A combined ANP and fuzzy TOPSIS based strategic analysis of electronic service quality in healthcare services

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Abstract

Service sector should provide continuous high quality performance to its customers. Reducing cost of healthcare services and providing high quality healthcare service have become global priorities. Since electronic services are currently used more than ever, need for using electronic healthcare services is highly felt. Purpose of present thesis was to investigate and analyze concept of electronic service quality (E-SQ) in healthcare field. There are many methods for measurement of E-SQ but in present research SERVQUAL methodology was used. In present research criteria related to E-SQ were exploited. They included six main criteria i.e. tangibles, responsiveness, reliability, information quality, assurance and empathy each one having their own sub-criteria. In present research multi-criteria decision making (MCDM) methodology was used which was a combination of Analytic Network Process (ANP) for obtaining criteria weights and FUZZY TOPSIS methodology for ranking dimensions of electronic SERVQUAL for healthcare service. According to results of present research hospitals Golsar, Qaem, Aria and Pour Sina respectively obtained rank one to four and each one received a rank based on criteria and sub-criteria identified in present research. Among the studied criteria, “information quality” gained first rank followed by “reliability”. The lowest rank belonged to “tangibles” among total six criteria. With respect to sub-criteria, first rank belonged to “customers’ trust” followed by “accurate information” and the lowest rank belonged to “design”.

Key words: Electronic service, Electronic service Quality (E-SQ), Electronic Healthcare, FUZZY TOPSIS, Network analysis process (ANP), SERVQUAL

Introduction

In today global conditions, firms not only should compete with domestic counterparts, but also they have to engage in competition with foreign ones and it is very important to provide services consistent with customers’ expectation to succeed in that competition and this in turn is of great importance for providing favorable and high quality services to customers. When expectations and requirements of customers are met, quality is realized and evaluation of this major factor is of great importance. In recent years concept of electronic or web-based service quality has been emerged with appearance of e-commerce and evaluation of electronic service quality has been enhanced (Buyukozkan and Cifci, 2012).

Because of increasing use of electronic services in Iran, it is felt that healthcare industry needs to employ these electronic services and more research is required in this field. This may lead to decrease in patients’ problems e.g. saving in their time with respect to presenting to hospital. With a well-designed plan, medical and administrative costs can be greatly reduced and this provides profitable consequences to both patients and their financial supporters. Using electronic services can save both time and costs. Evaluation of electronic service quality is one strategy which makes us able to become aware of quality of implementing various ICT applications such as e-commerce, e-government, e-banking, e-education, etc. and using that feedback, try to improve national conditions in this respect (Zahedi and Biniaz, 2008).

Present research seeks to study and analyze concept of e-service quality (E-SQ) in healthcare sector. There are a wide variety of methods to measure E-SQ among them service quality (SERVQUAL)
methodology was employed in present research because it is one of the most common and preferred methodologies to evaluate service quality.

**Research Literature Review**

Having access to appropriate healthcare is a basic right of the public. Providing adequate facilities and human resource together with appropriate electronic equipment to all areas especially remote and disadvantaged ones is a difficult and costly task. Exploiting telecommunication and information technology, people would be able to take advantage of equal accessibility to electronic healthcare and medical services to maintain their health and manage their healthcare and therapeutic requirements in a more appropriate way. Other advantages of this process include helping prevention and control of contiguous diseases, guiding healthcare professionals and accelerating delivery of medical and healthcare services (modarresi, 2003).

Service quality as an important and strategic lever plays a special role in success of service organizations (Kong and Jogaratnam, 2007). Electronic healthcare service is the same as other centers for production of services for customers (patients). Patient can choose the center which provides the best service with its specific price among various service centers and this choice is relevant to electronic healthcare service quality (Li et al, 2002).

Bilsel addressed performance improvement of healthcare-medical websites of hospitals in an uncertain and fuzzy setting in such a way that the model developed based on fuzzy ranking, evaluated every part of hospital websites and assessed quality of each part based on services provided by each department of the hospital (Bilsel et al, 2006). Chang studied improvement of performance of healthcare services of hospitals and addressed optimal design for healthcare websites of hospitals through external and internal integration of information and delivery of services needed by customers (Chang et al, 2007). Gruca and Wakefield studied process and enhancement of electronic healthcare websites of hospitals (Gruca and Wakefield, 2004). Hadwich (2010) provided a conceptual model for improvement of healthcare service quality in various dimensions and extended the model based on balanced score card and assessed quality with respect to various dimensions. Büyüközkan and Cifçi (2012) considered healthcare service quality evaluation as a multi-criteria decision making problem and provided a new approach based on two methodology i.e. Analytic Hierarchical Process to calculate criteria weights and TOPSIS to rank criteria in uncertain and fuzzy setting. The model was implemented in Turkish hospitals and accuracy of proposed framework was evaluated.

**Methodology**

Present research was an applied descriptive-survey study. In present paper websites belonging to hospitals Goslar, Pour Sina, Aria and Qaem were chosen for case studies. Since present paper seeks to combine ANP and FUZZY TOPSIS methodologies to evaluate electronic healthcare service quality, a questionnaire was used as research instrument. In principle questionnaires should be short and easy to respond. In developing ANP questionnaire, closed-end questions were used. In this respect in order to evaluate criteria influencing electronic healthcare service quality, nine options including equally important, a little more important, more important, much more important, obviously more important and their intermediate options were used. Responder could easily check the box next the appropriate option after reading related explanations.

Also closed-end questions were used in developing FUZZY TOPSIS questionnaire. In this respect in order to evaluate criteria influencing electronic healthcare service quality, five options including very bad, bad, medium, good, very good were used. Responder could easily check the box next the appropriate option after reading related explanations to rate the related sub-criteria.

Purpose of present research was to provide a framework to evaluate electronic healthcare service quality of hospitals and implementation of it for websites belonging to hospitals Goslar, Pour Sina, Aria and Qaem. Thus it was necessary for statistical population to have adequate experience related to websites. On one hand because of multi-dimensional nature of evaluation of electronic healthcare service quality of hospitals which complete understanding of it requires familiarity with such areas as IT, computing, website navigation, etc. and on the other hand based on expert group used in one study by Büyüközkan and Cifçi (2012) (these researchers employed five experts to evaluate service quality), in present study website users who regularly visiting them were chosen as statistical population. In total 20 people who were familiar with studied websites and healthcare services and had MA or PhD degrees in relevant fields were chosen as experts.

**Methods of analysis**

**Analytic network process (ANP)**

On the other hand up to now several instruments and methodologies have been developed for solving multi-criteria problems. One of the most efficient among them was AHP (Analytical Hierarchy Process)
developed by (Thomas L. Saaty in 1980). After some time it was found that AHP was not of required integrity, thus in 1996 an extended methodology known as Analytical Network Process (ANP) was developed by Saaty. Many decision making problems cannot be organized as hierarchical ones and should be dealt with as networks because they have dependencies and interdependencies between elements of higher and lower levels. Hierarchies have a linear bottom up structure. Networks extend in all directions and include cycles between and within clusters. One method for conducting calculations in ANP is to put weights obtained from pairwise comparison of criteria in a matrix known as supermatrix. To understand supermatrix concept, assume that a problem has n branches, \( C_1, C_2, \ldots, C_n \) and in ith branch, there are \( n_i \) elements. Thus if two branches i and j are selected and all elements of i are compared with the first element in j in a pairwise manner, the resulted pairwise comparison matrix represents comparison of all elements of branch i to the first element of branch j. If the comparison result is not significant, the related eigenvector would be zero (Saaty, 1996). Now if all elements of branch i are compared with all elements of branch j in a pairwise manner and their eigenvectors are obtained, the following matrix is resulted. After formation of the primary supermatrix known as unweighted supermatrix, it may be necessary to normalize columns of this matrix to obtain weighted or normalized supermatrix. Using transition probability matrices and Markov chains, Saaty demonstrated that the final weights for elements is obtained from the following relation:

\[
W = \lim_{k \to \infty} w^{2k+1}
\]  

Algorithm for fuzzy topsis

The way in which understandings and judgments are expressed are usually subjective, uncertain and together with ambiguity. Such an uncertainty and subjectivity is controlled using statistics and probabilities (Dubios and Prade, 1986). Since words have lower accuracy than numbers, thus lingual variables express and specify phenomena in an approximate way. In order to remove ambiguity and subjectivity which are natural quality of human judgments in decision making process, fuzzy logic was developed to express lingual variables (Zadeh, 1965). Zadeh and Bellman (1970) were the first researchers paid attention to decision making employing fuzzy sets and developed Fuzzy Multi-Criteria Decision Making (FMCDM). Various methods has been provided for FUZZY TOPSIS. These methods have been obtained by modifying the methodology proposed by (Chen et al, 1992). We used the methodology proposed by Chen et al (1992) and extended it to triangular fuzzy numbers. But in order to provide more explanation on FUZZY TOPSIS, in the following modified methodology of Chen et al (1992) is described in detail.

Step 1: developing fuzzy decision matrix

Assume that there are m alternatives, n criteria and k decision makers. Where \( A_1, A_2, \ldots, A_n \) are alternatives should be chosen or prioritized. \( C_1, C_2, \ldots, C_n \) are evaluation criteria or characteristics. \( \tilde{x}_{ij} \) represents rating of alternative \( A_i \) with respect to criterion or characteristic \( C_j \) by decision maker k.

\[
\tilde{x}_{ij} = \frac{1}{k} (\tilde{x}_{ij}^1 + \tilde{x}_{ij}^2 + \ldots + \tilde{x}_{ij}^k)
\]  

Step 2: normalizing fuzzy decision making matrix

Raw data obtained in the above should be normalized to eliminate systematic biases and inconsistencies in different dimensions and scales being used in MCDM problems. In present methodology linear normalization is used.

Step 3: developing weighted normalized fuzzy decision matrix

By assigning different weights to every criterion or characteristic, weighted normalized decision matrix may be obtained multiplying criteria importance weights in normalized fuzzy decision matrix. Normalized fuzzy decision matrix \( \tilde{V} \) is defined as follows.

Step 4: determining ideal solution and negative ideal solution

Now weighted normalized fuzzy decision matrix is formed. In present step positive and negative ideal solutions \( A^+ \) and \( A^- \) are defined as follows (Awasthi et al., 2010)
Step 5: calculation of distances

Distances of each alternative from positive and negative ideal solutions are calculated as follows:

\[ d_i^+ = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^+) \]

\[ d_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^-) \]

Step 6: calculation of closeness coefficient and prioritizing alternatives

With determination of closeness coefficient, rank of all alternatives can be found and the best alternative can be selected by decision makers. Closeness coefficient is calculated as follows:

\[ C_i = \frac{d_i^-}{d_i^+ + d_i^-}, \quad i=1,2,...,m \]
In present paper software Super decision was used to determine importance degree of each main criterion in terms of evaluation purpose (ANP methodology) and Table 2, based on Wang, was used to determine scores obtained by alternatives with respect to sub-criteria (Wang et al,2009).

Table 1. Lingual scale to determine rating of alternatives with respect to sub-criteria

<table>
<thead>
<tr>
<th>Lingual variable</th>
<th>Very bad</th>
<th>Bad</th>
<th>Medium</th>
<th>Good</th>
<th>Very good</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triangular fuzzy number</td>
<td>(1,1,3)</td>
<td>(1,3,5)</td>
<td>(3,5,7)</td>
<td>(5,7,9)</td>
<td>(7,9,9)</td>
</tr>
</tbody>
</table>

Employment of ANP Methodology

- After obtaining all results of comparisons and related weights, unweighted supermatrix related to ANP results is formed. In the unweighted supermatrix, results from all significant pairwise comparisons are provided.
- After calculation of a weighted supermatrix, weighted one is obtained. Finally using software Super Decision, limit supermatrix is obtained by eliminating columns in which all elements are zero.

Table 2. Final rank and weight for each criterion and sub-criterion based on ANP

<table>
<thead>
<tr>
<th>criteria</th>
<th>row</th>
<th>Factor</th>
<th>symbol</th>
<th>Normalized weight in cluster</th>
<th>Weight from limit supermatrix</th>
<th>Rank in cluster</th>
<th>Final rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main criteria</td>
<td>1</td>
<td>Tangibles</td>
<td>C1</td>
<td>0.1352</td>
<td>0.0676</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Responsiveness</td>
<td>C2</td>
<td>0.13564</td>
<td>0.06782</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Reliability</td>
<td>C3</td>
<td>0.19682</td>
<td>0.09841</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Information quality</td>
<td>C4</td>
<td>0.20826</td>
<td>0.10413</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Assurance</td>
<td>C5</td>
<td>0.1685</td>
<td>0.08425</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Empathy</td>
<td>C6</td>
<td>0.15558</td>
<td>0.07779</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Sub-criteria</td>
<td>1</td>
<td>design</td>
<td>C11</td>
<td>0.01832</td>
<td>0.00916</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Website content</td>
<td>C12</td>
<td>0.05404</td>
<td>0.02702</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Usability</td>
<td>C13</td>
<td>0.0404</td>
<td>0.0202</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Organizing website operations</td>
<td>C14</td>
<td>0.02244</td>
<td>0.01122</td>
<td>3</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Customer service</td>
<td>C21</td>
<td>0.07166</td>
<td>0.03583</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Technical performance</td>
<td>C22</td>
<td>0.02936</td>
<td>0.01468</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Possibility to receive back-up services</td>
<td>C23</td>
<td>0.03462</td>
<td>0.01731</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Employees' specialty</td>
<td>C31</td>
<td>0.0718</td>
<td>0.0359</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Brand and reputation</td>
<td>C32</td>
<td>0.03054</td>
<td>0.01527</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Accurate service</td>
<td>C33</td>
<td>0.05404</td>
<td>0.02702</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>Standardization</td>
<td>C34</td>
<td>0.04044</td>
<td>0.02022</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>Adequacy and availability of information</td>
<td>C41</td>
<td>0.0466</td>
<td>0.0233</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>Accurate information</td>
<td>C42</td>
<td>0.08982</td>
<td>0.04491</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>Up-to-date information</td>
<td>C43</td>
<td>0.07184</td>
<td>0.03592</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>Balance and compensation</td>
<td>C51</td>
<td>0.05086</td>
<td>0.02543</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>Customers' trust</td>
<td>C52</td>
<td>0.11764</td>
<td>0.05882</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>Retaining customers</td>
<td>C61</td>
<td>0.04434</td>
<td>0.02217</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>Links</td>
<td>C62</td>
<td>0.02416</td>
<td>0.01208</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>Customer-orientation</td>
<td>C63</td>
<td>0.08708</td>
<td>0.04354</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

Applying FUZZY TOPSIS Methodology

After obtaining importance weights for criteria using ANP methodology, rating studied hospitals is done with respect to related criteria.

In the next step, decision making tables obtained from averaged opinions of experts are normalized. It should be noted that all criteria being used in present research had positive side and result of normalizing decision making matrix was a triangular fuzzy matrix with positive numbers.

Now un weighted normalized decision matrix is formed. In this step fuzzy positive and negative ideal solutions \( A^+ \) and \( A^- \) are formed. Thus with respect to the above-said, positive and negative ideal solutions for 19 criteria.

After determination of positive ideal solution and negative ideal solution, distances from positive ideal solution and negative ideal solution are calculated. According to the above explanations, summed distances of each alternative from positive ideal solution and negative ideal solution can be calculated for all alternatives.
After calculation of summed distances of alternatives from positive ideal solution and negative ideal solution, closeness coefficient is calculated for each alternative. After calculation of $d^+_i$ and $d^-_i$, $CC_i$ is used as benchmark for ranking alternatives.

### Table 3. Closeness coefficient and rank of each alternative (hospital websites)

<table>
<thead>
<tr>
<th>Row</th>
<th>Alternative</th>
<th>$CC_i$</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Golsar Hospital</td>
<td>0.5584</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Pour Sina Hospital</td>
<td>0.3029</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Aria Hospital</td>
<td>0.4336</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Qaem Hospital</td>
<td>0.4667</td>
<td>2</td>
</tr>
</tbody>
</table>

### Conclusion

Present research aims to apply multi-criteria decision making (MCDM) techniques (integrated ANP and FUZZY TOPSIS) to evaluate electronic service quality of hospitals Golsar, Pour Sina, Qaem and Aria in order to identify the best alternative meeting needs and expectations of patients. After a comprehensive literature review, a systematic framework was proposed to evaluate electronic service quality based on SERVQUAL. This framework consisted of six criteria including tangibles, responsiveness, reliability, information quality, assurance, empathy. Also sub-criteria related to each criterion were identified.

Based on results of present research, consulted experts considered “information quality” as the most important factor for electronic healthcare service quality followed by “reliability”. The lowest rank belonged to “tangibles”.

According to experts’ opinions, “customers’ trust” was the most important sub-criterion influencing electronic service quality followed by “accurate information”. Third rank belonged to “customer-orientation” showing increasing importance of this sub-criterion for electronic service quality of today healthcare service centers. Next ranks respectively belonged to “up-to-date information”, “employees’ specialty” and “customer service”.

Great importance of “information quality” has led to the fact that two sub-criteria “accurate information” and “up-to-date information” are of high priorities in relation to electronic service quality. The least priorities belonged to “design” and “organizing website operations” which were sub-criteria of “tangibles”.

In ranking hospitals, first rank belonged to Golsar hospital and Qaem, Aria and Pour Sina hospitals respectively obtained ranks 2 to 4.

### Future Research

Present paper used integrated ANP-FUZZY TOPSIS approach to evaluate electronic service quality based on SERVQUAL and tried to provide guidelines related to evaluation of electronic healthcare service quality with the aim of identifying key factors influencing evaluation and improvement of electronic service quality of hospitals. Future studies may use other MCDM methods (e.g. FUZZY ANP, DEMATEL, Hierarchical Fuzzy TOPSIS, Fuzzy VICOR and other non-ranking methods) to evaluate electronic service quality in healthcare field and compare their results with those of present study.

### References


