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## TOWARDS A METHODOLOGY OF DEVELOPING MODELS OF E-SERVICE QUALITY ASSESSMENT IN HEALTHCARE

Anna Lantsberg, Klaus G. Troitzsch

### Abstract

The paper is devoted to solving the problem of assessing the quality of the medical electronic service. A variety of dimensions and factors of quality, methods and models applied in different scopes of activity for assessing quality of service is researched. The basic aspects, requirements and peculiarities of implementing medical electronic services are investigated. The results of the analysis and the set of information models describing the processes of assessing quality of the electronic service “Booking an appointment with a physician” and developed for this paper allowed us to describe the methodology and to state the problem of the assessment of quality of this service.

**Key words:** e-service, web-portal of medical e-services, e-service quality, regression analysis, assessment model, methodology.

### Introduction

Every year the Government of the Russian Federation involves an increasing number of IT-developers in an implementation of the concept “E-Government”. This fact is related to a wide range of the tasks that the concept defines. One of the tasks is the informatization of the vertical organisation of healthcare institutions. Special attention is paid to the development of the tools of interaction of government and municipal institutions with citizens via electronic services. An example of that service is booking an appointment of a patient with a physician. Requirements of reducing queues for the service, increasing the accessibility of medical services and optimizing the processes of data collection and processing define the necessity of development of this electronic service. At the present time about a quarter of Russian regions are covered by projects of the development and implementation of online registration offices. The Republic of Bashkortostan (<https://doctor.ufacity.info>) and The Republic of Chuvashia (<http://www.med.cap.ru/MedRegistry>), the Perm (<https://k-vrach.ru>) and Krasnodar Territories (<http://www.kubandoctor.ru/portal/medportal>), St. Petersburg (<http://www.myjpu.ru/>) and Samara (<http://www.regalon.ru/>) are among them. These projects are at the stage of implementation and initial approbation now.

The aim of the next stage is the assessment of the effectiveness of using systems of on-line registration offices with their updating and widespread implementation in future. The key aspect of the effectiveness is a consideration of the opinion of end-users to whom this service is addressed. In this case end-users are the patients who have used the service of booking an appointment with a physician. Existing Russian papers, devoted to different aspects of designing architectures of the on-line registration offices, do not pay the proper attention to the questions of developing and implementing systems of service quality assessment. This is an evidence that these questions are insufficiently dealt with.

The current paper is devoted to a description of the methodology of developing a model of quality assessment of the electronic service “Booking an appointment with a physician” which can be realized in a software-analytical module in the framework of an “On-line registration office” architecture. This system is focused on opinions of patients (users of the e-service). The base of the current research is an experience of European and American scientists in developing systems of assessing the quality of electronic services which were realized in different scopes of activity (including e-government).

## Problem statement

It is much more complicated to assess the quality of a service as compared to a product (commodity), as consumers do not only perceive the outcome of a service but also participates in its rendering. An assessment of quality of medical services has a set of additional conditions, including:

- higher requirements of observing the privacy policy and security of patients' data;
- the risk of irreversible effects up to a patient's death as a result of ambiguous, incompetent or untimely service rendering;
- the specific character of informing patients about available services and interviewing them about the quality of these services; the cause of the specific character is a variation of social status and age groups of citizens visiting state health care institutions.

Existing publications give us exhaustive information about methods and models that are now used for assessing the quality of services, and comparing them [1–10]. There are two approaches of assessing the quality of services. Conceptual models, produced to understand the evaluation process, are the base of the first approach [8]. The second approach is a result of empirical analysis and experimentation on different retailing sectors [2–4, 9]. The basic difference of these approaches lies in defining the dimensions of quality assessment and factors corresponding to these dimensions, according also to the scope of rendering a service.

Thus assessing electronic services assumes considering additional factors, that are determined by the requirements of the standard ISO/IEC 9126 [11] to the quality of implementing electronic services in software.

Furthermore the difference of approaches to the assessment of service quality is caused by the aim and tasks that define the research. The basic method focusing on monitoring factors of quality of services is the GAP analysis, which compares customer expectations about a service to the actual outcome of this service [5]. This method is not suitable if a consumer does not have any expectations about the service because of its novelty, or if a researcher wants to analyze the significance of quality factors and to design a model predicting the consumer behavior in response to a changing meaning of a factor (e.g. for planning financial disposition). In this case methods based on technologies of statistical analysis and data mining are effective. Besides regression and discriminant models, sometimes neural networks are the most frequently used techniques [12–15]. The possibility of full formalization of the process of decision making and implementing the models which assess the quality of services in software-analytical modules is the important advantage of these methods, especially in the case of electronic services.

The analysis of Russian projects of developing and implementing the electronic service "Booking an appointment with a physician" shows that all of them are realized at the regional level. Each region covered by one of these projects implements its own Web-portal of medical electronic services enabling a patient to book an appointment with a physician of any medical treatment facility participating in the program "On-line registration office" via Internet. Despite the fact that each region engages its own IT-developers to develop these portals, the scheme of implementing processes of providing users with the electronic service is similar. This will be shown below.

In Russia patients are registered in district municipal polyclinics according to their registration address. The demographic situation of each district is individual. It is defined by the social status, material welfare, age and gender of the inhabitants of the district. These peculiarities may become the key factors defining the different qualitative assessment of the same electronic service which is realized in different district municipal polyclinics of the region. Therefore it is necessary to monitor the quality of the electronic service in each medical

treatment facility and to plan a regional concept of developing the service considering the district's peculiarities. Existing distributed systems that are the base of the Web-portals of medical services do not include modules of quality assessment which would allow researchers to implement this functionality. Moreover there are no papers devoted to investigating these aspects of the development of models assessing the quality of *medical* electronic services.

The aim of this paper is a description of a methodology realizing an incremental analysis and preparation of data for developing a model implementing the assessment of quality of the electronic service and considering the aspects denoted above. The basic problems are:

- development of the information processes;
- selection of the dimensions and quality factors of the electronic service;
- statement of the problem of modeling the assessment of quality of the electronic service in terms of statistics.

### **Information model of the assessment of e-service quality**

The successful implementation of a project providing users with an electronic service directly depends on the ability of developers to monitor users opinions and to anticipate their expectations. This gives them an opportunity of disposing finances effectively and engaging users more and more. Therefore the aim of the tool realizing the assessment of the quality of the e-service can be formulated as a prediction of user behavior in response to changing characteristics of the e-service. The base of the tool is a model that combines a set of methods and realizes the prediction. Modeling the process of the prediction assumes:

- acquirement of factors of the quality of the e-service and selection of the most significant factors (inputs of the model);
- formalization of mechanisms of assessing the quality of the e-service by users (using technologies of modeling), which assumes:
- selection of classes of the assessment of the quality (outputs of the model).

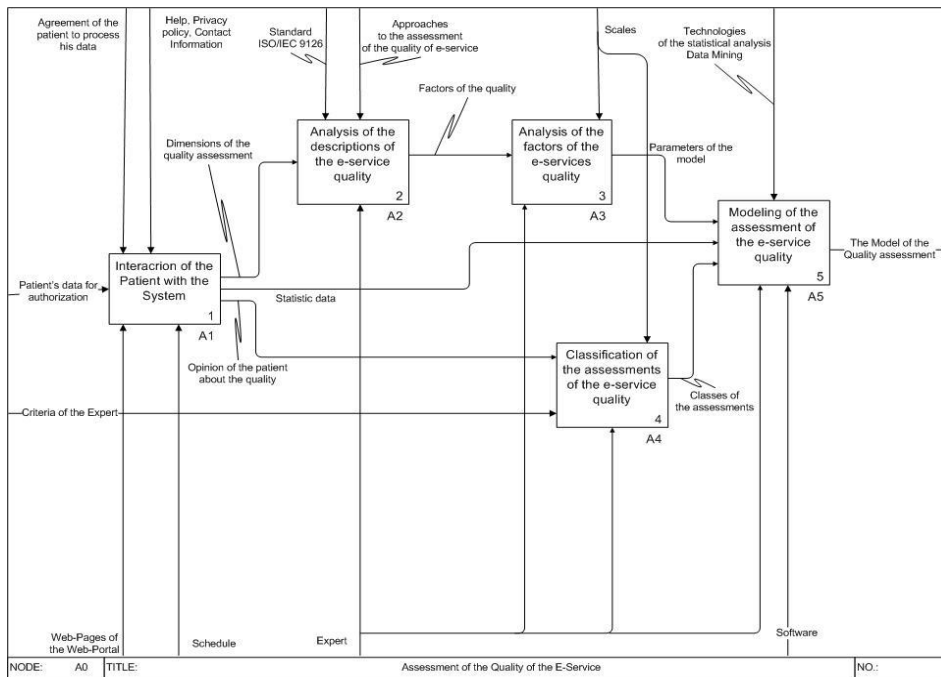
From the point of view of information technologies assessing the quality of the electronic service is a set of processes that can be presented as an information model. An incremental description of mechanisms of the realization of processes using methods according to each stage is called a methodology. The information model executed using the software Microsoft Office Visio 2007 in notation IDEF0 is presented in Fig. 1.

The processes presented in the context diagram in the activity boxes A1 through A4 describe a complex of actions for preparing data to modelling; the activity box A5 represents actions for developing the model.

The aim of the first activity box denoted in the diagram as “A1 – Interaction of the Patient with the System” is defining approaches and possible directions of acquisition of information about the quality of the service through identification of the basic stages of interaction of a patient with the system, providing him or her with the e-service via the interface of the Web-portal. The decomposition of this activity box is presented in Fig. 2.

The basis of the process described above is the result of an analysis of Russian projects implementing the e-service “Booking an appointment with a physician”. The research showed that despite the variety of interfaces and kinds of delivery of information and the ways of authorization of patients (either by passport data, or healthcare insurance or predefined login and password), the stages of implementing the process are the same. These Web-portals are supplied with full information about the rules of working with the system (sometimes with step-by-step instruction on each web-page) and about privacy policy.

Some Web-portals have feedback tools allowing developers to monitor users' opinions. These tools are present by issues with FAQs, users' reports, and forums. But the practice of introduction of these systems in foreign countries (e.g. the Website of English National Health Services <http://www.nhs.uk>) shows that an additional effective tool of monitoring patients' opinions is preparing questions with variants of answers or ratings with a request to estimate the service presented at the webpage using a scale that is predetermined by the researcher and posting them on the web-pages of the respective web-resource.

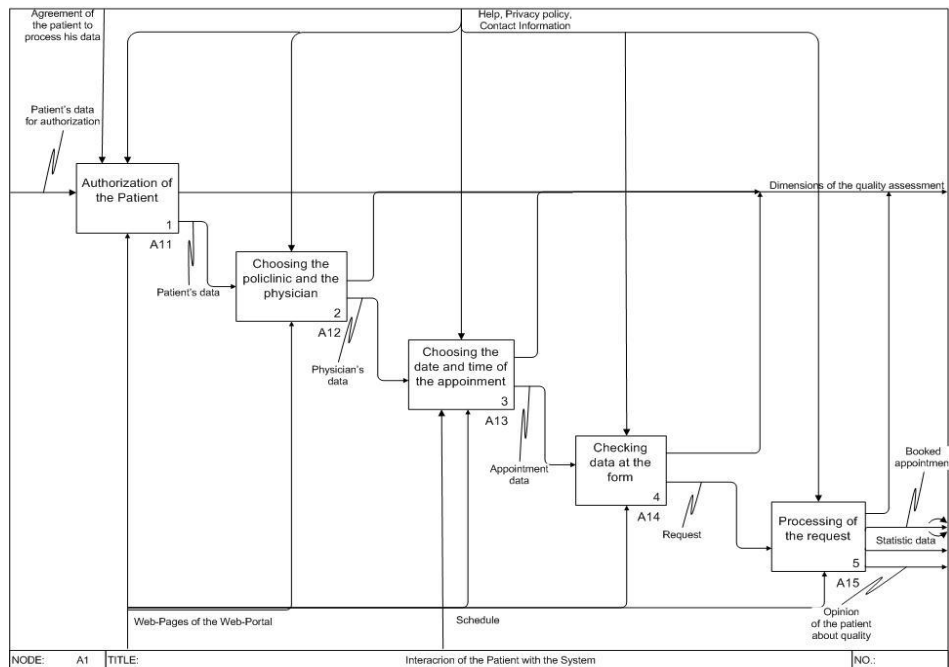


**Fig. 1. Information model of the process of assessing the quality of the e-service**

Thus the following collection of ways of acquisition of information can be defined:

- FAQ pages;
- forum;
- patients' reports;
- questionnaire on the web-pages;
- ratings posted by users on the web-pages.

To realize all of these ways of information acquisition it is necessary to engage experts who are able to analyze and reveal significant information using the technologies of data extraction (for the first three ways) and to develop questions with the variants of answers and rating scales.



**Fig. 2. Information model of providing a patient with the e-service**

### Factors of assessing the quality of the e-service

The aim of the activity boxes A2 “Analysis of the dimensions of assessing the quality of the electronic service” and A3 “Analysis of the factors of assessing the quality of the electronic service” is the analysis and preparation of the input data to modeling the assessment. The investigation of publications devoted to the assessment of the quality of services showed that all methods assume the definition of basic dimensions of the quality assessment corresponding to a field of providing the service at the first stage and selecting the fullest possible collection of factors for each dimension, at the second stage.

The basis of the majority of methods is the SERVQUAL scale proposed by Parasuraman in 1985 [8]. This scale combines factors of the quality of a service in five dimensions: Tangibles, Reliability, Responsiveness, Assurance, Empathy. Different modifications and additions of the scale with new dimensions corresponding to peculiarities of a field of providing services resulted in a variety of new methods [1–7].

Especially assessing the quality of an electronic service necessitates a consideration of the additional dimensions defined by the standard ISO/IEC 9126 of the assessment of software: Functionality, Reliability<sup>1</sup>, Usability, Efficiency, Maintainability and Portability. These dimensions are considered in a plenty of methods assessing the quality of electronic banking services, on-line shopping services and e-government services.

The collection of dimensions presented in this paper for assessing the electronic service “Booking an appointment with a physician” is developed with consideration of the requirements

<sup>1</sup> Here, reliability refers only to software aspects of a system whereas in the former list reliability refers to the whole service.

of the electronic service listed above. These dimensions also take into account the following conditions of the implementation of healthcare electronic services:

- possibility for users of any age group and any level of education to have a correct and quick access to the electronic service;
- quick and well-timed response of the staff of a medical treatment facility;
- possibility of redirection of the electronic service to another medical treatment facility in a case of emergency;
- higher attention to the security and privacy policy, which are the prerequisite of forming the trust of patients in this new type of interaction with a medical treatment facility;
- higher reliability and effectiveness as compared to the traditional ways of providing this service;
- possibility for users to register only once to receive more than one service (e.g. interaction with several medical treatment facilities of different levels via one Web-portal).

The scale presented in this paper has two main issues. The first issue combines the dimensions and factors assessing the electronic service from a point of view of effectiveness. This assumes the consideration of technical factors to a higher degree. The second issue is focused on the perception of users. The development of the factors of quality was accomplished according to the ways of acquisition of information about the satisfaction of users by the electronic service. However for the implementation of some dimensions it is necessary to know not only a subjective opinion of the users but also some technical characteristics of the system. These characteristics are also considered in this paper (Table 1).

The factors and the dimensions combining them are the input data for the problem statement and for modeling the assessment of the quality of the electronic service. It is obvious that the technical characteristics of the system, the results of the ratings and questionnaires listed above are the quantitative characteristics that are first scaled by the experts. The information obtained from the forums, the FAQ pages and the user reports is qualitative. Thus it requires additional processing by the experts before it can become the input for the model of the assessment.

#### **Modeling the assessment of patients' satisfaction by the quality of the e-service**

As denoted above the aim of the developed methodology is the description of the processes of defining the quality factors (what and how to measure) and the statement of the problem of developing the model of quality assessment (how to use the factors of quality for the prediction of user behavior) in terms of mathematical statistics.

The previous sections of the paper described the process of realizing the first stage. This section is devoted to describing the processes of a development of the model that is the base of decision making. These processes are represented in the context diagram by the activity boxes A4 "Classification of the assessments of the e-service quality" and A5 "Modeling of the assessment of the e-service quality".

Regression models combining the quality of a service (or the user satisfaction) with corresponding factors are often described in scientific papers. The authors use these models:

- to predict an influence of variables of different kinds on the satisfaction of users in a service;
- to classify users of a service according to a degree of their satisfaction in the service;



- to compare the effectiveness of providing a service across different branches or subdivisions of the organization.

**Table 1. The factors of the assessment of quality of the e-service**

|                                       | Dimension   | Technical approach<br>(monitoring)  | Questionnaire, Ratings   | FAQ, Users reports                                     |
|---------------------------------------|---|---|--|--|
| <i>Supply (Efficiency attributes)</i> |   |   |  |  |
| 1.                                    | Resource behavior                                 | –   | Satisfaction of user in the interface of web-pages<br>Satisfaction of user in the help-information ( <i>questionnaire at the reception</i> )   | Proposals of the user about improving of the interface |
| 2.                                    | Time behavior ( <i>defining an optimal time</i> ) | Monitoring the system response<br>Monitoring the time of response of the service provider (consultant)<br>Monitoring the time of confirmation of the booking (the final step of the transaction)  | Satisfaction of user in response time of the system<br>Satisfaction of user in response time of the service provider (consultant)<br>Satisfaction of user in time of confirmation of the booking   | –  |
| 3.                                    | Testability                                       | Monitoring work the services in the Internet (Monitoring of response time)  | –  | –  |
| 4.                                    | Instability                                       | –   | Which software have you updated for working with e-service? (Web-browser, flash-player etc.)   | –  |
| 5.                                    | Security  | Monitoring number of attempts of unauthorized access  | –  | Possible compliances of users                          |
| 6.                                    | Fault tolerance                                   | Monitoring appearance of errors in the system (defining the levels of the errors)<br>Monitoring termination of the transaction  | The cause why you didn't finish the booking transaction<br>–   | –<br>–   |
| 7.                                    | Recoverability                                    | Monitoring the time which user required to finish the booking after an error appeared<br>Monitoring termination of the transaction after an error appeared<br>Monitoring: Did user used the help-information after an error appeared or left the Web-page | –  | –  |
| 8.                                    | Maturity  | –   | <i>The question located at the Web-page with personal data for an experienced user:</i><br><br>Are there modifications of your personal data which you have requested?<br><br>Did we take into account your remarks (or desires) about content or interface of the Web-page? | Proposals of the user                                  |

**Table 1. The factors of the assessment of quality of the e-service (continued)**

| <i>Demand (User Convenience Attributes + Citizen Centricity Attributes)</i> |   |   |  |                       |
|---|---|---|--|-----------------------|
| 9.  | Understandability                               | Monitoring number of backtracking to the previous step                  | Assess by scale: Was it easy to find the Web-page with e-service?  | Proposals of the user |
|   |   | Monitoring number of addressing to the help-information on the Web-page | Assess by scale: Is it easy to use the Web-pages?  |                       |
| 10.   | Learnability                                    | –   | Was the help-information useful for you?   | Proposals of the user |
| 11.   | User dependence of time (24*7) availability     | Monitoring number of requests to the system at night and weekend        | Is it convenient for you if you send the request whenever you like and receive the confirmation of the booking at office hours?                | –                     |
| 12.   | Coverage of user requirements                   | –   | To what extent are user requirements covered in the service design?  | –                     |
| 13.   | Usability of local language / Multilinguality   | –   | To what extent can users use their local language in the interfaces?   | –                     |
| 14.   | Adapability to user properties                  |   | To what extent do the new services adapt themselves to attributes of citizen as compared to conventional services offered earlier?             | –                     |
| 15.   | Reduction of visits to registration office      |   | To which extent could users reduce their visits to the registration office?  | –                     |
| 16.   | Familiarity of staff with the packaged services | –   | To what extent is the staff of the service provider at service delivery station familiar with the services packaged for different user groups? | Proposals of the user |

Researchers mark out two basic groups of the models: models of user behavior and the service quality impact models. The models of the first group try to model the reaction of user to the service, particularly loyalty to the service. The models of the second group model the influence of user reactions to the service and its profitability.

In this paper we state the problem of the assessment of quality of the e-service “Booking an appointment with a physician” using the set of factors from the point of view of patients-users. In this case we can speak about the necessity of assessing a degree of satisfaction of the patients in the quality of the e-service. The patient can use this e-service via a regional Web-portal allowing him or her to book an appointment with a physician of any polyclinic of the region. Obviously the developing model must assess the quality of the e-service both at regional and polyclinic levels. This will allow developers to make the correct management decision of evaluating this e-service at the regional level.

Assume the regional Web-portal of the e-service operates with a certain number of polyclinics which we designate  $J$ . And assume  $n_j$ ,  $j = 1, \dots, J$  patients are booked and questioned in each of  $J$  polyclinics. Designate also:

- the satisfaction of patients with quality of the e-service of the polyclinic and Web-portal are  $y_{ij}^{11}$  and  $y_{ij}^{12}$ , respectively, where  $i = 1, \dots, n_j$ ,  $j = 1, \dots, J$ .

- assume  $H$  is a number of factors presented in Table 1, then the quality of each factor presented by its values is  $y_{ij}^{2h}$ ,  $i = 1, \dots, n_j$ ,  $j = 1, \dots, J$ ,  $h = 1, \dots, H$ .

In other words  $y^1$  is the satisfaction of a patient with the quality of the e-service (output of the assuming model),  $y^2$  is the objective quality of the factor (input of the assuming model). Experts deduce all values of the variables (inputs and outputs) presented by labels (e.g., *does not like*, *likes*, *likes very much*) on an ordinal scale. For each variable a set of  $K$  levels of codes is defined.

The necessity of using the variable of the objective quality of a factor  $y_{ij}^{2h}$  for each polyclinic is determined by the influence of the demographic and social situation in a district on the assessment of the quality. Let us use a set of covariates  $x_{ij}^s$ , where  $i = 1, \dots, n_j$ ,  $j = 1, \dots, J$ ,  $s = 1, \dots, S$  ( $S$  is number of covariates), for the description of these characteristics (presented for example by the local distribution of the patient's sex or age).

Thus the problem can be converted into the development of a model combining satisfaction of patients in the e-service  $y^1$  (output of the model) with the explanatory factors  $y^2$  (inputs of the model), conditionally or unconditionally on covariates  $x$ , which are also input data for the model. This model will allow us to reveal the degree of influence of each explanatory factor on the satisfaction of the patients, and the influence of the covariates on the explanatory factors, and it will allow us to compare assessments of the quality of e-services for each polyclinic and to define the cause of possible distinctions.

A. Moreno and D. Rios-Insua proposed the successful solution of a similar problem stated for modeling an assessment of the quality of bank services [14]. They presented a hierarchical ordinal regression model describing dependences stated above:

$$f(y^1 | z^1, y^2, x, \beta_1, \theta^1, \sigma_1, \sigma_2)$$

$$f(y^2 | z^2, x, \beta_2, \theta^3, \sigma_3)$$

Formatiert: Englisch (Großbritannien)

Obviously the parameters (and relations between them) of the first model define the quality of the e-service (on regional and polyclinics levels) whereas the parameters (and relations between them) of the second model define the structure of the explanatory factors. A set of latent variables  $z$  is used here to relate the variables discussed above with each other. For example the latent variable  $z_{ij}^{2h}$ ,  $h = 1, \dots, H$  is used to relate the explanatory factors  $y^2$  with each covariate  $x_{ij}^s$ :

$$z_{ij}^{2h} = \beta_j^{2h} (1, x_{ij}^s) + \varepsilon_{ijh}^3, \varepsilon_{ijh}^3 \approx N(0, \sigma_{3hj}^2)$$

$$z_{ij}^{2h} = l \Leftrightarrow \theta_{l-1}^{3hj} < z_{ij}^{2h} \leq \theta_l^{3hj}$$

where  $\beta_j^{2h}$  are regression weights,  $\sigma_{3hj}^2$  are variances,  $\theta_l^{3hj}$  are category cutoffs. In a similar way the latent variable  $z_{ij}^{11}$  and parameters  $\beta_1$ ,  $(y^2, x)$  and  $\sigma_2$  are used to relate  $y^1$  with  $y^2$ ; the latent variable  $z_{ij}^{12}$  and parameters  $\beta_1^{11}$  and  $\sigma_1$  is used to relate  $y^{12}$  and  $y^{11}$ .

To design a variety of regression models the authors describe in detail a two-step scheme of the logical deduction of  $y^1$  at the first stage and  $y^2$  at the second. Both of the stages are similar and realized Bayesian inference and a Monte-Carlo Markov Chain scheme.

The problem stated this way and its solution will allow developers in future to predict the reaction of the patients-users in response to changing factors. The regression models developed to solve this problem can become the relevant ingredient of the models solving the more global

problem like the disposition finances for the evolution of an infrastructure of the e-service “Booking an appointment with a physician”.

### **Methodology of assessing the quality of the e-service**

The stages and the basic aspects of preparing data to assessing the quality of the e-service “Booking an appointment with a physician” denoted above allowed us to formulate the methodology of processing the data.

1. Statement of the aim and problems of the assessment of quality of the e-service.

To realize this stage it is necessary to analyze corresponding papers, aims and problems of the Web-portal of medical electronic services and requirements of the developers of the Web-portal. In this paper the global aim of assessing is a regional conception of evolution of the infrastructure of the e-service “Booking an appointment with a physician”.

2. Investigation of the approaches and probable dimensions of data collection about quality of the service.

Designing information models of the processes of users working with the system allows developers to define the stages and to analyze the key aspects of the interaction. The examples of the models developed and presented in this paper allowed us to reveal five ways of collecting data presenting an opinion of the users.

3. Analysis of the dimensions and factors of quality of the e-service.

Implementing this stage requires the examinations of the standards and requirements to the dimensions of quality assessment according to the scope of an inquiry. Formulating the factors of quality is possible just in frameworks of the dimensions examined and stated above and can be implemented just in consideration of the available ways of data collection and with participation of experts ranking and scaling the data. We realized the development of the dimensions and factors of quality of the medical e-service on the base of methods assessing quality in different scopes, the standard of quality of software and specific conditions of the medical e-services realization.

4. Statement of the problem of assessing quality of the e-service in terms of mathematical statistics.

This stage is a key stage as in this phase knowledge is generated and stored about the scope and formalizing the problem. The selection of modeling methods defines the necessity of preprocessing input data and formulating outputs according to the problem using an experience of experts. The problem stated in the paper can be solved using regression analysis that defined the necessity of deducing the data to ordinal scales.

### **Conclusion**

The paper describes the methodology of preparing data for the analysis aiming to assess quality of the electronic service “Booking an appointment with a physician” from the point of view of the patients or, in other words, satisfaction of patients in the electronic service. This methodology can become a useful recommendation for developing tools of monitoring the opinions of users and for computer-aided assessing the quality of the electronic services for developers of the Web-portals of the medical electronic services. These tools can become the basis for the management decision making aiming to evolve an infrastructure of providing medical electronic services. Further work should consider the approbation of the methodology using data from one of the existing Web-portals of the medical electronic service “Booking an appointment with a physician” and developing the questionnaires, ratings, assessing factors and classes, and the assessment model according to the conditions of providing this electronic service.

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