



## Analysis of the Regional IT Services Market by Using Fuzzy Logic Methods

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**ABSTRACT:** The article analyzes the problems of assessing the development of the IT market in Russian regions subject to the impossibility to collect complete and reliable information and a uniform methodology to process it, as well as the opacity of the market itself. A review of the existing approaches to analyzing the problem has been made, and the use of fuzzy logic methods for assessing the regional IT market in the context of uncertainty has been stipulated by the authors. The offered methodology of the study includes a sample survey of IT services consumers in the Republic of Buryatia to analyze the demand and factors that influence the IT services market in Buryatia, interviewing representatives of the IT business of the Republic of Buryatia to analyze the supply in the IT services market in Buryatia, forming a model to identify the development of the regional IT services market by determining the input and output parameters of the model, constructing a knowledge base, and choosing one of the fuzzy inference methods.

Besides, a conceptual model of an expert-analytical system to identify the development of the regional IT services market has been given in the article. According to the results of testing it in MATLAB, the state of the regional IT services market has been assessed in the Fuzzy Logic module. The study is peculiar for using fuzzy logic methods when analyzing the probability characteristics of the IT services market.

**Keywords:** Region, market, IT services, model, fuzzy logic.

### I. INTRODUCTION

The formation and development of the IT services market are of systemic importance for the competitiveness of the region in the Russian and global markets. They change the spatial parameters, linking remote users on the Internet, and ensuring equal access to services and information resources [1].

The development of regional markets aims at providing all sectors of economy, including households, with efficient services, their sustainable and long-term growth in the context of the required infrastructure, favorable macroeconomic, social factors, and legal framework. A new incentive includes developments in the area of artificial intelligence and machine learning. According to Domingos [2], regularities of the development in this area and changes in the society are formed together with the ideas of such scientific areas as biology, philosophy, physics, and statistics. In this regard, it is necessary to assess the development of the regional IT services market. The peculiarity of the market localized on the territory is determined by the demand of consumers, both organizations and households, and considerable supply due to the specifics of the IT services promotion. The remoteness of regions and low population density make the study related to the market development even more actual. In terms of the supply, it is impossible to define the IT services market as local because its geographic and product boundaries are not limited by the territory. Customers and projects of leading IT companies are found on the whole Russian territory. In terms of the region, it is characterized positively, because companies can scale up their business, develop, and ultimately contribute to the development of the information space of the region.

The activities of IT companies are included in the Russian National Classifier of the Types of Economic Activity (OKVED: <https://www.regfile.ru/okved2.html>) 2019, into OKVED class 63 – information technology

activities. However, there have been no dynamics of official data in terms of value yet. The existing official statistical information mainly characterizes the share of organizations with personal computers, access to the Internet, websites, use of software, and costs of organizations for information and communication technologies (ICT), i.e. is based on the resource approach [3]. It is impossible to analyze the efficiency of IT services, their contribution to the value added, especially taking into account the rapid advancement of mobile services and smart technologies. Under these conditions, the information of international analytical agencies of the macroeconomic level is used.

The incompleteness of the information on the level of the regional market development makes it urgent to develop a methodology for studying the regional market of IT services in order to assess its development. It can be based on the empirical data from its survey.

### II. APPROACHES TO ANALYZING THE PROBLEM

The IT market develops dynamically, changes the architecture of organizations, the ideology of studying business processes, communication in the society and the global space. The determination of indicators of the IT services market is ambiguous because there is no uniform methodology and universal tools for the analysis. The works in this area include studies of such companies as International Data Corporation (IDC), Gartner, the Cnews analytical group, the Expert RA rating agency, and the leading providers of IT services. Each of them has its own methodology based on various quantitative data. It can be explained by a high degree of the market opacity, the lack of a common taxonomy of IT services, the methods used, their errors, different informational basis and methods of collecting information, as well as respondents.

The IT services mainly include intangible activities that have impact on the formation of a knowledge-driven

economy that is difficult to measure and value. In their article, N. Akhmad and P. Schreier address the problem of improving GDP calculations taking into account the new reality of forming the digital economy, state the increase in direct peer-to-peer operations between customers who are individuals and the corporate sector through the Internet interaction [4].

In the USA, the NASDAQ stock exchange index does not reflect the real situation in the market, but the investors' confidence in the market. According to V.V. Burov, "it is possible to speak about the market conditions not only on the basis of direct data on the status of players, but also on indirect indicators that reflect various manifestations of companies' activity and whose quantity can be assessed rather accurately" [5].

R.B. Vasiliev and G.A. Levochkina offered a method to assess the maturity of the Russian IT services market based on the product life cycle theory [6]. One of the criteria is pricing. According to it, the authors described the Russian IT services market as not mature enough, and pointed at the difference in the value of contracts for the same services under the same qualifications, differences in the cost of IT services between the capital and other regions of the Russian Federation.

Various methods are used to assess the IT services market, including socio-economic analysis, analysis of information resources, and use of ICT by households, government bodies, organizations, supply and demand, and ICT infrastructure [7]. To make such content analysis, the most important indicators of the companies' performance collected from various sources are used, data on the situation in the market, as a whole, and macroeconomic indicators are considered, and the socio-political situation in the country is studied. The IT services market is actively discussed at forums, conferences, seminars, corporate events of IT companies and in the media. However, there is still a problem on the transparency of information about the activities of IT companies.

According to L.Zade: "In order to say something essential about such problems, we must abandon our accuracy requirements and admit results that are a bit vague or uncertain" [8].

By its nature the fuzzy logic being a basis for fuzzy control is closer to human thinking and natural languages than traditional logical systems. Mathematical means of reflecting fuzziness of the initial information allow constructing the model that complies with the reality [8].

### III. METHODS

The choice of methods for collecting empirical data is due to the dynamism and complexity of the regional research object, the blurring of its geographical boundaries and the weak structure of the problems of its development in the post-crisis period.

The Buryat IT services market is characterized by a decrease in the demand substantiated by worsening of the service consumers' solvency, deficit of highly qualified IT personnel, an imperfect regulatory framework, the lack of a coherent IT infrastructure, and a reluctance of enterprises to invest in long-term IT projects.

In the methodology for studying the IT services market, the following steps have been singled out:

1. A sample survey of legal entities to analyze the demand and factors that have impact on the development of the Buryat IT services market. The

sample size was 190 organizations from 19,011 enterprises of the Republic of Buryatia (the sampling error was 3.51%).

2. The survey of IT business representatives to analyze the offer on the IT services market in Buryatia. The sample size was 44 organizations from 57 representatives of the IT industry in Buryatia (as estimated). The sample is homogeneous for the services provided (the sampling error was 7.1%).

3. Forming the model to determine the development of the regional IT services market includes three main steps:

- a. Determination of the input and output parameters of the model.

- b. Formation of the knowledge base.

- c. Selecting one of the methods of fuzzy inference.

When planning the study, we determined the following methods for collecting empirical data:

- the method of analyzing official data in cost form for services in the field of IT, based on the resource approach to the activities of organizations;

- the method of interviewing consumers and processing the data using fuzzy logic methods: the advantage of this method is the possibility of analysis in the conditions of incomplete information base;

- the method of expert assessment: it allows one to attract additional experts to clarify certain aspects related to the level of development of a regional IT services market.

According to the sample survey, consumers are going to create and introduce more information systems by using a computer network, which may affect the reduction in the structure of IT consulting services and IT outsourcing consumption. In general, according to the survey, the structure of IT services consumption in Buryatia will not change dramatically in the near future.

The consumption of IT services by the respondents was caused by a decrease in costs (37.3%), capitalization of the business and an additional source of investment (29.33%), as well as improvement of competitiveness (14.67%).

The discontent with the existing software is also one of the reasons to search for alternative solutions. As a result of the survey, only 50% of the surveyed consumers of IT services in Buryatia are fully satisfied with the software used. This factor also has impact on the growth of the planned use of the service – software development [9].

The purchasing behavior when acquiring IT services is also stipulated by external factors, such as crisis and sanctions, and it causes the revision of the business strategy.

There are two classes on the IT services market of Buryatia. They are local companies and integrators from other regions whose experience, resources, prices, products, and mentality differ. Local IT service providers are more focused on the hardware and network integration. Regional representatives that have experience in working on large-scale projects are engaged in automating business processes.

The most successful representatives of the republican IT services market are *BaikalSOFT*, *Stek*, *SPK Telecom*, *RB Soft*, *Parma Telecom*, etc. The main share of IT service providers is distributed between such services as network and system integration (26%), software development (26%), IT consulting (25%), and IT outsourcing (10%). This distribution also characterizes the Russian market [9].

It is necessary to note that the expansion of the IT services market in Buryatia is the result of distribution and supply of equipment and software within the integration projects. The IT services market in the Republic of Buryatia is at its nascent stage, and most IT companies do not specialize in any specific segments of the industry due to their insufficient level of development and small scale, and provide a mixed range of services and products.

In order to accumulate the expert knowledge about the IT services market, an expert system is offered because

many important factors can be assessed only by an expert in the "If-That" rules' format. Using the theory of fuzzy sets allows efficiently processing incomplete, inaccurate, and stochastic input data.

#### IV. STUDY MODEL

Fig. 1 shows the conceptual model of the expert-analytical system for determining the level of developing the regional IT services market.

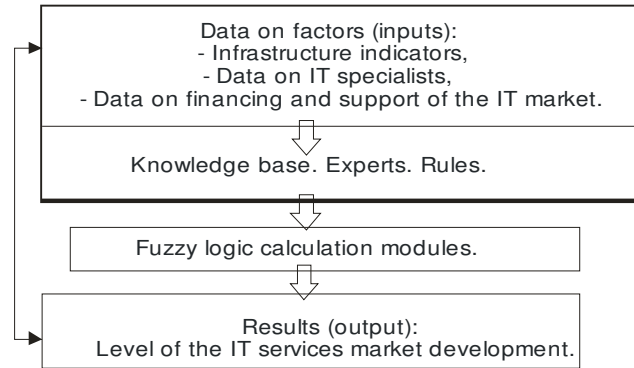


Fig. 1. Conceptual Model of a Fuzzy Expert System.

The model assesses the regional IT services market taking into account the following factors: qualified IT specialists, IT infrastructure, venture and state support. The output variable is the development of the IT services market (O), the input variables are based on the expert knowledge about the socio-economic, legislative and infrastructural terms and conditions of the regional IT services market.

The following input factors are entered:

The information on IT specialists:

$I_1$  – qualification of the specialists working in the area of IT services,

$I_2$  – the number of IT graduates.

The information on financing IT services:

$I_3$  – the volume of financing IT projects by subjects of the Russian Federation (budget, support funds),

$I_4$  – the volume of IT costs by enterprises,

IT Infrastructure:

$I_5$  – the demand for IT services, and

$I_6$  – the quality of IT infrastructure.

The value of the linguistic variable "the market development" can be expressed as high (H), low (L), or medium (M).

The qualitative assessment of input variables is based on expert opinions (qualifications of specialists, IT infrastructure quality, and demand for IT services).

To describe the subsets of term sets, the trapezoid membership function performed in the MATLAB environment in the Fuzzy Logic module (Fig. 2) was introduced. The experts were the owners of IT companies, heads of IT services of large organizations, IT specialists, and university professors.

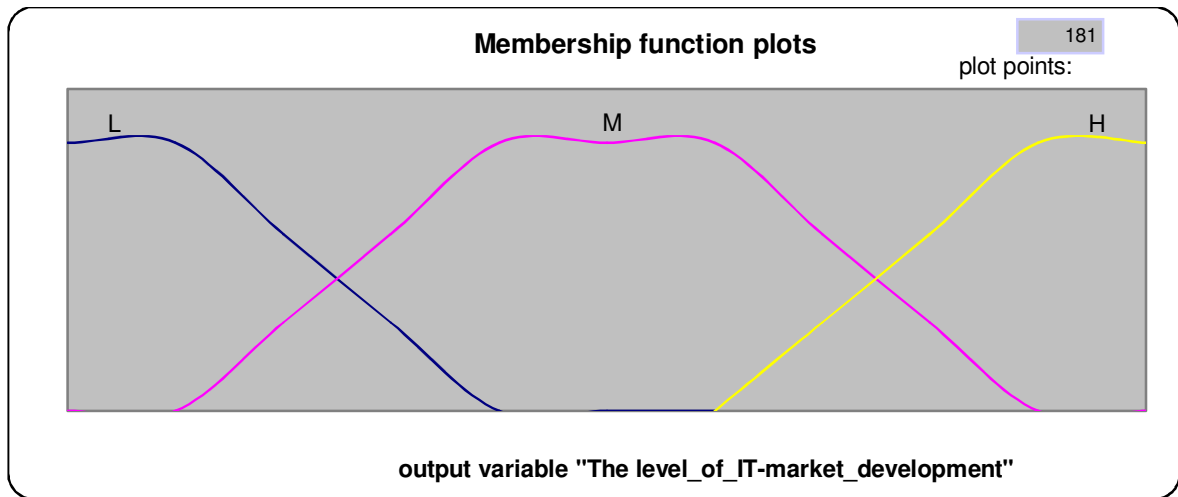


Fig. 2. Typical Trapezoidal Membership Functions for the Values of the Output Variable Term "Development".

To solve the partial membership of the variable in two fuzzy sets, the rule of priority of larger belonging value  $\mu(x)$  in two fuzzy sets is used, and if  $\mu$  values are equal, the priority rule of larger value of the set center is used [10].

The membership functions on 01-media are determined for each variable by the expert method, and are subject to change over time (dynamic parameters). In case the expert has additional information, the grid points may be asymmetrical, in the other case, they will be symmetrical. Fuzzy conclusions (according to Mamdani) about the fuzzy values of output variables are formed in a typical way based on the rules (expert knowledge) [11]. For example, the statement {If  $I_1 = M \wedge I_3 = L \wedge I_5 = M$  then  $O = "M"$ } means: with an average qualification level of IT specialists, low funding, and an average demand for IT services, the development of the IT services market in the region will be average. The limit number of such rules in terms of combining a full k-factor search with three term sets of values for one output factor is 3k. For a real economic system, the number of such rules is much smaller and is transparent [12].

Each rule is defined on a set of input linguistic variables  $I_k$  with a certain term and membership function value. The use of the membership, connection and consequence relations allows obtaining fuzzy knowledge for the output parameter with its term-value and the relevant value of the membership function [13].

## V. RESULTS

The model example for the output variable  $O$  – the market development – made by using the MATLAB software, is considered. These are the rules for the development of the IT services market:

1. If ( $I_1$  is H) and ( $I_4$  is L) and ( $I_6$  is H) then ( $O$  is H);
2. If ( $I_2$  is M) and ( $I_3$  is H) and ( $I_5$  is L) then ( $O$  is M);
3. If ( $I_1$  is M) and ( $I_3$  is L) and ( $I_6$  is M) then ( $O$  is M);
4. If ( $I_1$  is H) and ( $I_4$  is M) and ( $I_5$  is H) then ( $O$  is M);
5. If ( $I_2$  is L) and ( $I_4$  is L) and ( $I_5$  is L) then ( $O$  is M);
6. If ( $I_2$  is H) and ( $I_4$  is L) and ( $I_6$  is L) then ( $O$  is L);
7. If ( $I_1$  is H) and ( $I_3$  is M) and ( $I_5$  is H) then ( $O$  is H);
8. If ( $I_2$  is M) and ( $I_3$  is L) and ( $I_5$  is L) then ( $O$  is L);
9. If ( $I_1$  is L) and ( $I_3$  is H) and ( $I_6$  is H) then ( $O$  is M);

The final stages of forming a model include compilation and dephasing by using the Rule Viewer module. At these stages, there is transition from fuzziness to certain values of the output variable [14]. For example, when detailing the rule {If  $I_1 = M \wedge I_3 = L \wedge I_5 = M$  then  $O = "M"$ }, the linguistic variable is  $I_1 = 0.38$ ,  $I_3 = 0.12$ ,  $I_5 = 0.55$ , and the output variable  $O$  takes the value 0.5, which corresponds to the average level of the market development in the region.

Thus, there is transition to a natural language that is understandable to managers for making decisions on regulating the IT services market. The number of input factors can be increased to make deeper analysis of the state and development of the object under study.

## VI. CONCLUSION

The developed methodology of the study and the model for assessing the regional IT services market make it possible to take into account any number of changes in the internal and external environment that determine the dynamics and structure of its development. Taking into account the limited scope of the demand in the market, the further development of the methodology involves a survey of segmented groups of households that expand the consumption of IT services and mobile services. The use of the model makes it possible to form the

knowledge base by processing weakly structured knowledge of experts on a formalized basis to assess the regional IT services market that can be used to develop scenarios of the market development in the context of multicriteriaity and uncertainty.

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