
Abbreviated running title: MEHOS: Method for adaptive human factors quality evaluation of hospital services

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Abstract

A method for adaptive human factors evaluation of hospital service quality (MEHOS) is proposed. It is based on a SERVQUAL checklist tool using a neural networks-based evaluation model. This method enables the adaptive determination of the most important human factors criteria and of the generation of recommendations for improving the hospital service quality. This method is illustrated and validated by a case study in a Turkish hospital. Data from hospital patients are collected by the checklist tool. Then human factors evaluations are calculated using categorical regression, ordered regression and MEHOS method. The last one showed significantly better performance. Based on MEHOS the most important human factors criteria that affect service quality in the health care industry were determined. Relevant recommendations and measures for improving the hospital service were proposed. After their implementation the health service quality index of the hospital rose by 51%. The advantages, drawbacks and further developments of MEHOS are discussed.

Keywords: Human factors evaluation; Hospital service quality; Neuro-fuzzy model

1. Introduction

Today, service industries are preponderant and account for 60 or 70 percentage of the total worldwide GNP (Franklin, 1997). One of the fastest growing industries in the service sector is
the health care industry. While all hospitals provide basically the same types of services, they do not provide the same quality of service (Puay and Nelson, 2000). Since 1980 the role of hospital service quality (HSQ) has been widely recognized as a critical determinant for the success and survival of a hospital in today’s competitive environment. Any decline in patient satisfaction due to poor service quality would be a matter of concern (O’Keeffe and O’Sullivan, 1997).

In the health care industry, the rising technological developments as well as quality standards have had an important impact on medical care, surgical techniques, drugs, equipment, and the organization and delivery of health care (Kunst and Lemmink, 2000; Lee et al., 2000). Despite the improvements in the health care industry, it is still very difficult for the patients to evaluate the quality of service received either before or after its delivery. In choosing a hospital, patients usually seek information on indicators of medical competence and assurance. They especially seek evidences indicative of the hospital’s quality such as certificates, quality awards, or other evidences of the physicians’ and staffs’ qualifications and the utilization of most recent medical developments and techniques.

Service quality in the health care can be defined in various ways depending on who the evaluators are; e.g. practitioners, patients. However, the patient’s perspective is increasingly being viewed as the most meaningful indicator of health care service quality (Rust and Oliver, 1994; McAlexander et al., 1994). From this perspective the health care service quality is a result of the comparison that patients make between their expectations about a service and their perception of the way the service has been performed. Hence service quality is often conceptualized as the comparison of service expectations with actual performance perceptions (Brady and Cronin, 2001; Brady et al., 2002; Koerner, 2000; Parasuraman et al., 1985, 1988; Rust et al., 2002). The research on service quality is dominated by the SERVQUAL checklist tool, which is based on the so-called “gap” model (Bloemer, 1999).

There are numerous studies measuring service quality in the health care industry using SERVQUAL. Usually in these studies different types of mathematical and statistical methods are used such as exploratory factor analysis (Andaleeb, 2001; Babakus and Mangold, 1992; Carmen, 1990; Walbridge and Delene, 1993), confirmatory factor analysis (Brady et al., 2002;
Taylor and Cronin, 1994), structural equation modeling (Kathleen, 2002; Cloe et al., 1995; Lytle and Mokwa, 1992; Kara et al., 2002, 2005), regression analysis (Kara et al., 2002, 2003; Peyrot et al., 1993), discriminant analysis (O’Conner et al., 1994), conjoint analysis (Carman, 2000), and gap analysis (Fayek et al., 1996; Yavas and Donald, 2001).

The increases in computer power, on the one hand, and the decrease in computer costs, on the other hand have stimulated the research on Artificial Neural Network (ANN). Recently many ANN models have been applied in service industry (Rao and Jafar, 2002; Castillo et al., 2001; Goss and Vozikis, 2002; Lisboa, 2002). Many ANN applications in health care industry use ANN models as an alternative to multivariate statistical methods such as logistic regression analysis. They attempt to show that ANN models have better predictive power than multivariate statistical methods.

Goss and Vosikis (2002) used ANN approach to measure the likelihood of intensive care unit recovery and compared it with logistic regression model. This study showed that ANN approach predicts mortality rate in intensive care units more correctly than the statistical technique. Goss and Ramchandani (1998) evaluated the survival prediction accuracy in the intensive care units using ANN approach comparing it with binary logistic regression model. The study concluded that ANN outperforms binary logistic regression model. Morrison et al. (1997) employed ANN technique to predict total health care costs of Medicaid recipients.

There are various studies in the health care, which employed ANN techniques with supervised learning to measure hospital performance or to predict health care costs in the hospital. However, we could not find any study that uses ANN methods to evaluate health care service quality by SERVQUAL-based patient’s survey. We found only a few studies using ANN methods and SERVQUAL questionnaire instrument in other service industries. For example, Tsaur et al. (2001) employed backpropagation neural networks model for analyzing the guest loyalty toward international tourist hotels. They compared ANN approach with logistic regression model. The ANN model outperforms regression models in overall model fitting. Davies et al. (1996) used backpropagation neural network model to measure ATM user attitudes. Behara et al. (2002) employed ANN technique to evaluate service quality of auto dealerships in the Netherlands using SERVQUAL based customer survey.
There are many methods for HSQ evaluation. Their drawback is that they do not provide recommendations for improving HSQ. Here we propose a neuro-fuzzy-based method for adaptive human factors quality evaluation of hospital services (MEHOS), which also generates improvement recommendations for health care services. Based on a case study MEHOS supports better understanding of consumers' perceptions of hospital service quality and its improvement.

2. Description of MEHOS Method

The individual steps of the MEHOS method are shown on Fig.1. Principal purposes of this method are: 1) aggregating the hospital service data for quantitative human factors evaluations; 2) selection of important HSQ evaluation criteria for the generation of human factors recommendations and measures for HSQ improvements.

Step 1: Knowledge base design

For human factors evaluation and design of HSQ, a knowledge base including the following evaluation criteria: tangibility, reliability, responsiveness, assurance and courtesy can be developed (see Fig.2). MEHOS is based on the adapted SERVQUAL (Parasuraman et al., 1985, 1988, 1991) service quality checklist tool (cf. Appendix). Carman (1990) applied this tool to several types of services and adapted it for the hospital industry. The MEHOS checklist tool consists of two parts. The first one contains 26 questions that identify HSQ evaluation criteria for tangibility, reliability, responsiveness, assurance and courtesy. These questions are asked to patients under treatment at the hospital for measuring their perceptions of the service quality performance of the hospital. In the second part of the checklist tool, a single question regarding patients' overall evaluation of hospital service quality is asked. For the above criteria a criteria hierarchy is defined (see Fig.3). To each criterion, a weight is associated by expert estimates. Each weight represents the relative importance of each sub-criteria within their category.

Step 2: Data collection

During this step the patients' evaluations of the single criteria at the lowest first layer of the criteria hierarchy are determined.

Step 3: Criteria hierarchy learning
During this step of the MEHOS method the initial weights of criteria hierarchy are trained. Because of the strong nonlinear correlation between evaluation criteria we chose a nonlinear evaluation model: the backpropagation (BP) algorithm (Garson 1998). It carries out supervised learning of neural network weights using training data as inputs and known output minimizing the mean square error. In this study, patients’ perception related to pre-specified HSQ criterion is paired with overall HSQ evaluation. During the training process, the neural network (cf. Fig.5) learns the relationship between output and input criteria. The network arcs connect the processing units -the neurons. With each neuron input a weight is associated, which represents its relative importance in the set of neurons inputs. The inputs of each neuron from other neurons are aggregated. Its net value represents a weighted combination of the neuron inputs. The hierarchy is coded in a hierarchical neural network, where each neuron corresponds to a criterion. The single criteria correspond to the network inputs. The complex criteria correspond to the neurons at hidden layer and to the output neuron. The net function of the neural network is used as an evaluation function. The BP algorithm is a gradient algorithm, which minimizes the average square error between the current output and the target value by modification of the network weights. We consider a neural network with 26 inputs, five hidden neurons and an output neuron (cf. Fig.4).

**Step 4: Lack analysis**

A goal of MEHOS method is to support the lack analysis. This is accomplished by determining the most important single criteria at input layer whose improvement will lead to the most significant increase of the HSQ index.

The lack analysis consists in sequential computation of HSQ indices $K_{j,K}^{(l)}$ for the criteria of each network layer as follows:

For the criterion $j$ an index $K_{j,K}^{(l)}$ is calculated, which characterizes the quality of criterion $a_j$ from human factors viewpoint.

For input layer
\[ K^{(i)}_{j^*} = a^{(0)}_{j^*} \times w^{(0)}_{j^*} \times 10 \]

where the standardization of every \( a^{(0)}_{j} \) and \( w^{(0)}_{j} \) in the interval \([0,1]\) is accomplished as follows:

\[
a^{(0)}_{j} = \frac{a^{(0)}_{j} - a^{(0)}_{min}}{a^{(0)}_{max} - a^{(0)}_{min}} \quad \text{and} \quad w^{(0)}_{j} = \frac{w^{(0)}_{j} - w^{(0)}_{min}}{w^{(0)}_{max} - w^{(0)}_{min}}
\]

For indices \( K^{(i)}_{j^*} \) of all criteria three fuzzy sets are defined (see Fig.6). They represent the values of the linguistic variable hospital service quality determined by clustering analysis and experts:

- **Good HSQ** \( K^{(i)}_{j^*} \in [6.5,10] \): green area
- **Acceptable HSQ** \( K^{(i)}_{j^*} \in [4.5,6.5] \): yellow area
- **Bad HSQ** \( K^{(i)}_{j^*} \in [0,4.5] \): red area.

Starting from output network layer to input network layer the indices \( K^{(i)}_{j^*} \) of all criteria are computed. Top down for the next layer are computed indices only for these criteria, which are successors of criteria with indices \( K^{(i)}_{j^*} < 6.5 \). This procedure continues similar up to the input layer inclusively. The following decision rules for selection of single criteria at input layer are formulated:

- When \( 4.5 < K^{(i)}_{j^*} \leq 6.5 \), an HSQ improvement is recommended;
- When \( K^{(i)}_{j^*} < 4.5 \), a redesign of hospital service is required.

Both decision rules activate a hypermedia-based support (cf. Fig.7), which uses a hypermedia knowledge base. It consists of knowledge components in the form of tables, data, graphics, speech/tone, animation, recommendations, etc. The sequence of the presentation of these knowledge components to the user is system-controlled (automated) or user-controlled (manually).

**Step 5: Improvement/redesign recommendations**
A team of experts discusses the results at the previous step. Thus, improvement/redesign recommendations are generated by the MEHOS software tool (cf. Fig.7).

3. Case study

For illustrating and validating of MEHOS method a case study in an Istanbul hospital for civil servants and their families was carried out.

In the data collection step particular attention was paid to the pre-testing of the questionnaire: Data for this study were gathered using a SERVQUAL-based questionnaire (cf. Appendix) that was distributed to 200 patients in the hospital. 139 usable questionnaires were returned giving a response rate of 69.5 percent, which was considered satisfactory for the subsequent analysis. Each checklist item was rated on a seven-point Likert scale anchored at the verbal statement “Strongly Disagree” to which is associated a value of 1 and the verbal statement “Strongly Agree” valued at 7.

3.1 Comparison of MEHOS method with conventional evaluation methods

The MEHOS method was compared with other known evaluation models. We selected categorical regression (Agresti, 1990) and ordered regression (Hosmer and Lemeshow, 2000) because the data was measured in the ordinal scale.

The MEHOS neural network consists of 26 nodes at input layer, of 5 nodes at hidden layer, and of a node at output layer. The single criteria at input layer were scaled to the unit interval [0,1]. As activation function at hidden layer the sigmoid function was chosen. For neural network learning at MEHOS step 3 a generalized delta rule was applied.

By the BP algorithm we divided the data in training and test samples and in data set 1 and data set 2. Data set 1 consists of a training sample of 110 patients and a test sample of 29 patients. Data set 2 consists of a training sample of 100 patients and a test sample of 39 patients. The results (cf. Fig.8) showed that the best method for both data sets is MEHOS. For data set 1 it has the lowest mean squared error: 0.22 for the training sample and 0.15 for the test sample. The ordered regression ranks at second place with respective mean squared errors of 0.48 and 0.49; and categorical regression takes the last place with respective mean squared errors of 0.87 and 0.86. Similar are the results for data set 2 (cf. Fig.8).
3.2 Lack analysis and generation of improvement/redesign recommendations

The current service quality of the hospital was analyzed according to MEHOS steps 4 and 5. Relevant improvement and redesign recommendations were generated. The evaluation of current service quality was carried out using a 10-point scale. It was evaluated and improved in the following three stages. If the score of service quality is less than 4.5, the HSQ is allocated to the red area indicating that the health care service should be redesigned. If the score of service quality is in the interval 4.5–6.5, the HSQ is allocated to the yellow area signifying that the health care service needs some improvement. If the score of service quality is greater than or equal to 6.5 the HSQ is allocated to the green area. In this case the health care service does not need to be improved. At the first stage the overall service quality (HSQ index) was determined. Then at the second stage, each criterion was evaluated and based on this evaluation a decision was taken as to which criterion should be improved or redesigned. As mentioned above the overall service quality presents a combination of tangible and intangible criteria. The intangible criteria are reliability, responsiveness, assurance and courtesy. At the third stage considering the criteria scores that were calculated at second stage, redesign and improvement plans were developed.

At the first stage the score of the current overall service quality (HSQ index) of the hospital was 4.97. Since this value is in the interval 4.5–6.5 the overall service quality belongs to the yellow area. Hence, it does not need any redesign; improvement will suffice. At the second stage, during the top-down procedure, each criterion score was calculated. assurance, reliability, and courtesy all received scores below 4.5 (0.0, 2.02, and 3.42, respectively) and thus were placed in the red area. On the other hand, responsiveness and tangibility scores were, respectively, 8.10 and 10 and hence were placed in the green area, having scored above the 6.5 limit. Consequently, the former three criteria require redesign while the latter two does not need any urgent improvement. As shown in Table 1, among the complex criteria assurance ought to receive the first priority, reliability the second, and courtesy the third.

As mentioned above, assurance has the lowest score as a complex criterion, and belongs to the red area. Therefore, this criterion should be considered by managers of the hospital as the most important criterion to be redesigned. Assurance refers to employees’ knowledge and
their ability to inspire trust and confidence. When choosing a hospital, patients usually pay special attention to find evidence of hospital’s quality such as ISO 9000 certificates, quality awards, or other evidences of the physician and staff’s qualifications. On the basis of such evidence, patients assess the quality of hospital services and develop confidence in the hospital care process and its outcomes. In this study assurance includes two single criteria. The first single criterion is “being able to trust nurses and staff of the hospital” (22); and the second one is “patients can feel safe in their transactions with hospital employees” (23) (cf. Appendix). The initial value of single criterion 23 was 0.73. This means that patients of the hospital feel safe in their transactions with nurses and staff of this hospital. However, initial value of single criterion 22 was 0.51. This value indicates that patients do not fully trust nurses and the staff. In fact, both single criteria are related to the quality of nurses and staff of the hospital. Patients do not receive timely assistance from the nurses, primarily because of insufficiency of numbers; or, putting it in other terms, because of too much overload. This leads to dissatisfactions and complaints on the part of patients as well as the nurses themselves. A further problem is that a majority of nurses are close to the retirement age and resist training in state-of-the-art technology. This also creates a lack of motivation since, being close to the end of their careers, they do not expect any promotion. In addition, lack of modern management methods, poor motivation, inappropriate reward methods, and poor working conditions are important factors for their dissatisfaction. Therefore, their job quality and consequently external patients’ satisfaction level decreases.

**Reliability** has the second lowest score 2.02 and was below the threshold value of 4.5. Thus, reliability belongs to the red area and should be considered for redesign by hospital managers. Reliability is defined as the ability to perform the promised service dependably and accurately. It means that the hospital performs the service right the first time. Reliability has four single criteria (10-13). Single criteria 10 “Food is delivered by a certain time” has the highest score. Instead of preparing food in the hospital, they outsourced it from a professional company. Now both internal and external patients are satisfied with food service. The most important redesign area in reliability is related to the hospital staff. Hospital staff is not able to carry out their promises by a certain time, and they could not tell their patients exactly when services
would be performed. The number of doctors (surgeons) of the hospital is much more than the number of nursing staff in this hospital. Operating loads per doctor is not high compared to nurses’ operating loads. The next improvement area in this criterion was keeping patient's records accurately. It may be pointed out that hospitals generally do not maintain an appropriate recent keeping system. Causes of this problem are deficiencies in staff quality, education and management information system.

The third criterion is **courtesy**. It involves politeness, respect, consideration, and friendliness of contact personnel. Courtesy refers to attitude and behavior of the hospital employees toward the patients and their families. Since its score is 3.42, courtesy belongs to red area. Therefore, this criterion should be redesigned as well. Courtesy has three single criteria. Criterion 26 “Hospital visitors are treated well” has the lowest score among these three single criteria. The second redesign should be carried out in nurses’ behavior toward patients. The causes of these problems are the lack of adequate quality and quantity of nurses and staff. Although nurses’ attitudes toward patients and their visitors are at an acceptable level, inadequacy of their numbers makes it impossible to render the desired levels of services. Therefore, this hospital needs to recruit new staff and train the existing staff and nurses.

**Responsiveness** is the fourth improvement criterion. It refers to the prompt service in the discharging process, the admission process, and at the transactional operations such as punctual services when needed. In addition, responsiveness refers to explanations about treatments, and any procedure in the hospital. According to the findings, responsiveness has a score of 8.10 and belongs to the green area. Therefore, there is no need to do anything about responsiveness.

The **tangibility** was found as the most efficient criterion in the service quality model. There is no need to indulge in any immediate improvement in this area. Tangibility refers to the whole range of assets in the hospital including updating the assets, cleaning the room, etc. Analysis results indicate that this hospital does not have any problem about tangibility.

In this case study, if the above mentioned recommendations are applied in the assurance, reliability and courtesy areas and the requisite redesigns are implemented (that is, if the single assurance criterion 22 was raised from 0.51 to 1.00, the single reliability criteria 11,12 and 13
were raised from, respectively, 0.61, 0.65, and 0.49 to 1.00, and the single courtesy criteria 25 and 26 were raised from 0.48 and 0.38 to 1.00), the HSQ index would rise by 51%; that is from 4.97 to 7.5 as shown in figure 9. In other words, the overall service quality which was in the yellow area will now be in the green area.

4. Conclusions

The health care providers need a better understanding of the key dimensions constituting health care quality and valid approaches to their measurement. There is considerable discrepancy regarding health care service quality: what to measure and how to measure. In this study, to alleviate some of these difficulties, a method for adaptive human factors quality evaluation of hospital services was proposed. It is based on a SERVQUAL checklist tool using a neural networks-based evaluation model. This method enables the adaptive determination of the most important human factors criteria and of the generation of recommendations for improving the hospital service quality. This method is illustrated and validated by a case study with 139 patients in a non-profit Istanbul hospital. The most important criteria for measuring health care service quality and improvement and redesigning areas were determined. For delivering a high quality service, health care providers must concentrate on intangible factors such as reliability and assurance. According to the evaluation of these two factors, nursing care was found to be the most important criterion. Therefore, to improve and redesign nursing department, the most significant effort must be devoted to modern managerial practices such as recruiting new nursing staff, training them in both technical and interactive skills, compensating them, empowering them, promoting teamwork, developing internal processes and supporting technology, and treating employees as internal customers. After implementation of such redesign recommendations, the health service quality index of the hospital was increased by 51%.

Advantages, disadvantages and further developments of MEHOS are presented below.

4.1 Advantages

- This method enables the adaptive determination of the most important human factors criteria and of the generation of recommendations for improving the hospital service quality.
• MEHOS showed significantly better performance (much lower error rate) in comparison to other evaluation methods such as categorical regression and ordered regression. MEHOS neural network modeled better non-linear dependencies characterizing the health service quality data.

• By MEHOS, not only the critical factor and related improvement areas regarding the service quality in a hospital can be ascertained, but also the degree to which the service quality can be improved after taking corrective actions by hospital managers.

• Hospital managers can measure by MEHOS their hospitals’ service quality from the customer’s viewpoint.

• Using the lack analysis, hospital managers can formulate their management strategies to redesign and to improve their service delivery system.

• The result of the evaluation can assist in the appropriate allocation of the annual budget and of other management resources.

4.2 Disadvantages

• The costs of improvement and redesign activities and their impact on hospital profitability are not considered.

• Service quality improvement and redesigning activities were carried out under non-restricted constraints.

4.3 Further Developments

• MEHOS conceptual domain can be extended by measuring the relationship between service quality and patient satisfaction, loyalty and its influence on performance of the hospital.

• This study can be applied in profit-oriented hospitals and customer profile can be evaluated and compared with patients of non-profit hospitals.
• The evaluation of current service quality was carried out according to the service recipients’ perception. It will be very valuable to add physicians’ perception of service quality when designing and improving the health care delivery system.

• MEHOS did not consider expectations of patients. It could be further developed to consider expectations of patients and measure how expectation effects overall service quality.

• MEHOS performance could be increased by using fuzzy backpropagation model (Nikov and Stoeva, 2001; Stoeva and Nikov, 2000).

5. References


Appendix

Checklist (Carman, 2000) about patient's perception of the service quality of the hospital.

**Tangibility**

1. Hospital has up to date equipment and technology.
2. Physical facilities in hospital are visually appealing.
3. Bathrooms are very clean in hospital.
4. Rooms of the hospital are very clean.
5. Hospital meals are attractive.
6. Hospital food has right temperature.
7. Nurses of the hospital respect to privacy.
8. Hospital rooms are quiet.
9. Parking in hospital is convenient.

**Reliability:**

10. Food is delivered by a certain time in hospital.
11. When hospital staff promises to do something by a certain time, they do it.
12. They keep patients' records accurately in hospital.
13. They tell their customer exactly when services will be performed.

**Responsiveness:**

14. Patients who will be discharged have prompt service from employees of the Hospital for the discharging operations.
15. Patients are delivered prompt services from nurses when the patient needs to them.
16. Patients who come to hospital get prompt service from employees of hospital for the admission operation.
17. Employees of hospital are always willing to help their patients.
18. Employees of hospital explain appropriately customer' question about discharging process.

<table>
<thead>
<tr>
<th>Tangibility</th>
<th>Reliability</th>
<th>Responsiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Hospital has up to date equipment and technology.</td>
<td>10. Food is delivered by a certain time in hospital.</td>
<td>14. Patients who will be discharged have prompt service from employees of the Hospital for the discharging operations.</td>
</tr>
<tr>
<td>2. Physical facilities in hospital are visually appealing.</td>
<td>11. When hospital staff promises to do something by a certain time, they do it.</td>
<td>15. Patients are delivered prompt services from nurses when the patient needs to them.</td>
</tr>
<tr>
<td>3. Bathrooms are very clean in hospital.</td>
<td>12. They keep patients' records accurately in hospital.</td>
<td>16. Patients who come to hospital get prompt service from employees of hospital for the admission operation.</td>
</tr>
<tr>
<td>4. Rooms of the hospital are very clean.</td>
<td>13. They tell their customer exactly when services will be performed.</td>
<td>17. Employees of hospital are always willing to help their patients.</td>
</tr>
<tr>
<td>5. Hospital meals are attractive.</td>
<td></td>
<td>18. Employees of hospital explain appropriately customer' question about discharging process.</td>
</tr>
</tbody>
</table>
19. Employees of hospital explain customer’ question appropriately about the any procedure.
20. Treatment is explained to the patient very clearly in hospital.
21. Discharging process is explained to the patients' family.

Assurance
22. Customers trust nurses of hospital.
23. Patients can feel safe in their transactions with hospitals' employees.

Courtesy
24. Hospital employees are polite during admissions procedure.
25. Nurses are cheerful.
26. Hospital visitors are treated well.

Overall HSQ
27. Overall quality of hospital service.
Table 1

Complex criteria, their evaluations, and relevant areas and actions
<table>
<thead>
<tr>
<th>Complex criteria</th>
<th>Evaluations</th>
<th>Areas</th>
<th>Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assurance</td>
<td>0.00</td>
<td>Red</td>
<td>To be redesigned</td>
</tr>
<tr>
<td>Reliability</td>
<td>2.02</td>
<td>Red</td>
<td>To be redesigned</td>
</tr>
<tr>
<td>Courtesy</td>
<td>3.42</td>
<td>Red</td>
<td>To be redesigned</td>
</tr>
<tr>
<td>Responsiveness</td>
<td>8.10</td>
<td>Green</td>
<td>No need for improvement</td>
</tr>
<tr>
<td>Tangibility</td>
<td>10.00</td>
<td>Green</td>
<td>No need for improvement</td>
</tr>
</tbody>
</table>
Table 2

Single criteria, relevant complex criteria and evaluations
<table>
<thead>
<tr>
<th>Single criteria Nr.</th>
<th>Single criteria</th>
<th>Related complex criteria</th>
<th>Evaluations</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>When hospital staff promises to do something by a certain time, they do it.</td>
<td>Reliability</td>
<td>0.61</td>
</tr>
<tr>
<td>12</td>
<td>They keep patients' records accurately in hospital.</td>
<td>Reliability</td>
<td>0.65</td>
</tr>
<tr>
<td>13</td>
<td>They tell their customer exactly when services will be performed.</td>
<td>Reliability</td>
<td>0.49</td>
</tr>
<tr>
<td>22</td>
<td>Patients trust nurses of hospital.</td>
<td>Assurance</td>
<td>0.51</td>
</tr>
<tr>
<td>25</td>
<td>Nurses' behavior is very polite against patient.</td>
<td>Courtesy</td>
<td>0.48</td>
</tr>
<tr>
<td>26</td>
<td>Hospital visitors are treated well.</td>
<td>Courtesy</td>
<td>0.38</td>
</tr>
</tbody>
</table>
Fig. 1. MEHOS sequence of steps
Knowledge base design

Data collection

Criteria hierarchy learning

Lack analysis

Improvement recommendations
Fig. 2. HSQ evaluation criteria
Fig. 3. HSQ evaluation criteria hierarchy
Fig.4. Neural network based hierarchy of HSQ evaluation criteria
Fig. 5. Criteria weights learning
Single criteria evaluation by patients

\[ a_{ij}^{(0)} \rightarrow 1.26 \]

Target determination

Initial weights determination

\[ w_{ij}^{(0)} \rightarrow 1, \forall i, j \in \{1, 2\} \]

Complex criteria evaluation

\[ a_{ij}^{(0)} \rightarrow 1.5 \]

\[ t = a_{ij}^{(0)} \]

yes

New weights determined by BP algorithm

\[ w_{ij}^{(0)} \rightarrow 1, \forall i, j \in \{1, 2\} \]

Complex criteria evaluation

\[ a_{ij}^{(0)} \]

\[ t = a_{ij}^{(0)} \]

yes

Learned neural network weights

no
Fig. 6. Membership functions $\mu_k$ of the fuzzy sets good, satisfying and bad
Fig. 7. Adaptive generation of improvement/redesign recommendations
Fig. 8. Comparison of evaluation methods
Categorical regression
Ordered regression
MEHOS

1st training sample n=110
1st test sample n=29
2nd training sample n=100
2nd test sample n=39
Fig. 9. Global HSQ index before and after HSQ improvements
Comparison of initial and improved HSQ indices:

- Initial HSQ index: 4.97
- Improved HSQ index: 7.48

Global HSQ index range: 0 to 10