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Assessment of service efficiency using public service models

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Abstract
The intensification of mutual competition in the modern complex market economy requires the improvement of the quality and efficiency of service providing, as in all fields. As a result, new types of services must be introduced, their quality improved, and new methods of measuring their effectiveness developed. The current evaluation methods are based on the statistical analysis of survey data from service consumers. In contrast to previous methodologies, the suggested method is based on evaluating the efficiency of a service type using mathematical models from public service theory. An objective function comprising the service quality indicator, organizational expenses, service profit, and the value of the time customers spend using the service is suggested as an evaluation indicator. Based on mathematical models of public service, the objective function's coordinators were chosen. The minimal value of the objective function determines how effective the suggested service type is. The obtained results allow us to calculate the costs and profits of the company offering the service and thus evaluate the effectiveness of the service. The suggested model considers both the interests of the service's users and the corporation providing the service.

Keywords
Public service models, Service user flow, Service time, Service devices, Time spent

Introduction
In the modern complex market economy, increased competition requires the need to improve the quality and efficiency of services provided in the service sector, as in all other sectors. This, in turn, indicates the need to introduce new types of services, develop new methods for improving their quality and assessing their efficiency. The relevance of the issue has led to the conduct of many studies [1 – 9]. The most common model in this direction is the five-stage model of service quality assessment proposed by a group of scientists [1]. This model is also called the service quality gap model or GAP. Based on it, a practical method called SERVQUAL was developed for assessing service quality [2][3][6]. These methods are based on statistical processing of the results

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obtained through a questionnaire of the differences in the perceived quality of the offered service and the quality of the organization that offers it.

Another widely used method for assessing the quality of the service provided is the "mystery shopping" method [8][9][15–20]. This method is also based on statistical regression of surveys conducted among users and is somewhat more expensive than the SERVQUAL method.

The main idea of the methods for assessing the quality of services provided in the above works is the statistical processing of the opinions of service users and their results. The customer, being the most important and integral element in the service system, expresses his subjective opinion about the quality of the services provided to him and his participation in the service process, which makes these methods practical. With the help of these methods, the consumer evaluates the visible part of the elements participating in the service process. However, this process is the result of the invisible activity of the service organization.

Based on the methods considered, the level (value) of service provision that satisfies users is determined, and on its basis, the service enterprise determines its technical and economic indicators.

In the proposed method, unlike existing methods, the service quality indicator is determined based on an objective function that includes the costs of organizing it and the benefits obtained from providing this service, as well as the value of time lost by users. The mathematical expression between the objective function and the quality indicator of the service provided is determined based on mathematical models of the theory of public service provision.

The objective function should include all factors that affect the quality of customer service. These factors include the costs of organizing the service, the revenue received (lost) from the services provided, and the amount of time lost by customers in the process of receiving the services provided. The efficiency of the service being introduced can be determined by determining the optimal value of the objective function. Therefore, the main goal of this work is to determine the efficiency of the type of service being offered based on the objective function.

Method

A company that provides services to customers spends a certain amount of money to set up its business. These expenses include the purchase of equipment to provide services and its operation, as well as the costs of paying employees. These costs are directly related to the quality of service. Naturally, the higher the quality indicator (the lower the losses), the more devices are needed. We denote such costs as $K_1(P)$ at a given cost of service P.

The company that organized it receives a certain amount of income from the services provided or loses it from the services not provided. Naturally, if the quality of the service is high (the more service facilities are available, the better organized), the more income is received or the less income is lost. We denote the dependence of the company's losses on quality indicators as $K_2(P)$.

The quality of service provided to customers also affects the time they spend using these services. Because a decrease in quality, i.e., a reduction in the number of service providers, increases the waiting time for service. This leads to delays in data transmission and loss of personal and business time for customers. In the era of information and communication, each customer's personal and working time has a certain value. Therefore, such losses lead to certain losses for service users. We denote such losses by $K_3(P)$.

Therefore, the factors related to the quality of service provided to customers constitute the total costs, and these costs can be viewed as an objective function.

$$K(P) = K_1(P) + K_2(P) + K_3(P) \quad (1)$$

Naturally, to determine the effectiveness of the proposed type of service, it is necessary to minimize the objective function. The value of the quality indicator corresponding to the minimum value of this function indicates the optimal value of the quality of service.

Since there is a certain relationship between service devices and quality indicators, the objective function can be expressed in terms of service devices as follows.

$$K(m) = K_1(m) + K_2(m) + K_3(m) \quad (2)$$

Taking into account certain constraints, it is possible to determine the minimum value of this objective function, the quality of service indicators, and the optimal value of service devices that provide this quality,

$$K(m) = K_1(m) + K_2(m) + K_3(m) \to min \quad (3)$$

$$K(m_{opt}) = K(m)_{min},\ m_{opt} \to P_{opt} \quad (4)$$

To determine the economically optimal cost of providing a service, it is necessary to mathematically express the components of the objective function in terms of service devices or quality indicators. To solve this problem, we use the theory of public service provision.

It is known that the service process is formed by the interaction between two participants (players)—the service user and the service provider (Figure 1). To evaluate the process of providing services to users within a certain quality standard of this system, it is necessary to create a mathematical model of the system. The mathematical model being created is an analytical representation of how the system responds to external influences. An external influence can be seen as a flow of requests (requests) generated by users. The system's response to the flow of requests is described based on its state, i.e., whether service devices are busy or free, the state of waiting areas, the waiting time for the service to start, etc.

Considering that the flow of external influences from users occurs at random times with random values and that the service system responds to this flow randomly, it is appropriate to use mathematical models of the queuing theory (QT) to represent this process in a mathematical form [10][18].

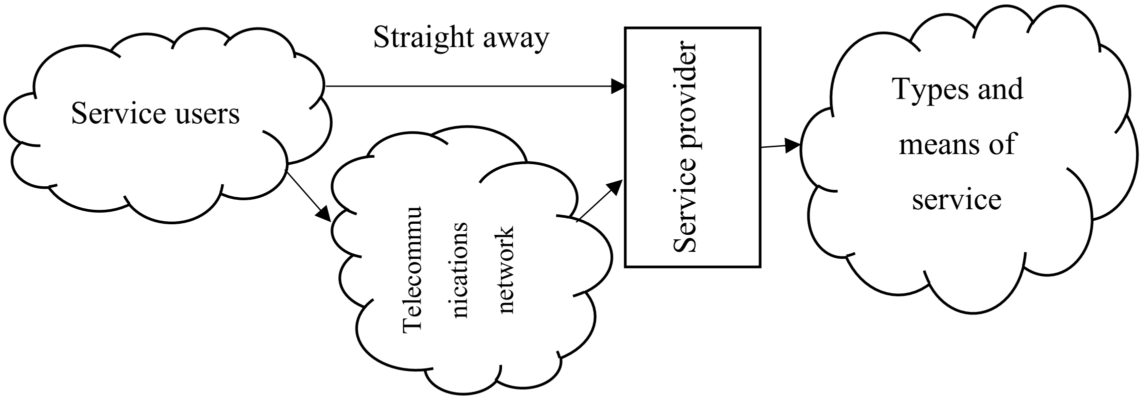

Figure 1. Service system

It is known that the mathematical model of the QT consists of the following elements [12]:

1 the flow of requests entering the service system. Such requests form the input flow. The model requires the mathematical expression of the input flow to be determined;
2 the time it takes for the system to service each request (ST). This time is determined by the occupied time or busy time of the service devices;
3 order for servicing incoming requests to the system (SO);
4 internal structure of service devices.

As an example, let's consider the most commonly used model, which reflects most service systems: M/M/m/r<∞ (where M is the flow into the system, subject to an exponential law; M is the service time, subject to an exponential law; m is the number of service devices; and r is the number of waiting areas). We determine the quality indicators and the number of service devices required to solve the above problem of this model [12][13][17]. The probability of loss (or non-service) of requirements.

$$P = \frac{(m-A)\left(\frac{A}{m}\right)^{r}}{\left[\frac{m-A}{E_m(A)} + A\left(1-\left(\frac{A}{m}\right)^{r}\right)\right]} \quad (5)$$

In this case, A is the load generated by users, r is the number of queues, and $E_m(A)$ is Erlang's first formula;

- average waiting time for customers to start their service

$$\gamma = \frac{P(\gamma > 0) * \bar{t}_{xiz}}{(m-A)} \quad (6)$$

- The probability that the average waiting time for customers to start a service session will exceed a specified value is $P(>t_{sk})$

$$P(>t_{sk}) = P(>0)e^{-\beta(m-A)t_{sk}} \quad (7)$$

average number of customers waiting to be served

$$s = \frac{A * E_m(A)}{(m-A)} \quad (8)$$

Based on the above service system indicators, the components of the target function can be identified as follows.

When the load on the service devices A and the quality indicator of service are known, the number of service devices can be determined using the above formula, and based on this, the costs of their purchase and operation can be determined as follows:

$$K_1(m) = \sum_{i=1}^{n} C_i \, m_{i1} \quad (9)$$

Here C_i is the cost of one i-type element, taking into account operating costs; m_i is the number of i-type devices. The number of such devices is determined using expression (1) based on the load A_i, quality P_i and other indicators.

We determine the revenue generated (or lost) from providing the service. Naturally, the higher the quality of the service (more service operators, waiting areas, etc.), the more revenue is generated or the less revenue is lost. If a service company receives N requests, then N_{xiz} (N_{xiz} = N·(1-P) of them will generate such income, but for certain reasons, N-N_{xiz} = N_{yok} = N·P of the total requests will be lost without service, that is, income will be lost. Here, the probability of loss P is determined using expression (1). This part of the losses is due to the busyness of the service devices and waiting areas. However, in the waiting-mode service systems, users who generate requests can wait for a certain allowed time t_{sk}. Exceeding this time, the waiting time t_k leads to users leaving the system. The loss of the service company due to the impatience of users is the total demand N=N·P(>t_{sk}). Here P(>t_{sk}) is determined using (2). Therefore, the loss of revenue of the service company is determined as follows, when the profit received per demand is C_y.

$$K_2(m) = C_y N[P + P(> t_{sk})] \quad (10)$$

It is known that since time has a certain value, each customer's personal and working time also has a certain value. As the quality of service deteriorates, that is, the probability of loss increases, the time it takes for customers to receive the service increases (formula 2). This leads to the loss of personal and working time of customers. In addition, in the information society, information is an economic category. The information contained in the transmitted message has a certain value [11][14]. The average time of its transmission depends on the medium. The dependence of the information message on the time of transmission is different for messages of different natures. production, whether the delay in the production of information in production leads to slow production of the production control process, etc., leads to the production of work orders. Such losses can be taken into account.

$$K_3(m) = C_3 \gamma_n N \tag{11}$$

where C_3 is the average value of the user unit time.

The values of the users' unit working and non-working time can be determined based on statistical data.

Therefore, based on the expressions obtained above, mathematical expressions were determined (found) with the objective function components and the quality of service provided to service users.

Results and Discussion

The change in the sizes of these components depending on the number of service devices is shown in Figure 2. As can be seen from the figure, as the number of service devices increases, the company's direct costs also increase, and this situation causes a certain amount of damage to the company. However, due to the improvement in service quality, the company's revenue from providing services increases and its lost revenue (loss) decreases, which brings a certain amount of profit to the company. In addition, improving service quality reduces the waiting time of users for the service to start, which also reduces operating and downtime costs. It is clear from this that the interests of the service company and the interests of its users are in conflict (Figure 2).

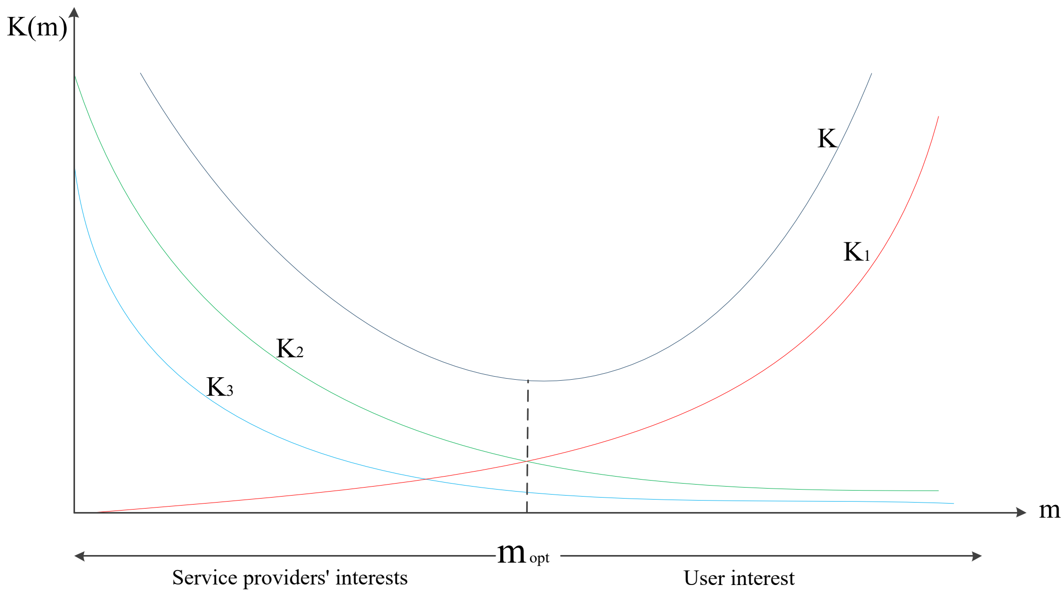

Figure 2. Objective function changes with respect to service devices

We will consider the determination of the quality indicators and efficiency of the service systems proposed above using the example of banking services. In this,

daily customer flow N=500;

average service time per customer $\bar{t}_{xiz}$= 5 minute;

average user time C_3 = 0.5 dollar/minute;

the cost of each employee and service device, taking into account operational costs C_i = 50 $;

permitted waiting time t_{sk}=10 minute;

average profit per customer C_y= 10 $.

Now, using this data, we determine the optimal value of bank employees based on the proposed model. The results are presented in the following graphic form (Figure 3).

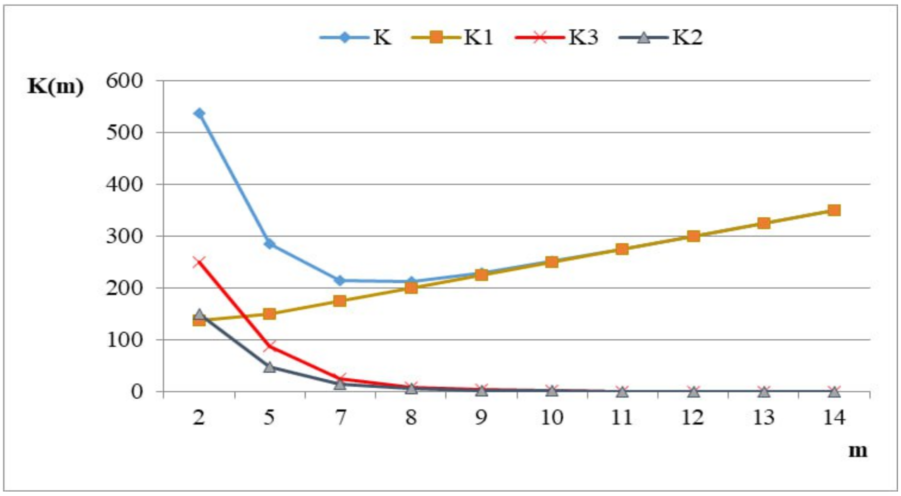

Figure 3. Graph for determining the optimal value of bank employees

It can be seen from the graphs that an increase in the number of bank employees significantly reduces waiting time, which reduces the loss value of customers. At the same time, the increased costs of employees reduce the company's profits. According to the results obtained, the optimal number of bank employees is 7-8. Determining the optimal number of bank employees will moderate the balance of benefits and costs.

Therefore, based on the proposed model, it is possible to determine the efficiency of the service system and determine the value of the optimal service tool for it.

It should be noted that the deterioration of the quality of service to a certain value leads to the non-use of this type of service, since the reduction of the number of service devices from the optimal value corresponding to the minimum value of the objective function can lead to a decrease in the quality of service indicator below its threshold value.

Once the economically optimal cost of service facilities has been determined, it is possible to determine the optimal value of the quality of service corresponding to this value. Naturally, it is rational to organize services if the additional costs incurred as a result of adding service facilities are less than the benefits received from improving the quality of service to users and reducing downtime.

Conclusion

The proposed objective function for assessing and optimizing the quality of service provision involves balancing the interests of the company and customers in order to achieve economic efficiency. The interests of the company are reflected in optimizing the costs of organizing the service and increasing the profit from the services provided, while the interests of customers are aimed at improving the quality of service and reducing time losses.

This approach allows you to take into account the total costs of providing a service - organizational costs, lost revenue, and customer time. Improving the quality of service not only brings financial benefits to the company, but also ensures the convenience of using the service for customers. At the same time, determining optimal quality indicators allows the company to organize services economically and meet customer requirements. This model creates broad opportunities for scientific and practical assessment of service efficiency.

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