_{VAS} \geqslant S_{BC}) = 0$	$V(S_{VAS} \geqslant S_{CCA}) = 0.196$	$V(S_{VAS} \geqslant S_{BI}) = 1$
$V(S_{BI} \geqslant S_{NP}) = 0$	$V(S_{BI} \geqslant S_{LTS}) = 0$	$V(S_{BI} \geqslant S_{GVQ}) = 0$	$V(S_{BI} \geqslant S_{CC}) = 0$	$V(S_{BI} \geqslant S_{BC}) = 0$	$V(S_{BI} \geqslant S_{CCA}) = 0$	$V(S_{BI} \geqslant S_{VAS}) = 0.638$

Table 4
List of inputs and outputs of DEA.

Input items	Output items
Input (1) = BTS Down Time (BTS)	Output (1) = No. of subscriber (N)
Input (2) = Call success rate (CSR)	Output (2) = Billing Credibility (Billing)
Input (3) = Call drop rate (CDR)	Output (3) = Complain resolved within four weeks (CompR)
Input (4) = Good voice quality (GVQ)	Output (4) = Percentage of call answered in CC (percentage)

DEA result (less than 5 million mobile subscribers).

suring the relative efficiency by using the Data Envelopment Analysis and AHP of non homogeneous decision making units. Ramanathan (2006) have proposed a DEAHP method to generate the local weights of alternatives from the pairwise comparison matrices by using DEA and by using AHP to aggregate the final weights of alternatives. Wang et al. (2008) proposed a different method which uses the AHP–DEA method to determine the weights of criteria, linguistic terms such as Low, Medium and high by using Fuzzy AHP and DEA method to determine the values of the linguistic terms to aggregate bridge risks under different. The main advantage of this hybrid AHP/DEA method is that by using inputs and outputs data we can derive mathematically all pair wise comparisons in Fuzzy AHP and DEA models and there is no any form of subjective analysis engaged within the methodology.

4.5. Variables' selection and linear programming analysis: DEA

This paper uses latest published data for 2012 year compiled by TRAI (www.trai.gov.in). The datasets was divided into three different datasets which are divided based on population (less than 50 lakhs, between 50 and 90 lakhs and greater than 50 lakhs). The logic behind this purpose that we want to compare the efficiency of large DMUs with same populated DMU in that region. The sample size of all three different DMUs are 48, 25 and 25.

Table 4 gives statistics of different parameters of the sample being analyzed by DEA. According to the rule, the No. of DMUs should be at least twice the sum of No. of outputs and inputs (Cooper et al., 2000). In this paper there are four inputs and four outputs. This requires a total of 16 DMUs in each category. This indicates that we have satisfactory sample size in each category.

5. Empirical analysis

We used the four inputs and four outputs parameters and we chosen these parameters because inputs parameters have an impact or influence over the output parameters. For example, good voice quality would definitely influence on complaints numbers. Tables 5, 7 and 9 represents summary statistics for variables. The average number of faults/BTS downtime for first group (Less than 50 thousand) is 0.505833 with a standard deviation of 0.680098 calls. Similarly the average numbers of faults/BTS downtime in second group (Between 50 and 90 lakhs) and third group (More than 90 lakhs) are 0.4004 and 0.3494 with standard deviation of 0.507247 and 0.48807 calls respectively. On an average call success rate are 98.52708, 98.6916 and 99.1388 for first, second and third group with a standard deviation of 1.017992, 1.046475 and 0.626957 delays respectively. Measuring the global technical efficiency (TE) is the main feature of DEA. TE can be decomposed into two parts: pure technical efficiency (PTE) and other part is scale efficiency (SE). Technical efficiency can measure the any DMU success

Table 5
Summary statistics of inputs and outputs for first group.

	BTS	CSR	CDR	GVQ	*N*	Billing	CompR	Percentage
Max	3.31	99.89	2.1	100	4,908,640	2.12	100	98.32
Min	0.01	96	0.03	95.18	1,003,455	0	95.1	50.08
Average	0.505833	98.52708	1.060208	97.87417	2,893,374	0.074583	99.02979	88.03083
SD	0.680098	1.017992	0.591476	1.320023	1,266,005	0.300416	1.40681	12.82759

Table 6
Technical efficiency and return to scale for first group sample.

S. no	DMU	CCR (O) score TE/ overall efficiency	BCC (O)score PTE on A/C of inefficient operation	SE = CCR/BCC disadvantage position	No. of subscribers	RTS	Benchmarks
1	Aircel Limited (Maharashtra)	1	1	1	1,172,751	Constant	1
2	BSNL (Guj)	0.970383	0.99	0.980185	4,042,990	Constant	16
3	Uninor (Guj)	0.98334	1	0.98334	4,068,995	Increasing	3
4	Aircel (A.P)	1	1	1	1,964,589	Constant	16
5	Uninor (A.P)	1	1	1	3,896,912	Constant	5
6	Aircel (Karnatka)	0.989282	1	0.989282	1,422,729	Constant	12
7	Uninor (Karnatka)	0.99332	0.999394	0.993922	1,171,684	Constant	5,43
8	IDEA (TN)	1	1	1	2,316,260	Constant	8
9	Uninor (TN)	0.957394	0.9667	0.990373	1,182,886	Constant	16
10	Videocon (TN)	1	1	1	1,003,455	Constant	10
11	Reliance (Kerala)	1	1	1	3,449,810	Constant	11
12	Bharti Airtel (Kerala)	1	1	1	3,530,394	Decreasing	12
13	Aircel (Kerala)	0.999823	1	0.999823	1,708,665	Constant	13
14	Reliance (Punjab)	0.983162	0.9904	0.992692	3,292,577	Increasing	12
15	BSNL(Punjab)	0.977308	1	0.977308	4,399,519	Constant	15
16	Vodafone Essar (Punjab)	1	1	1	4,584,423	Constant	16
17	Aircel (Punjab)	1	1	1	1,094,327	Constant	17
18	IDEA(Haryana)	0.997402	0.9976	0.999802	3,688,890	Constant	16,22,27
19	Reliance (Haryana)	0.995991	0.996366	0.999624	2,592,520	Constant	1,12,17,27,33
20	Vodafone Essar (Haryana)	1	1	1	4,495,910	Constant	20
21	Bharti Airtel (Haryana)	1	1	1	2,388,657	Constant	21
22	BSNL (Haryana)	1	1	1	3,044,732	Constant	22
23	BSNL (West U.P)	1	1	1	4,777,796	Constant	23
24	Aircel Limited (West U.P)	0.995191	1	0.995191	2,131,207	Constant	12,17,27
25	Uninor (West U.P)	1	1	1	4,908,640	Constant	25
26	IDEA (Raj)	1	1	1	4,517,819	Constant	26
27	Aircel Limited (Raj)	1	1	1	2,501,285	Constant	27
28	BSNL (MP)	1	1	1	4,512,460	Constant	28
29	Vodafone Essar (MP)	1	1	1	4,280,400	Increasing	29
30	BSNL (WB)	1	1	1	3,542,474	Increasing	30
31	IDEA (WB)	0.9955	1	0.9955	2,416,854	Constant	31
32	Uninor (WB)	0.987587	0.990411	0.997149	4,152,311	Constant	3,16,28,36
33	Reliance (HP)	1	1	1	1,559,429	Constant	33
34	Bharti Airtel (HP)	0.9933	0.9933	1	1,909,948	Constant	12
35	BSNL (HP)	1	1	1	1,716,626	Constant	35
36	Uninor (Bihar)	1	1	1	4,852,878	Constant	36
37	Reliance (Odisha)	1	1	1	4,377,698	Constant	37
38	BSNL (Odisha)	0.96558	0.97	0.995443	4,327,034	Constant	16,23,29
39	Vodafone Essar (Odisha)	1	1	1	2,731,175	Constant	39
40	Reliance (Assam)	0.99059	0.9941	0.996469	3,247,231	Constant	12,27
41	BSNL (Assam)	0.998638	1	0.998638	1,167,502	Constant	16
42	Bharti Airtel (Assam)	0.990888	1	0.990888	3,876,246	Constant	16
43	Vodafone Essar (Assam)	1	1	1	2,363,905	Constant	43
44	Bharti Airtel (NE)	0.990717	0.9995	0.991213	2,506,020	Constant	16
45	BSNL (NE)	0.980905	0.99	0.990813	1,575,330	Constant	1,23,27,29
46	Reliance (NE)	0.984396	0.9886	0.995748	1,110,159	Constant	12,27
47	BSNL (J&K)	0.98252	1	0.98252	1,055,386	Constant	16,35
48	Bharti Airtel (J&K)	0.988695	0.9942	0.994463	2,250,447	Constant	12

DEA results (5–9 million mobile subscribers).

Table 7
Summary statistics of inputs and outputs for second group.

	BTS DownT	CSR	CDR	GVQ	*N*	Billing	CompR	Percentage
Max	1.93	99.97	1.9	99.9	8,758,805	0.63	100	99.11
Min	0.04	95.5	0.12	95.41	5,283,628	0	95.15	56.32
Average	0.4004	98.6916	0.8436	98.1944	6,992,790	0.062	98.8016	89.3204
SD	0.507247	1.046475	0.542549	1.410507	904614.1	0.121392	1.316552	8.780566

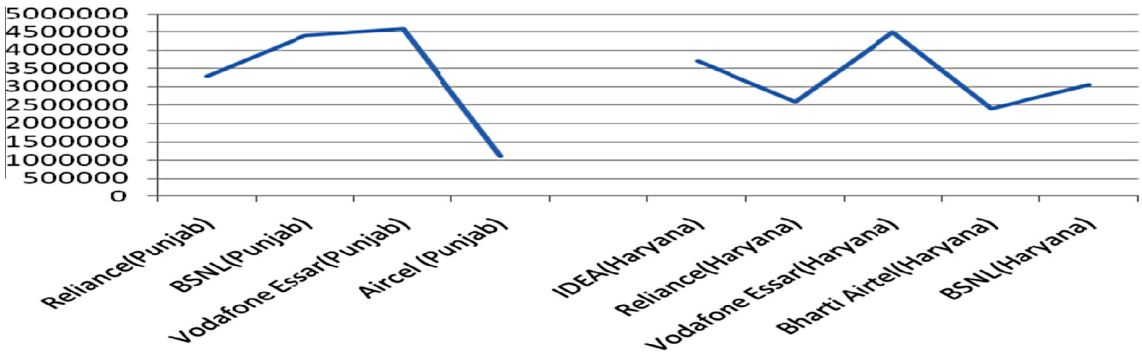


Fig. 5. Line diagram between number of subscribers and DMUs of Punjab and Haryana.

Table 8
Technical efficiency and return to scale for second group sample.

S. no	DMU	CCR (O) score TE/ overall efficiency	BCC (O)score PTE on A/C of inefficient operation	SE = CCR/BCC disadvantage position	No. of subscribers	RTS	Benchmark
1	BSNL (MH)	1	1	1	6,664,044	Constant	1
2	Uninor (MH)	0.994632	1	0.994632	5,283,628	Increasing	2
3	IDEA (GJ)	1	1	1	8,206,969	Constant	3
4	Reliance (GJ)	1	1	1	7,575,497	Constant	4
5	Bharti Airtel (GJ)	1	1	1	7,258,811	Constant	5
6	Reliance (AP)	1	1	1	8,045,285	Constant	6
7	IDEA (KN)	0.995554	1	0.995554	6,119,350	Increasing	7
8	Vodafone Essar (KN)	0.998274	1	0.998274	6,926,656	Decreasing	8
9	Reliance (KN)	0.994594	0.996872	0.997715	7,329,696	Decreasing	13,18,21,24,25
10	Reliance (TN)	1	1	1	8,027,261	Constant	10
11	BSNL (TN)	0.99282	1	0.99282	7,675,637	Decreasing	11
12	IDEA (Kerala)	1	1	1	7,731,037	Constant	12
13	Vodafone Essar (Kerala)	1	1	1	6,003,174	Constant	13
14	BSNL (Kerala)	1	1	1	7,026,292	Constant	14
15	IDEA (Punjab)	1	1	1	5,571,990	Constant	15
16	Bharti Airtel (Punjab)	1	1	1	6,883,578	Constant	16
17	Reliance (UP-W)	0.981311	0.985428	0.995822	7,808,720	Constant	3,24,25
18	Bharti Airtel (UP-W)	1	1	1	6,749,356	Constant	18
19	IDEA (UP-E)	0.999496	1	0.999496	7,474,273	Decreasing	19
20	Uninor (UP-E)	0.96896	1	0.96896	7,414,320	Constant	20
21	Reliance (Raj)	0.999094	1	0.999094	6,450,463	Decreasing	21
22	BSNL (Raj)	0.963976	0.98	0.983649	5,600,647	Constant	18,25
23	IDEA (Bihar)	1	1	1	5,645,833	Constant	23
24	Reliance (Bihar)	1	1	1	8,758,805	Constant	24
25	Vodafone Essar (Bihar)	1	1	1	6,588,425	Constant	25

DEA result (more than 9 million mobile subscribers).

Table 9
Summary statistics of inputs and outputs for third group.

	BTS	CSR	CDR	GVQ	*N*	Billing	CompR	Percentage
Max	2.4	99.96	1.59	99.89	18,882,255	0.1	100	97.96
Min	0.01	97.17	0.08	95.7	9,033,124	0	98	61.54
Average	0.3496	99.1388	0.7412	98.3572	12,605,888	0.0288	99.4456	90.5784
SD	0.48807	0.626957	0.474159	1.132101	2951694.5	0.033861	0.7159	8.144649

Table 10
Technical efficiency and return to scale for third group sample.

S. no	DMU	CCR (O) score TE/ overall efficiency	BCC (O) score PTE on A/C of inefficient operation	SE = CCR/BCC disadvantage position	No. of subscribers	RTS	Benchmark
1	Reliance (MH)	0.990757	0.996157	0.994579	12,415,626	Constant	16,24
2	Vodafone Essar (MH)	1	1	1	13,301,998	Constant	2
3	IDEA (MH)	1	1	1	15,337,967	Increasing	3
4	Bharti Airtel (MH)	0.999501	1	0.999501	10,192,569	Decreasing	4
5	Vodafone Essar (GJ)	1	1	1	16,074,103	Constant	5
6	IDEA (AP)	1	1	1	10,670,306	Constant	6
7	Bharti Airtel (AP)	1	1	1	18,882,255	Constant	7
8	BSNL (AP)	0.978408	0.98	0.998376	9,033,124	Constant	7,11,16
9	Bharti Airtel (Karnatka)	0.999007	1	0.999007	16,058,635	Decreasing	9
10	Vodafone Essar (TN)	1	1	1	10,301,780	Constant	10
11	Aircel Limited (TN)	1	1	1	18,612,058	Constant	11
12	Bharti Airtel (TN)	1	1	1	10,112,329	Constant	12
13	IDEA (UP-W)	0.994535	0.995888	0.998641	10,363,169	Constant	3,7,23
14	Vodafone Essar (UP-W)	1	1	1	9,595,618	Constant	14
15	Reliance (UP-E)	0.990837	1	0.990837	10,943,984	Constant	15
16	Vodafone Essar (UP-E)	1	1	1	15,263,993	Constant	16
17	BSNL (UP-E)	1	1	1	9,746,604	Constant	17
18	Bharti Airtel (UP-E)	0.990379	0.990576	0.999801	15,233,908	Constant	3,7,16,22,23
19	Vodafone Essar (RJ)	0.999119	1	0.999119	9,135,758	Decreasing	19
20	Bharti Airtel (RJ)	1	1	1	14,749,272	Constant	20
21	Reliance (MP)	1	1	1	12,943,010	Constant	21
22	IDEA (MP)	1	1	1	14,431,948	Constant	22
23	Bharti Airtel (MP)	1	1	1	10,032,361	Constant	23
24	Reliance (WB)	1	1	1	12,394,667	Constant	24
25	Bharti Airtel (WB)	1	1	1	9,320,160	Constant	25

by producing maximum output from given number of inputs and scale efficiency measures DMU's success by making a choice of best possible and an optimal set of inputs. A BCC model estimates the PTE (Pure technical efficiency) and CCR model measures the global TE. There are three steps of this empirical analysis. In first step, CCR efficiency measured. In second step BCC is measured. CCR efficiency gives TE and BCC gives inefficiency of service providers. Finally we measure the scale efficiency (SE). SE is the ratio of CCR and BCC. Scale efficiency (SE) gives the information about communication service providers those are operating in disadvantage conditions. For example, in first group

Punjab (Reliance) and Punjab (BSNL) are overall inefficient or simply less than efficient because CCR scores are 0.983162 and 0.977308 respectively. Both reliance and BSNL in Punjab are operating inefficiently because their BCC score or pure technical efficiency (PTE) is 0.9904 and 1 respectively. Both are performing under disadvantage position as their scale efficiency (SE) is also less than 1 as displayed in Table 6. However Vodafone and Aircel in Punjab are both highly effective and efficient in terms of scale efficiency (SE) and pure technical efficiency PTE. The result is also reflecting in number of

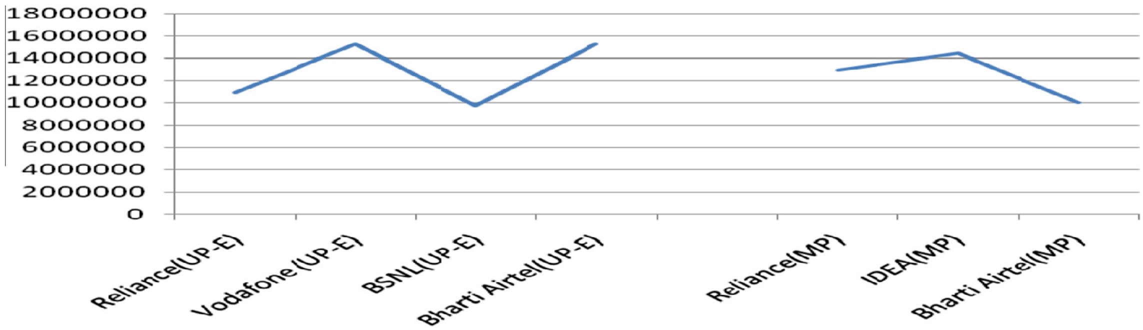


Fig. 6. Line diagram between number of subscribers and DMUs of UP (E) and MP.

telecom subscribers. From the line diagram (Fig. 5) we can see as technical efficiency (TE) is increasing, subscribers are also increasing. A similar scene can be seen in case of Haryana. In Haryana there are five telecom service operators namely IDEA, Reliance, Vodafone, Airtel and BSNL. Except IDEA and Reliance all service providers are technologically efficient because they have (CCR score = 1). However IDEA and Reliance are inefficient because they are operating or performing under disadvantageous conditions. (SE = 0.999802 and 0.999624). We can see a positive correlation between TE and total number of mobile subscribers in Haryana. Now we will focus on RTS which is displayed in Tables 6, 8 and 10 and which is identified or labeled by the BCC output-oriented model. Where constant RTS prevails, all the telecom service operators who are highly effective or fully efficient in CCR model are also efficient in BCC model. In Punjab BSNL, Vodafone and Aircel, Vodafone in Haryana, Airtel and BSNL in Haryana, Reliance in UP (E), Vodafone in UP (E) and BSNL in UP (E) have this status. This RTS property has an important role for scaling the inputs and outputs without increasing and without decreasing the efficiency. In first group out of 48 DMUs, 26 service providers have ability to achieve this states and one service provider are showing the decreasing return to scale (RTS). In second group out of 25 DMUs, 15 service providers have ability to achieve this state and 5 service providers are displaying the decreasing return to scale (RTS). In third group out of 25 DMUs, 17 service providers have ability to achieve this particular state and 3 service providers are showing the decreasing return to scale (RTS). So they have a chance or possibility to improve their efficiencies by decreasing their activities. In first group Uninor (Gujarat), Reliance (Punjab), Vodafone (MP) and BSNL (WB) are showing an increasing RTS that means they are trying to improve their efficiency by transforming and scaling up operations and some of them are operating under disadvantageous condition (see Fig. 6).

This observation gives us a conclusion for these companies need to up-scale their operations in India, the main reasons of inefficient telecom service are because of their disadvantageous working environment.

6. Conclusion and policy implication

This study has important implications for practice. In this research we studied on how telecom companies measures relative efficiency using DEA based on performance and customer's preferences. Many providers don't have ability to achieve the maximum efficiency due to many adverse conditions. The result of this analysis shows that private utilities like Airtel, Vodafone and Idea lie on the efficiency frontier. Though the government has taken keen interest and formulated initiatives for liberalizing the telecom sector, privatization has observed several obstacles. While political instability and lack of consensus on economic liberalization have been the main reasons for slowdown of the reform processes, conflict of interest between the policy makers and service providers, strict licensing conditions and unjustified license bids by the private licensees have also marred the process. One of the primary reasons for inefficiency among the service providers has been the inability to attain maximum efficiency in their operating performance. Customer expectations can only be met by emergence of a better competitive environment, which can be achieved by fine-tuning of the government policies. So problem being faced by the telecom industries, some changes in strategic and policy level could possibly mark a difference. However, rigorous analysis reveals a significant edge of the older private utilities, as they consistently perform better and hence may be used as benchmarks for the development of new utilities. Mere improvements in the infrastructure of telecom towers is not suffice for stimulating growth in the eastern region of India. Development of several other complimentary factors such as education and work force training, challenging/upcoming business environment and favorable transportation networks are pertinent to the growth of telecom systems/services in this region. In states with a good market potential, there is a dire need for the telecom policy makers to enhance the socioeconomic and environmental factors along with encouraging investments in telecom infrastructure. This will not only help in resolving the regional disparity in telecom services, but will also lead to more efficient resource allocation. Our results also point to the meaningful implications for the business practitioners in the Indian mobile industry. Going by the current forecasts for 3G or 4G markets, 3G mobile networks are the need of hour and Indian telecom service providers should deployed them without further delays. Introduction of such newer services would promote healthy/positive business warfare between secondary and leading telecom service providers that will ultimately lead to wider telecom market simultaneously enhancing customer satisfaction. For example, service providers may roll

Please cite this article in press as: Kumar, A., et al. Analyzing customer preference and measuring relative efficiency in telecom sector: A hybrid fuzzy AHP/DEA study. Telemat. Informat. (2014), http://dx.doi.org/10.1016/j.tele.2014.10.003

out a subsidy or offer a free mobile handset or slash call rates in low-income level regions. Another possibility is segmentation of all the telecom regions into groups based on diffusion. This will enable implementation of need-based specific marketing mix strategies for different groups in different telecom regions. Secondly, knowledge of regional disparities in 3G subscription and market potential would enable policy makers of Indian telecom sector to prioritize investment across different states. The major states in the eastern region seem appropriate as the first target markets for speeding up the 3G diffusion. The consideration of the socioeconomic characteristics of the targeted states is also important while deciding the specific market strategies by the telecom service providers. The result of this research can provide telecom policy makers for making license terms and conditions for improve telecom infrastructure. We plan to carry out further studies for utilization of Malmquist productivity index. Using Malmquist productivity index we can measure the closeness or distance of observations from the frontier over time. After that we can also make comparison at other countries such as Brazil, Russia, China and South Africa with Indian scenario using this hybrid fuzzy AHP/DEA approach and measuring the efficiency of CS&L for mobile subscribers based on slack based measurement.

7. Uncited reference

Q6 TRAI (2012).

References

Banker, R.D., Cao, Z., Menon, N., Natarajan, R., 2010. Technological progress and productivity growth in the U.S. mobile telecommunications industry. Ann. Oper. Res. 173 (1), 77–87.
Bayraktar, E., Tatoglu, E., Turkyilmaz, A., Delen, D., Zaim, S., 2012. Measuring the efficiency of customer satisfaction and loyalty for mobile phone brands with DEA. Expert Syst. Appl. 39 (1), 99–106.
Bohlin, E., Burgelman, J.-C., Rodriguez Casal, C., 2007. The future of mobile communications in the EU. Telematics Inform. 24 (3), 238–242.
Bowen, W.M., 1990. Subjective judgements and data envelopment analysis in site selection. Comput. Environ. Urban Syst. 14 (2), 133–144.
Chan, F.T.S., Kumar, N., Tiwari, M.K., Lau, H.C.W., Choy, K.L., 2008. Global supplier selection: a fuzzy-AHP approach. Int. J. Prod. Res. 46 (14), 3825–3857.
Chang, D.Y., 1996. Applications of the extent analysis method on fuzzy AHP. Eur. J. Oper. Res. 95, 649–655.
Debnath, R.M., Shankar, R., 2008. Benchmarking telecommunication service in India an application of data envelopment analysis. Benchmarking 15 (5), 584–598.
Facanha, L.O., Resende, M., 2004. Price cap regulation, incentives and quality: the case of Brazilian telecommunications. Int. J. Prod. Econ. 92, 133–144.
Giokas, D.I., Pentzaropoulos, G.C., 2000. Evaluating productive efficiency in telecommunications: evidence from Greece. Telecommun. Policy 24, 781–794.
Giokas, D.I., Pentzaropoulos, G.C., 2008. Efficiency ranking of the OECD member states in the area of telecommunications: a composite AHP/DEA study. Telecommun. Policy 32, 672–685.
Haq, A.N., Kannan, G., 2006. Fuzzy analytical hierarchy process for evaluating and selecting a vendor in a supply chain. Int. J. Adv. Manuf. Technol. 29, 826–835.
Huang, C.C., Chu, P.Y., Chiang, Y.H., 2008. A fuzzy AHP application in government-sponsored R&D project selection. Omega 36, 1038–1052.
Ilangkumaran, M., Kumanan, S., 2009. Selection of maintenance policy for textile industry using hybrid multi-criteria decision making approach. J. Manuf. Technol. Manage. 20 (7), 1009–1022.
Kreng, V.B., Wu, C., 2007. Evaluation of knowledge portal development tools using fuzzy AHP approach: the case of Taiwanese stone industry. Eur. J. Oper. Res. 176, 1795–1810.
Liberatore, M., Nydick, R., 2008. The analytic hierarchy process in medical and health care decision making: a literature review. Eur. J. Oper. Res. 189 (1), 194–207.
Madden, G., Savage, S.J., 1999. Telecommunications productivity, catch-up and innovation. Telecommun. Policy 23, 65–81.
Madden, G., Coble-Neal, G., Dalzell, B., 2004. A dynamic model of mobile telephony subscription incorporating a network effect. Telecommun. Policy 28 (2), 133–144.
Majumdar, S.K., 1997. The impact of size and age on firm-level performance: some evidences from India. Rev. Ind. Organ. 12, 231–241.
Moreno, P., Lozano, S., Gutiérrez, E., 2013. Dynamic performance analysis of US wireline telecommunication companies. Telecommun. Policy 37, 469–482.
Nigam, V., Thakur, T., Sethi, V.K., Singh, R.P., 2012. Benchmarking of Indian mobile telecom operators using DEA with sensitivity analysis. Benchmarking 19 (2), 219–238.
Pan, N.F., 2008. Fuzzy AHP approach for selecting the suitable bridge construction method. Autom. Constr. 17, 958–965.
Ramanathan, R., 2006. Data envelopment analysis for weight derivation and aggregation in the analytic hierarchy process. Comput. Oper. Res. 33 (5), 1289–1307.
Resende, M., 2008. Efficiency measurement and regulation in US telecommunications: a robustness analysis. Int. J. Prod. Econ. 114, 205–218.
Saen, R.F., Memariani, A., Lotfi, F.H., 2005. Determining relative efficiency of slightly non-homogeneous decision making units by data envelopment analysis: a case study in IROST. Appl. Math. Comput. 165 (2), 313–328.
Sastry, P., 2009. Identifying leaders and laggards—a method and application to US local telephone companies. Telecommun. Policy 33 (3–4), 146–163.
Satty, T.L., 1980. The Analytic Hierarchy Process. McGraw-Hill, New York.
Seifert, L.M., Zhu, J., 1998. Identifying excesses and deficits in Chinese industrial productivity (1953–1990): a weighted data envelopment analysis approach. Omega 26 (2), 279–296.
Q7 Sung, N., 2012. Inter modal competition and a slowdown in the productivity growth of US local exchange carriers. Industrial and Corporate Change.
TRAI, 2012. Annual Report 2011–12, Telecom Regulatory Authority of India, Available at: <www.trai.gov.in>.
Q8 Wang, Y.-M., Liu, J., Elhag, T.M.S., 2008. An integrated AHP–DEA methodology for bridge risk assessment.
Yang, H.-H., Chang, C.-Y., 2009. Using DEA window analysis to measure efficiencies of Taiwan's integrated telecommunication firms. Telecommun. Policy 33 (1–2), 98–108.
Yang, T., Kuo, C., 2003. A hierarchical AHP/DEA methodology for the facilities layout design problem. Eur. J. Oper. Res. 147 (1), 128–136.
Zadeh, L.A., 1965. Fuzzy sets. Inf. Control 8, 338–353.
Zahedi, F., 1986. The analytic hierarchy process: a survey of the method and its applications. Interface 16 (4), 96–108.
Zeithaml, Valarie A., Leonard, L.B., Parasuraman, A., 1996. The behavioral consequences of service quality. J. Marketing 60 (2), 31–46.
Zhu, J., 2003. Quantitative Models for Performance Evaluation and Benchmarking: Data Envelopment Analysis with Spreadsheets. Kluwer Academic Publishers, Boston.

Please cite this article in press as: Kumar, A., et al. Analyzing customer preference and measuring relative efficiency in telecom sector: A hybrid fuzzy AHP/DEA study. Telemat. Informat. (2014), http://dx.doi.org/10.1016/j.tele.2014.10.003