Bulletin of the *Transilvania* University of Braşov • Vol 10(59), No. 2 - 2017
Series III: Mathematics, Informatics, Physics, 155-170

COMPUTER FUZZY MODEL REGARDING PHARMACIES INTEGRAL PERCEPTIONS BY VISITORS

Liudmyla DOROKHOVA[1] **and Oleksandr DOROKHOV**[2]

Abstract

The paper considers the development of a computer model for the task of determining consumer estimates of pharmacy institutions by visitors and clients in terms of quality and service conditions. The main criteria and parameters for such an assessment were chosen, and their hierarchical tree was constructed. Then, the units of measurement and the ranges of the parameters to be evaluated were determined. Given the lack of certainty of opinions and assessments of consumers, it is advisable to solve the problem on the basis of fuzzy modeling methods. Thus the most appropriate computer simulation tool, the FuzzyTECH specialized software has been chosen. In this environment, an appropriate model has been created. For this, input and output linguistic variables, as well as their terms, has been defined. Then the corresponding membership functions and fuzzy logic inference rules were constructed. Further, the corresponding surfaces of the fuzzy inference were obtained. The developed computer model was tested during the evaluation of a group of pharmacies in the city of Kharkiv. The calculated resulting estimates are fairly close to those obtained using other, more cumbersome methods. The approached described and the model presented showed fairly valid results, despite its relative simplicity. Thus, the described implementation of the fuzzy-multiple model of generalized customer service evaluation in pharmacy institutions is a very useful practical computer tool for solving problems of improving the level of pharmaceutical service. The proposed computer model is also applicable to other tasks of assessing the quality of service in conditions of uncertainty.

2000 *Mathematics Subject Classification:* 68U35, 91B06, 91B26, 91B42, 94D05, 03B52, 03E72, 28E10.

Key words: computer modeling, fuzzy logic, quality of service, consumer estimates, FuzzyTECH, fuzzy modeling

[1]Faculty of Pharmacy, National Pharmaceutical University, Ukraine, e-mail: liudmyladorokhova@gmail.com

[2]Faculty of Economics Informatics, Kharkiv National University of Economics, Ukraine, e-mail: aleks.dorokhov@meta.ua

1 Introduction

New opportunities for computer modeling, which appeared in recent years, are increasingly being used to solve a wide range of economic problems. Among them, the study, modeling, and forecasting of consumer behavior in the markets of goods and services are quite important, as well as modeling the attitude of buyers to merchandises, their producers, sellers, trade, and service enterprises [3, 8, 9, 12, 15].

At the same time, in the context of the globalization of markets and the rapid development of new methods of communication, consumer solutions become dependent on many factors, often having a difficultly formalized, indistinct, unclear, insufficiently defined character. Such unclear initial data in the models is caused by both objective reasons, lack or difficulties in obtaining information, and psychological, personal, emotional, social aspects of consumer behavior.

For these reasons, it is sufficiently justified and convenient to use different methods and models based on the theory of fuzzy sets. The possibility of a computer implementation of such models is provided by the availability of appropriate specialized software, which makes such modeling a tool, practical, accessible and convenient for ordinary users.The possibility of such modeling of consumer estimates and preferences exists for different markets for goods and services, including the pharmaceutical market and pharmaceutical services for the population in pharmacy institutions.

2 Determination of the components of the integral perception of the pharmacy by buyers of pharmaceutical products

A very significant number of scientific publications are devoted to the research of various components of the perception of the pharmacy institution in general and the service in it by consumers [1, 2, 5-7, 10, 11].

Usually, various surveys are conducted first, and then they are processed by statistical methods. The results obtained are visualized in various ways, further, they are also discussed, evaluated and interpreted. Often at this stage of the research are completed and finished [4, 13, 14, 17].

At the same time, multifactor, multicriteria models for obtaining the direct integral quality of service indicators directly on the basis of input parameters, without intermediate calculations, various kinds of simplifications by this time are developed and presented insufficiently [16].

For this reason, we have defined the tasks of creating one of these types of models, based on the approaches of fuzzy logic and fuzzy modeling with its subsequent implementation in the corresponding software product on the computer for the further practical application.

Based on literary sources, practical research and case studies, several important parameters were chosen that determine the overall quality of service and

perception of the pharmacy by visitors.

The composition of these parameters, of course, is not final; it can be expanded, supplemented or detailed if necessary. However, this does not affect the overall proposed modeling methodology that allows us to consider the problem posed in the following formulation.

The parameters selected for consideration were grouped by us into a tree (shown in Figure 1), which illustrates the possible variant of the final decision by the consumer according to the evaluation of a certain pharmacy by the level of the service criteria presented. The colors (in Figure 1 and, respectively in Figure 2) mark such elements as: grey elements, not used in the further construction of the model; blue input parameters on first level; lilac intermediate and input parameters on second level; green - intermediate parameters on third level; orange - final output result (estimation).

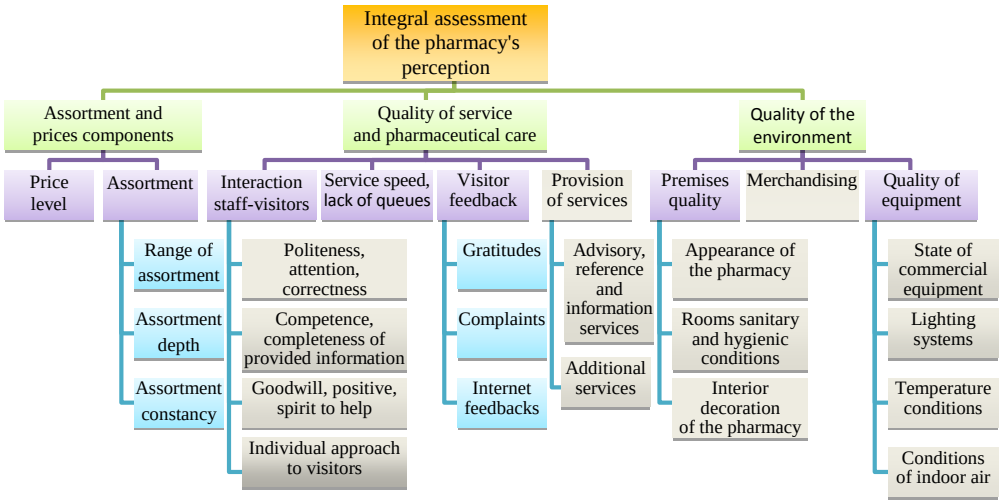


Figure 1: Tree of criteria for assessing pharmacies by visitors

Before practical implementation of the simulation (development of the fuzzy model for pharmacy evaluation from the part of visitors), it is expedient to briefly characterize some of the selected parameters.

Thus, the breadth of the assortment reflects the completeness (availability for the consumer in the pharmacy) of drugs and medicinal products according to classification characteristics (standard groups), and the depth of the assortment is the number of positions in each individual group (from the maximum possible to purchase in Ukraine). The stability of the assortment characterizes the stability (constancy in time) of the availability of medicinal products on sale in the pharmacy.

These three characteristics together characterize the assortment as a whole, and together with estimates of the price level characteristic of a certain pharmacy, can be considered as an assortment price component of the quality of service.

Another group of parameters can reflect the quality of work of pharmacy staff with visitors.

Variable name	Type (input, intermediate, output)	Range, unit of measurement
width_assortment	Input, first level	0÷1 coefficient (less ÷ more)
depth_ assortment	Input, first level	0÷1 coefficient (less ÷ more)
constancy_assort	Input, first level	0÷1 coefficient (less ÷ more)
assortment	Intermediate, second level	0÷5 point (worse ÷ better)
grievance	Input, first level	0÷30 complaints per month
commendation	Input, first level	0÷30 thanks per month
internet_respons	Input, first level	-30÷30 per month (complaints÷thanks)
responses	Intermediate, second level	0÷5 point (worse ÷ better)
prices	Input, second level	1÷3 point (high ÷ low)
Q_price_assort	Intermediate, third level	0÷5 point (worse ÷ better)
civility	Input, second level	0÷5 point (worse ÷ better)
waiting	Input, second level	0÷20 minutes (less ÷ more)
Q_service	Intermediate, third level	0÷5 point (worse ÷ better)
appointments	Input, second level	0÷5 point (worse ÷ better)
building	Input, second level	0÷5 point (worse ÷ better)
Q_environment	Intermediate, third level	0÷5 point (worse ÷ better)
Quality_total	Output (final), fourth level	0÷5 point (low ÷ high)

Figure 2: Model variables and parameters

Although not all buyers are so active in leaving leave written evidence about the quality of service (remarks, comments or gratitude in the book of complaints, written requests regarding defects or improvement services to the management of the pharmacy or to the higher supervisory authorities), or reviews on social networks and the Internet.

Nevertheless, by the number of such appeals and comments, the ratio of positive and negative ones for a certain period of time (in our example, a month), it is possible to get a fairly accurate general assessment of the state of affairs with the level of quality of care in a concrete pharmacy (drugstore).

Additionally, we can take into account the level and quality of staff interaction with visitors (courtesy, attention, correctness, competence, goodwill, positive attitude to help, etc.) through direct customer surveys. Together, these components fairly faithfully reflect the service component of the quality of service level.

Finally, as noted above the physical state, internal view and interior decoration of pharmaceutical establishment are very important. In the model proposed and described these moments reflect two generalized parameters - the quality of premises and quality of equipment. The first of them includes the appearance of the pharmacy, the state of the hall, its interior decoration, etc., the second - the state of furniture and other trade equipment and accessories, lighting, tempera-

ture control, the air conditioning and similar components. Together, these two parameters comprise quality of customer environments indoor shopping pharmacies hall.

Determined in this way the three generalized parameters - assortment and price component of quality, service quality and quality of environment together can be combined into the final, integrated assessment, which can be considered as an assessment of the perception of the pharmacy by the visitor as a whole.

Corresponding explanations for computer model (names of variables, their linguistic terms, numerical characteristics of variables) are presented in Figure 2.

It is clear that, depending on the circumstances and requirements for the degree of detail of the model, other characteristics of pharmacy services can be defined and included (as separate parameters), but the principle of constructing the model and calculations in it is preserved, which makes the approach proposed to modeling the assessment of the pharmacy institution by the consumer sufficiently universal, flexible and able to solve the problem in specific practical conditions.

3 The development of the model in the fuzzy modeling program FuzzyTECH

For the practical implementation of the model, which was generally described above and shown in Figure 1, several similar in functionality packages, specialized software FuzzyTECH were selected for the modeling of proposed fuzzy evaluation systems.

This program among other similar programs characterized by a fairly simple interface, ability to work even for a low-skilled user, sufficient features of the free trial demo version, which allow complete simulation and solving of the assigned task.

There is a detailed help system and test cases which greatly facilitate understanding of the basics of fuzzy modeling as a whole, study of the basic principles of creating a variety of fuzzy inference systems and features of their practical implementation in this program.

Also, this program has acceptable requirements for the technical characteristics of the computer, quite compact in size, works on almost all versions of Windows, easily transferred from one computer to another, which makes it one of the most successful developments of this class for fuzzy modeling in practical conditions. All this is what determined its choice.

Thus, the model proposed after processing in the program takes the form shown in Figure 3.

Without losing the generality of the formulation and solution of the problem, all variables were represented by sets of piecewise linear (triangular and trapezoidal) membership functions with three terms (low, high, medium), having different parameters in accordance with the data in Figure 2.

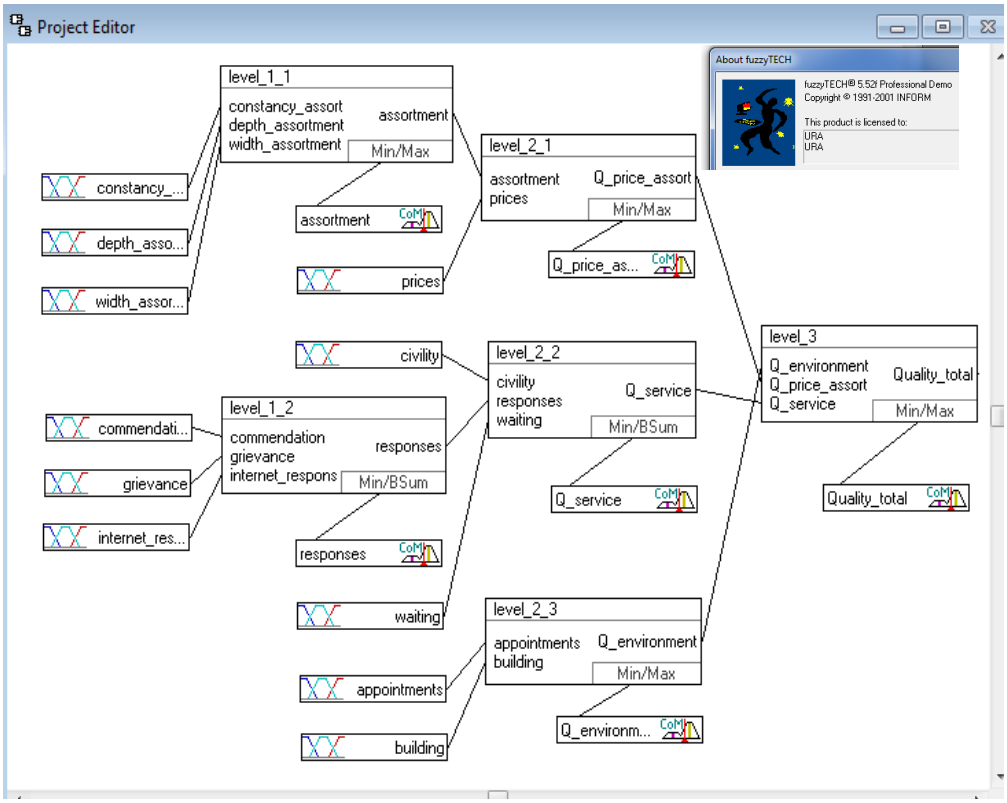


Figure 3: The proposed model in FuzzyTECH program

The corresponding form of functions for input parameters: width, depth, and stability of the assortment in detail is shown in Figure 4. This figure also presents a generalized assortment evaluation and rules, by which it was obtained.

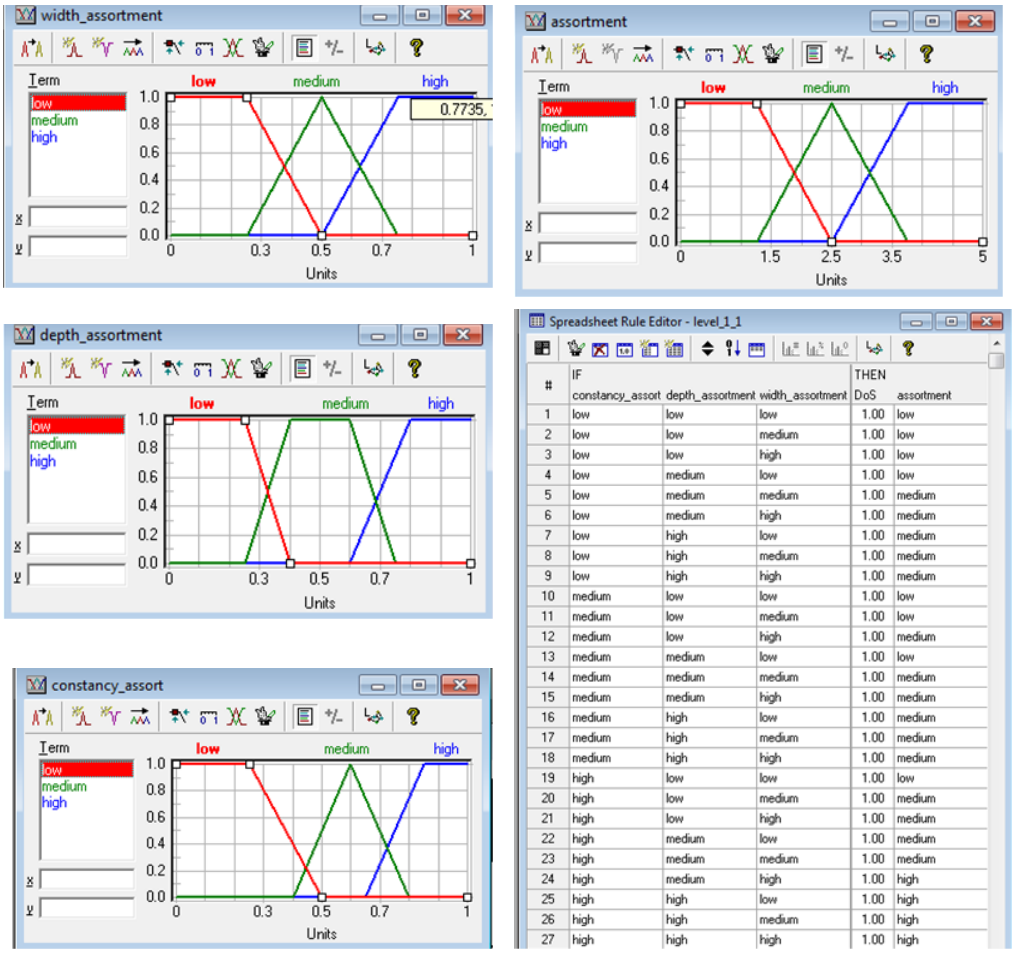


Figure 4: Membership functions for width, depth, stability of the assortment, assortment evaluation, and rules

The graphical representation of all other variables of the model proposed is shown in Figure 5, and the corresponding rules for fuzzy inference are shown in Figure 6.

The resulting estimate, in turn, acts as an input parameter, together with an estimate of the level of prices at the pharmacy (in points, and higher prices correspond to a smaller score and vice versa) for an assortment-price component of quality.

On the other branch of the low (first) level of tree, there are parameters which reflect the feedback of visitors regarding the service, namely: number of recorded written complaints and comments, observations, as well as clients thanks, and the

total balance (number) of responses in social networks (where negative is reflected with a minus sign, and positive - with positive values).

It should be noted that the data were examined for a 30-day period (month). If the number is greater than 30, we also consider this indicator to be equal to 30. For the Internet network, positive and negative reviews are summarized, which gives the final result.

The summarizing feedback variable, in turn, is the input for the integral quality of service parameter along with other input parameters: waiting (waiting time in the queue, we accepted up to 20 minutes maximum) and staff interaction with customers(it is estimated by expert polls on a 5 point scale).

As already noted above, the state of the premises and its equipment, along with other components, are the important factors of perception of service level by the visitors. In the model proposed, these parameters correspond to the parameters appointments and building.

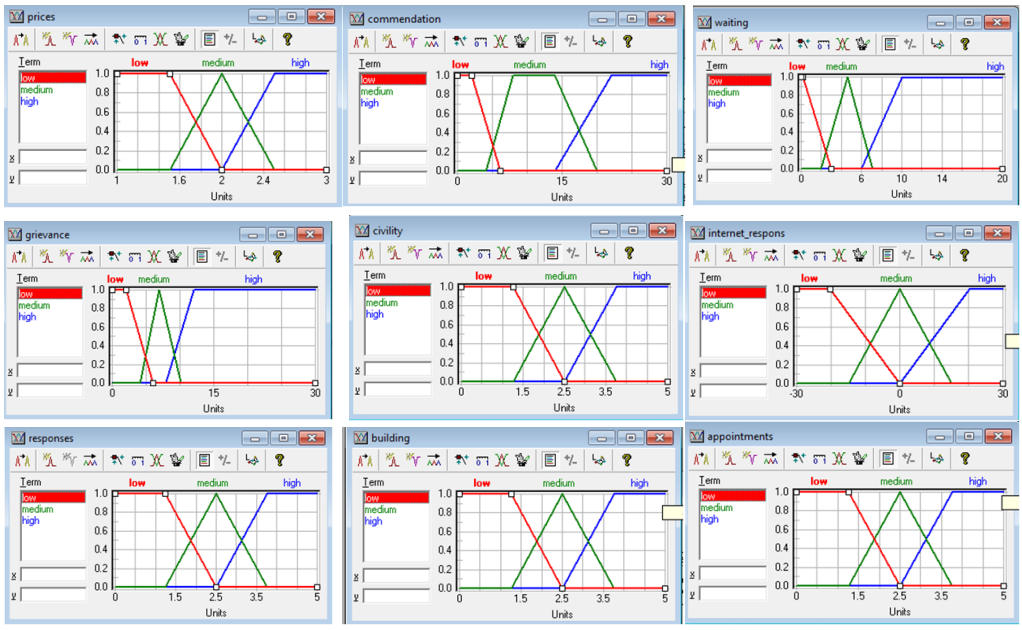


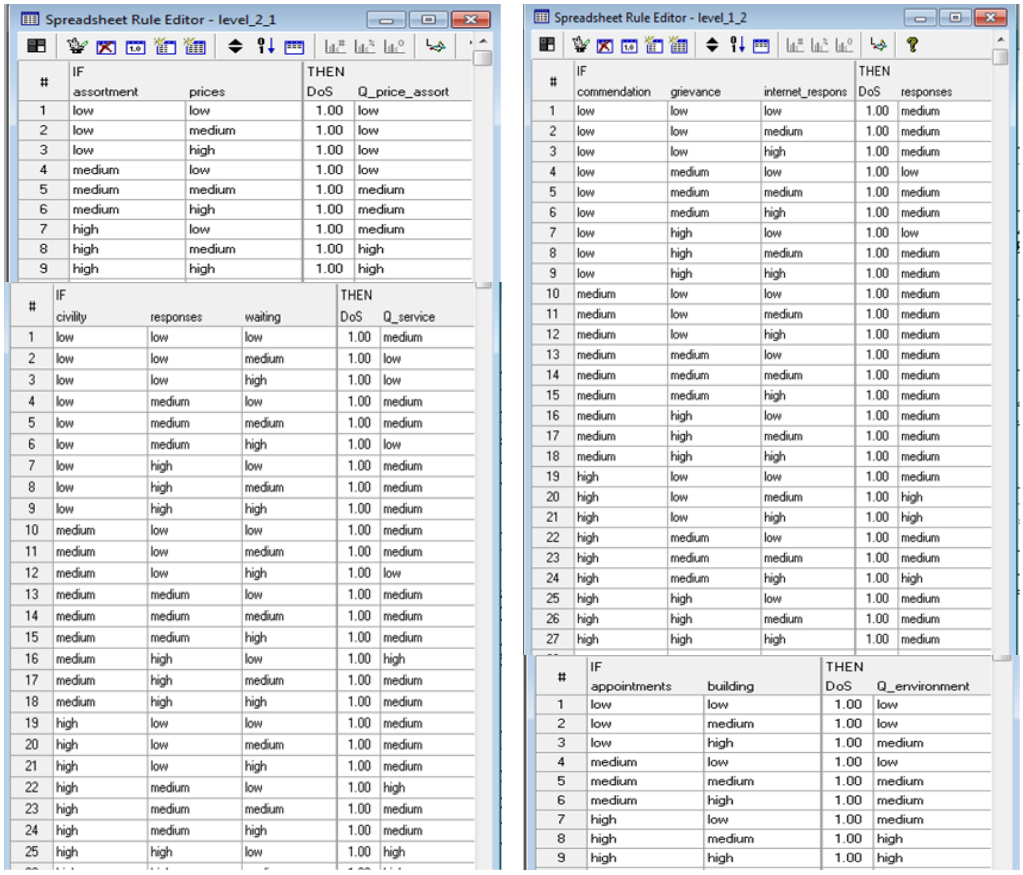
Figure 5: Membership functions of the fuzzy model described

Then the final integrated quality assessment of the service environment will also be obtained in the 5 point system.

It should be noted that the components of the service environment (appearance of the premises, entrance design outside and inside lighting, trading equipment, advertising means, convenience for visitors, places for rest and waiting orders, access to the Internet, etc.).

If necessary, the statement can be modeled in more detail which will be the subject of a separate further study and modeling.

Thus, eventually, we can get three components (input variables) to determine



Spreadsheet Rule Editor - level_2_1

#	IF assortment	prices	THEN DoS	Q_price_assort
1	low	low	1.00	low
2	low	medium	1.00	low
3	low	high	1.00	low
4	medium	low	1.00	low
5	medium	medium	1.00	medium
6	medium	high	1.00	medium
7	high	low	1.00	medium
8	high	medium	1.00	high
9	high	high	1.00	high

#	IF civility	responses	waiting	THEN DoS	Q_service
1	low	low	low	1.00	medium
2	low	low	medium	1.00	low
3	low	low	high	1.00	low
4	low	medium	low	1.00	medium
5	low	medium	medium	1.00	medium
6	low	medium	high	1.00	low
7	low	high	low	1.00	medium
8	low	high	medium	1.00	medium
9	low	high	high	1.00	medium
10	medium	low	low	1.00	medium
11	medium	low	medium	1.00	medium
12	medium	low	high	1.00	low
13	medium	medium	low	1.00	medium
14	medium	medium	medium	1.00	medium
15	medium	medium	high	1.00	medium
16	medium	high	low	1.00	high
17	medium	high	medium	1.00	medium
18	medium	high	high	1.00	medium
19	high	low	low	1.00	medium
20	high	low	medium	1.00	medium
21	high	low	high	1.00	medium
22	high	medium	low	1.00	high
23	high	medium	medium	1.00	medium
24	high	medium	high	1.00	medium
25	high	high	low	1.00	high

Spreadsheet Rule Editor - level_1_2

#	IF commendation	grievance	internet_respons	THEN DoS	responses
1	low	low	low	1.00	medium
2	low	low	medium	1.00	medium
3	low	low	high	1.00	medium
4	low	medium	low	1.00	low
5	low	medium	medium	1.00	medium
6	low	medium	high	1.00	medium
7	low	high	low	1.00	low
8	low	high	medium	1.00	medium
9	low	high	high	1.00	medium
10	medium	low	low	1.00	medium
11	medium	low	medium	1.00	medium
12	medium	low	high	1.00	medium
13	medium	medium	low	1.00	medium
14	medium	medium	medium	1.00	medium
15	medium	medium	high	1.00	medium
16	medium	high	low	1.00	medium
17	medium	high	medium	1.00	medium
18	medium	high	high	1.00	medium
19	high	low	low	1.00	medium
20	high	low	medium	1.00	high
21	high	low	high	1.00	high
22	high	medium	low	1.00	medium
23	high	medium	medium	1.00	medium
24	high	medium	high	1.00	high
25	high	high	low	1.00	medium
26	high	high	medium	1.00	medium
27	high	high	high	1.00	medium

#	IF appointments	building	THEN DoS	Q_environment
1	low	low	1.00	low
2	low	medium	1.00	low
3	low	high	1.00	medium
4	medium	low	1.00	low
5	medium	medium	1.00	medium
6	medium	high	1.00	medium
7	high	low	1.00	medium
8	high	medium	1.00	high
9	high	high	1.00	high

Figure 6: Sets of rules for intermediate calculations

the final (integral) assessment (perception) of the pharmacy by the visitor namely assortment-price component, quality of service and quality of the pharmacy institution's environment.

Then the final evaluation, the acquisition of which is the goal of modeling can be determined on the basis of the corresponding membership functions and decision rules shown in Figure 7.

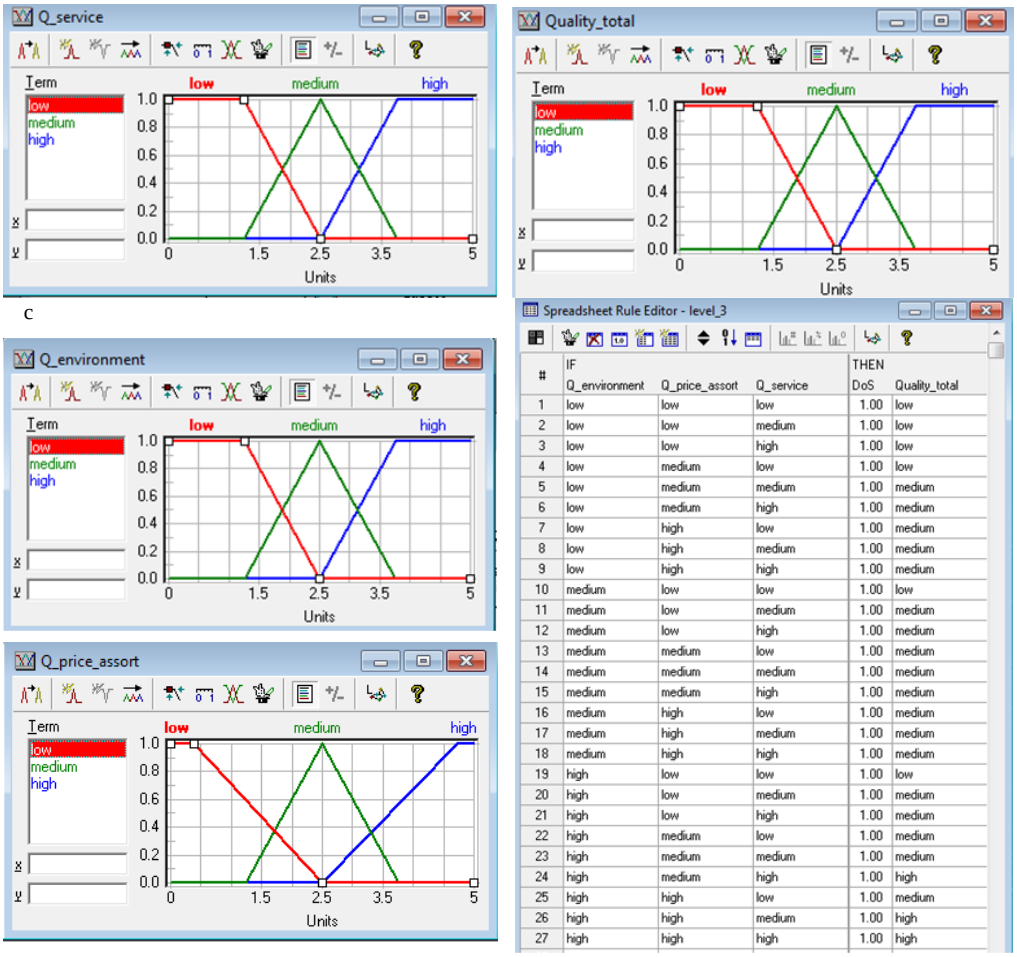


Figure 7: Variables and rules for final evaluation

Now, to take advantage of the model developed, the user just needs to enter the numerical values of the input data in the appropriate fields (estimates of certain variables, parameters, coefficients, etc.) and obtain the calculated results for the intermediate variables and the final integral estimate.

An example of this window with the data entered and the results is shown in Figure 8.

In this window, the input data can be set as a direct set of required digits in the upper input window, or with the scroll bar at the bottom.

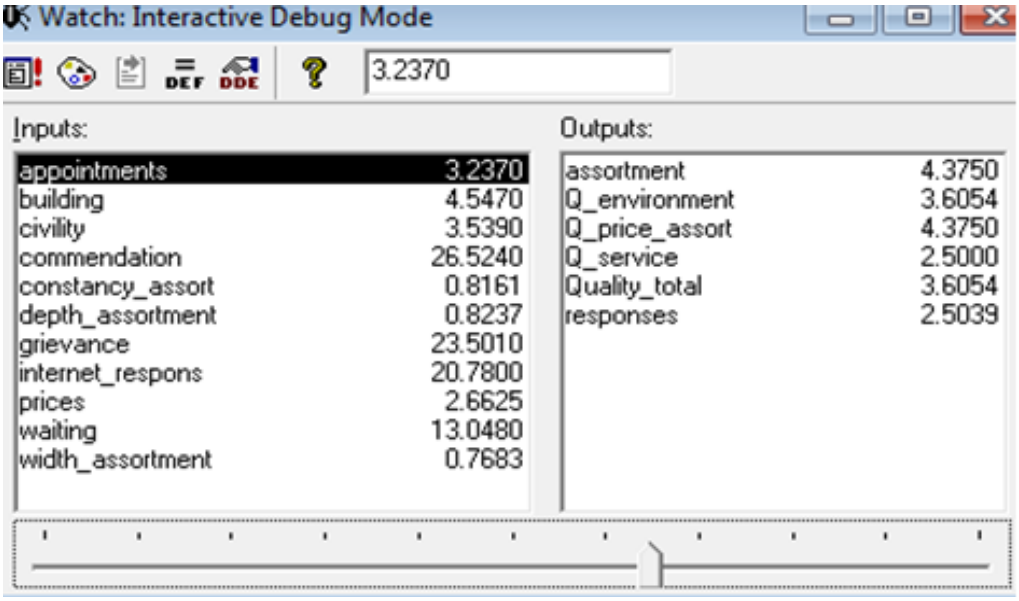


Figure 8: Window for data entry and obtaining results of calculations

For analyzing of the effect of individual changes in each parameter on the total incoming dependence so-called fuzzy inference surfaces can be applied, examples of which are shown in Figure 9.

Such surfaces allow tracking the effect of two (arbitrarily chosen by the user) input parameters on the corresponding output variables (results).

It is possible to observe certain zones where a change in the value of a parameter has a significant effect on the final result, as well as other (opposite in nature of the impact on the resulting parameters) areas, where the changes do not have such an impact.

This analysis allows making the right management decisions regarding efforts to improve certain parameters, to achieve tangible positive results in general (improvement of integrated assessments of service quality) at a certain ratio of all parameters.

4 An example of practical application of the model for evaluating of pharmacies in Kharkiv

The model developed was tested by evaluating with its help several pharmacies in the central part of the city of Kharkov (the name and address of the pharmacies are given in Figure 10).

With regard to the assessment of specific pharmacies, a purely illustrative example is given below.

The authors emphasize that all initial data are taken from open external sources, as well as on the basis of the subjective perception of participants in

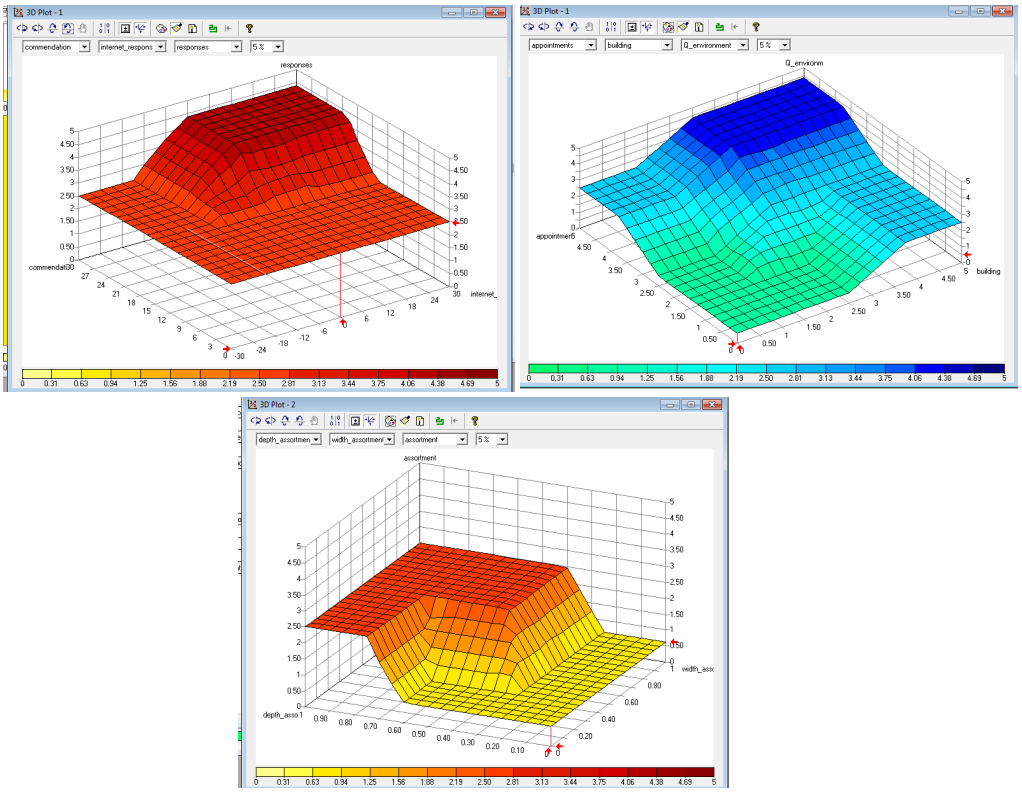


Figure 9: Fuzzy inference surfaces for all pairs of initial parameters at the last level

№	Pharmacy name	Pharmacy address
1	LLC “Pharmacy №308”, pharmacy №1 “First pharmacy”	Constitution Square 20
2	Private JSC “Kharkivapteka 2”, pharmacy №2	Constitution Square 20
3	Megadrugstores “Health”, national network, pharmacy	Science Avenue 9/8
4	Private Firm “Gamma 55”, Central №1, pharmacy №11	Constitution Square 1
5	Trading Network “Pharmacies of low prices”, pharmacy №1	Pushkin Street 10
6	“Good Day Pharmacies”, pharmacy №10	Cosmic Street 16

Figure 10: Pharmacies that were evaluated

expert surveys.

Accordingly, the initial data and the results of calculations only demonstrate the capabilities of the model developed and described, in no way claiming absolute truth from the point of view of the real commercial activities of the pharmacies examined.

The corresponding input data (obtained both through surveys and expert evaluation, on-site direct observation, in the shopping areas of these pharmacies) and the results of calculations for the model are shown in Figure 11.

Parameters: **Pharmacies №№:**	**1**	**2**	**3**	**4**	**5**	**6**
width_assortment	0.9	0.8	0.95	0.9	0.7	0.65
depth_ assortment	0.6	0.6	0.7	0.6	0.5	0.5
constancy_assort	0.85	0.85	0.8	0.77	0.7	0.6
Assortment	4.84	4.8	4.88	4.21	3.13	2.52
Grievance	2	6	1	2	4	5
Commendation	5	2	7	2	0	0
internet_respons	15	0	10	2	-2	-5
Responses	4	2.5	3.8	2.8	2.2	1.99
Prices	2.5	1.5	1.7	1.4	1.9	1.5
Q_price_assort	4.86	2.5	3.68	1.88	2.67	1,02
Civility	4.5	2.5	4	3	2.5	2
Waiting	2.1	3	1	2	3	4
Q_service	4.59	2.5	4.84	3.42	2.5	2.1
Appointments	4.7	3	4.9	3.8	3.5	3
Building	4.8	3.5	4.8	4	3	3
Q_environment	4.81	3.29	4.81	4.1	3.9	3.17
Quality_total	4.68	2.5	3.72	2.48	3.1	1.68

Figure 11: Numerical example of estimates for six pharmacies

With regard to ways of improving the assessment (that is, the quality of care), the results of calculations confirm the growing importance of quality factors in the work of pharmaceutical personnel (such as attention to the buyer, courtesy, competence, qualification, interaction with the visitor etc).

Also, this confirmed the importance of the good modern design of the pharmaceutical institution inside and outside (lighting, the condition of the room, cozy atmosphere, convenience for customers, and other similar characteristic).

Indeed, at relatively close price parameters of the assortment in the competitive market of pharmaceutical services in Ukraine, the quality of services is crucial for commercial success, a stable and confident position of the pharmacy.

5 Conclusions

Thus, the simulation results obtained indicate that the model correctly defines the generalized estimates of the perception of the pharmaceutical service provided

to visitors in concrete pharmacies.

However, it remains necessary to specify and clarify the type and numerical parameters of the membership functions and their terms.

Also, studies should continue on the justified determination of the relationship between individual rules and criteria (in the statement presented, these values are the same everywhere).

On the other hand, the adjustments to individual decision rules may be necessary.

In conclusion, it should be noted that the approach, proposed, used and described regarding the evaluation of services based on fuzzy modeling using special software products is quite universal.

It allows building similar computer models for estimating, predicting and analyzing service levels in real, fuzzy, unclear, poorly defined conditions for a wide range of problems of mathematical and computer modeling in the economy.

References

[1] Boonen, L., Schut, F., Koolman, X., *Consumer channeling by health insurers: natural experiments with preferred providers in the Dutch pharmacy market*, Health Economics **17(3)** (2008), 299-316.

[2] Breen, L., Xie, Y., *Waste not, want not. What are the drivers of sustainable medicines recycling in National Health Service hospital pharmacies (UK)?*, International Journal of Procurement Management **8(1/2)** (2015), 82-103.

[3] Carreras, M., *On optimal location with threshold requirements*, Socio-Economic Planning Sciences **33** (1999), 91-103.

[4] Gebauer, H., *Robust management policies for positioning pharmacies as healthcare service providers*, European Management Journal **26** (2008), 175187.

[5] Goel, P., Ross-Degnan, D., Berman, P., Soumerai, S., *Retail pharmacies in developing countries: A behavior and intervention framework*, Social Science and Medicine **42(8)** (1996), 1155-1161.

[6] Hakonsen, H., Sundell, K., Martinsson, J., Hedenrud, T., *Consumer preferences for over-the-counter drug retailers in the reregulated Swedish pharmacy market*, Health Policy **120(3)** (2016), 327-333.

[7] Horsfield, E., Kelly, F., Sheridan, J., Stewart, J., *Could community pharmacies help to improve youth health? Service availability and views of pharmacy personnel in New Zealand*, International Journal of Public Health **59(5)** (2014), 789-798.

[8] Kokodey, T., *A technique for modeling and projecting consumer behavior*, Economy and Forecasting **3** (2011), 127 - 150.

[9] Laroche, M., *New developments in modeling Internet consumer behavior*, Journal of Business Research **63 (910)** (2010), 915-918.

[10] Moinier, X., *Do Pharmaceutical Customers Behave as Patients or Consumers?*, Post-Print hal-01275754 (2014).

[11] Mueller, D., Wichardt, P., *Why not sell lottery tickets in a pharmacy: on conflicting product features and consumer choice*, Applied Economics Letters **18** (2011), 1497-1500.

[12] Richard, M.-O., Chebat, J.-C., *Modeling online consumer behavior: Preeminence of emotions and moderating influences of need for cognition and optimal stimulation level*, Journal of Business Research **69** (2016), 541553.

[13] Stargardt, T., Schreygg, J., Busse, R., *Pricing behaviour of pharmacies after market deregulation for OTC drugs: The case of Germany*, Health Policy **84(1)** (2007), 30-38.

[14] Svechla, S., Fischer, J., Ferdinand, H.-M., *Critical Success Factors for Online-Shops of Drugstores*, Markenbrand **2** (2014), 17-25.

[15] Vukasovic, T., Mikuliae, N., *Product Offerings Testing through Customer Satisfaction*, Management **9(3)** (2014), 223237.

[16] Zaheer-Ud-Din, B., *Economic Evaluation of Pharmacy Services*, Academic Press, 2016.

[17] Zhang, X., Meiser, D., Liu, Y., Bonner, B., Lin, L., *Kroger Uses Simulation-Optimization to Improve Pharmacy Inventory Management*, Interfaces **44(1)** (2014), 70-84.