Methods and Models of Machine Learning in Managing the Competitiveness of Audit Companies

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Abstract. The growing demand for audit services, the entry into local markets of international audit firms and their further offensive strategy aggravate the competitive confrontation, both between national operators and between national and international audit entities. The increasing complexity of audit firms activities in the face of global competition leads to the need to develop effective mechanisms for managing their competitiveness. It should be noted that audit firms cannot achieve advantages over competitors in terms of technical, design, commercial or other characteristics of the product due to the nature of the audit service. For the same reasons, audit companies cannot strengthen their competitive position by organizing pre- or after-sales services. It is obvious that the competitiveness components of audit firms require a separate study, and the task of identifying the factors that form the competitive advantages of audit firms requires a specific solution. The paper proposes a set of models for assessing and analyzing the competitiveness of audit companies, which, based on Machine Learning methods (main components, expert, cluster, regression analysis, forecasting, panel data analysis techniques), can improve the validity of assessing the competitiveness level of audit firms, and determine the factors that render the dominant influence on the level of the enterprise competitiveness, to formulate recommendations on ensuring a high level of audit company competitiveness.

Key words: audit companies, competitiveness, assessment, forecasting, strategy, model, Machine Learning methods

I Introduction

The current stage of economic development is characterized by increased competition. This is due to large-scale integration processes and the complexity of companies activities in global competition. Therefore, not a single organization and not a single enterprise, whatever its size and importance, can afford to ignore the objective need to monitor the level of competitiveness and develop preventive actions to improve its competitive position. In these conditions, the competitiveness management of the company becomes one of the basic subsystems of strategic management, the effectiveness of which largely determines the viability of the company.

The foregoing fully applies to audit companies. It should be noted that the audit services market is characterized by high development dynamics associated with the need to reduce the risk of institutional investors, managers, owners when making management decisions, expanding the range of professional services provided by audit companies in the field of profitability analytics, diagnostics and optimization of business processes of client companies etc. (Grand Views Research. 2019). Traditionally, the highest demand for audit services is observed in large regional metropolitan areas. In Ukraine, such agglomerations include, in particular, Kiev, Kharkov, and Odessa, characterized by predominantly high growth rates of per capita GRP over the past decade (State Statistics Service of Ukraine, 2019). Despite the high level of demand for the services of audit companies, the dynamics of the number of subjects of audit activity in Ukraine is negative (International institute of Audit, 2017), which indicates an increase in the quality standards of audit services, increased competition between audit firms and the need to formulate an adequate strategy to ensure competitiveness and strengthening competitive market position.

The problem of managing the competitiveness of companies is widely considered in the scientific literature. So, Zima (2012) proposed the structure of a decision support system in the competitiveness management system of an industrial enterprise in an unstable economic environment. Studies by Guryanova, Klebanova, Trunova (2017) are devoted to the development of a model basis for information and analytical systems for managing the financial competitiveness of industrial enterprises. Tatar, Sergienko, Kavun, Guryanova (2017) address the issues of assessing the impact of currency “shocks” and environmental factors on the level of competitiveness of metallurgical enterprises. Research by Celtekligil, Adiguzel (2019); Guimarães, Severo, Vasconcelos, (2018) are dedicated to assessing the impact of adaptive response rates on technological innovation on a company's competitiveness. Piskun, Klebanova (2014), Li, Yong-Quan, Liu, Chih-Hsing Sam (2018), Ferrer, Teresa, Garcés (2018) discuss the impact of organizational structures on the level of competitiveness, sustainability and viability of companies. A large number of works deal with various aspects of competitiveness management at various levels of management. So, in the work of Aleksandrov, Buruk (2012), the issues of developing mechanisms for managing product competitiveness as a basic component of

a company's competitiveness are considered. Researches of Birkentale, Winter (2012), Zhu Zhihong, Zhu Zhiwei, Xu Ping, Xue Dawei (2019) are devoted to the macroeconomic aspects of enterprise competitiveness management. The issues of evaluating models for assessing and diagnosing competitiveness of companies are considered in the work of Agovino, Matricano, Garofalo, (2020).

It should be noted that despite of the unconditional prospects of the approaches discussed in the above literature, the issues of assessing the competitiveness of audit companies whose activities have a certain specificity remain insufficiently studied. Thus, audit companies cannot achieve advantages over competitors in terms of technical, design, commercial or other characteristics of the product due to the nature of audit services. For the same reasons, audit companies cannot strengthen their competitive position by organizing pre- or after-sales services. It is obvious that the components of the competitiveness of audit firms require a separate study, and the task of identifying the properties that form the competitive advantages that ensure the competitiveness of audit firms requires a specific solution. This led to the choice of research topic.

II Methodology and Data

The aim of the study is to develop models for assessing and analyzing the competitiveness of audit companies, which unlike to existing ones, are based on the integrated application of Machine Learning methods (main components, expert, cluster, regression analysis, forecasting, panel data analysis techniques), that allow to improve the validity of assessing the competitiveness level of audit firms, to determine the factors that render the dominant influence on the level of enterprise competitiveness, to assess the sustainability of competitive advantage in dynamics, to formulate recommendations on ensuring a high level of audit company competitiveness.

The methodological approach proposed in the work to develop a complex of models is shown in Fig. 1. The following is a brief description.

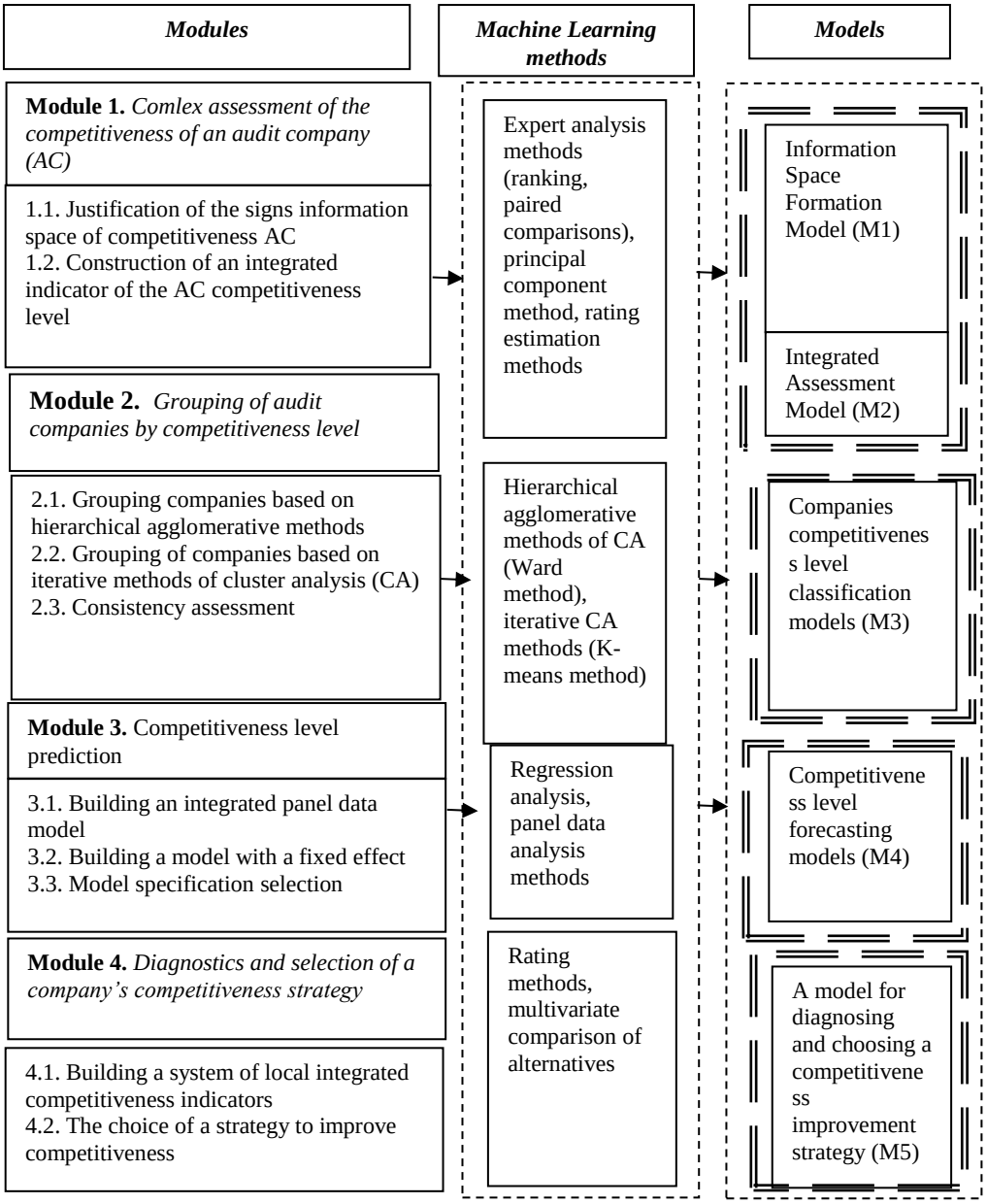


Fig. 1. The relationship between modules and models for assessing the competitiveness of audit companies

To build a model for the formation of a diagnostic feature space (M1), expert assessment methods and the principal component method are used. The expert survey procedure was carried out according to the following algorithm: formation of examination questions; formation of a group of experts; formation of rules for processing expert opinions; statistical processing of expert assessments and determination of the degree of coordination of expert opinions. To process the results of expert evaluation, the ranking method, the method of pairwise comparisons were used. Assessment of the consistency of expert opinions was carried out on the basis of Friedman statistics and the coefficient of concordance.

The application of the method of principal components makes it possible to single out a system of generalized factors, analyze the distribution of factor loads, and determine the significance of the influence of individual factors on the competitiveness level of audit companies. The algorithm of the principal component method provides for: determining the matrix of pair correlations, finding eigenvalues and vectors, matrix of factor mapping, evaluating the information content and interpreting the main components, finding the equations of the main components, studying the dynamics of the values of generalizing factors.

The construction of the M2 model is carried out using rating methods. Most often, the integral score is defined as the arithmetic mean of standardized attribute values. The construction of an integrated assessment involves the following steps: the formation of the information space of signs; the choice of a indicators standardization method; substantiation of the function of weight coefficients; determination of the indicators aggregation method.

To develop the M3 model, methods of cluster analysis (MCA) are used. MCA can be divided into groups: hierarchical (this group includes methods of the nearest neighbor, distant neighbor, middle communication, centroid, median communication); iterative (K-means method, dendrite method, balls method); factor methods; thickening methods; methods based on graph theory. Each of the groups includes many approaches and algorithms. To implement the classification model in the study, the method of "k - means" is used. It is advisable to use it when the researcher has a preliminary idea of the number of clusters (Guryanova, Milevskiy, Bogachkova, Lytovchenko, Polyanskiy, 2018). The choice of the method is due to its following advantages: simplicity, flexibility, rapid convergence.

The construction of the M4 model is carried out using econometric analysis methods, in particular, panel data analysis methods. The following types of panel data models are considered: conventional model; fixed effect model. Model specification selection is based on the F-test. The forecast obtained on the basis of panel data models allows assessing the stability of the company's position in the cluster.

In the final module for developing a strategy to increase the competitiveness level, the M6 model is developed on the basis of multi-criteria comparison of alternatives, in particular "the web" method.

The above methodological approach was implemented based on data from International networks and associations (Top 40 International Networks, Associations and Alliances: Finding growth amid uncertainty). Taking into account the information security of indicators, three groups of indicators of competitiveness of audit companies were identified in open databases: *group 1(G1) - economic performance of the audit organization* (income (Var1), number of firms (Var2), number of offices (Var3)); *group 2 (G2)* - level of professionalism of audit organization employees (professional staff (Var4), female partners (Var5)); *group 3 (G3)* - business reputation and level of trust to the audit organization (number of countries this company works with (Var6), number of partners (Var7)).

Data processing was carried out using Statistica, EViews.

III Results and analysis

In the first module of the study, a model of the information space of attributes of AC competitiveness was constructed. Employees of audit companies were involved to build an expert model of the diagnostic feature space. Expert competency was assessed using the self-assessment method. Processing of expert analysis data was performed using two methods: ranking and partial pairwise comparison method.

The ranking was carried out in such a way: each expert had to assign to the ranking objects (competitiveness indicators) a natural number from 1 to 7: 1 - the minimum rating (the least significant indicator), 7 - the maximum rating (the most significant indicator). The results are shown in Fig. 2.

Friedman ANOVA and Kendall Coeff. of Concordance (Sp
ANOVA Chi Sqr. (N = 12, df = 6) = 55,78571 p = ,00000
Coeff. of Concordance = ,77480 Aver. rank r = ,75433

Variable	Average Rank	Sum of Ranks	Mean	Std.Dev.
Var1	6,666667	80,00000	6,666667	0,492366
Var2	4,333333	52,00000	4,333333	0,492366
Var3	2,333333	28,00000	2,333333	0,778499
Var4	5,583333	67,00000	5,583333	1,164500
Var5	1,083333	13,00000	1,083333	0,288675
Var6	3,416667	41,00000	3,416667	0,792961
Var7	4,583333	55,00000	4,583333	1,928652

Fig. 2. Indicator ranking results

The values of the coefficient of concordance, statistics χ^2, equal respectively 0,7748; 55,79 (Fig. 2), allow us to conclude that the opinions of experts are agreed, i.e. the reliability of the results obtained as a result of the examination is high. According to the results of the survey, the most significant indicator is the indicator Var1 - the company's income, the least significant indicator Var5 - the female partners.

As an alternative data processing method, a partial pairwise comparison method was considered. The results of expert analysis are shown in Fig. 3.

Variable	Friedman ANOVA and Kendall Coeff. of Concordance ANOVA Chi Sqr. (N = 12, df = 6) = 65,58750 p = ,000 Coeff. of Concordance = ,91094 Aver. rank r = ,90284 **Average Rank**	Sum of Ranks	Mean	Std.Dev.
Var1	6,583333	79,00000	5,583333	0,514929
Var2	2,833333	34,00000	1,916667	0,792961
Var3	2,333333	28,00000	1,333333	0,492366
Var4	6,083333	73,00000	5,000000	0,603023
Var5	1,333333	16,00000	0,416667	0,514929
Var6	3,500000	42,00000	2,500000	0,674200
Var7	5,333333	64,00000	4,250000	0,452267

Fig. 3. Results of partial pairwise comparison of indicators

An analysis of the data (Fig. 3) allows us to conclude that the results obtained using the partial pairwise comparison method are more consistent: the concordance coefficient is 0,91094; $\chi^2 -$ criterion – 65,587. Therefore, in the future, when constructing a comprehensive assessment of the level of competitiveness, weights were used, obtained on the basis of the method of partial pairwise comparisons.

The results of expert analysis coincide with the results of processing statistical data of 20 leading audit companies by the method of principal components. The results of constructing the system of principal components are shown in Fig. 4.

Value	Eigenvalues (Spreadsheet19) Extraction: Principal components **Eigenvalue**	% Total variance	Cumulative Eigenvalue	Cumulative %
1	4.816401	68.80573	4.816401	68.80573
2	1.091158	15.58797	5.907559	84.39370

Fig. 4. Assessment of the information content of the main components

As can be seen from fig. 4, the first two main components account for 84.39% of the variation in the initial system of features, which is sufficient to display all significant correlation relationships. The “scree plot” shown in Fig. 5 also allows us to conclude that the optimal number of principal components is two.

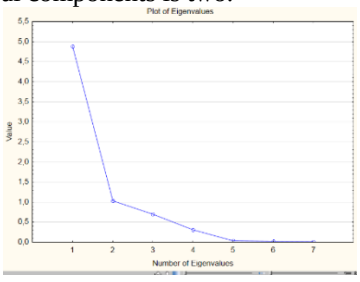
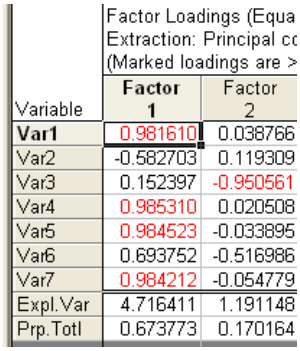


Fig.5. The «scree plot»

Fig. 6 shows factor loads. Statistically significant factor loads indicate a high information content of the system of diagnostic indicators formed above.



Variable	Factor Loadings (Equa Extraction: Principal cc (Marked loadings are > Factor 1	Factor 2
Var1	0.981610	0.038766
Var2	-0.582703	0.119309
Var3	0.152397	-0.950561
Var4	0.985310	0.020508
Var5	0.984523	-0.033895
Var6	0.693752	-0.516986
Var7	0.984212	-0.054779
Expl.Var	4.716411	1.191148
Prp.Totl	0.673773	0.170164

Fig.6. Factor loadings

The final stage of the first module (Fig. 1) is the construction of an integral indicator of the audit companies competitiveness level on standardized data. A complex assessment is defined as the arithmetic average weighted, taking into account weights that reflect the significance of indicators obtained on the basis of the method of partial pairwise comparisons. The calculations are presented in table. 1.

Tab. 1. Integral indicator of the company's competitiveness

Rank	Company	Complex assesment	Rank	Company	Complex assesment
1	Deloitte Touche Tohmatsu	26,54	10	TAG Alliances	6,40
2	PwC International	25,23	13	Baker Tilly International	5,95
3	EY Global	23,86	12	Nexia International	5,90
4	KPMG International	20,99	15	Moore Stephens International	5,72
5	BDO Global	11,64	17	HLB International	5,09
6	Geneva Group International	8,52	14	The Leading Alliances/ LEA Global	4,93
11	Crowe	7,23	18	Kreston International	4,67
8	RSM International	7,00	16	Prime Global	4,51
7	Praxity	6,86	19	Fiducial International	3,20
9	Grant Thornton International	6,82	20	BKR International	2,96

The results obtained allow us to conclude that the ranking obtained coincides with the rating of International networks and associations. Thus, Spearman's rank correlation coefficient for the two ratings is 0.97. The value of the Student criterion, equal to 73.67, allows us to conclude that the results are consistent with a 99% confidence level. At the same time, the simulation results show that the rating of the first six companies coincides with the rating of International networks and associations, and some companies have changed their position. So, the company Growe took 11th place, and now takes 7th place. This is due to the fact that this company has a large number of professional employees and works with many countries, and it was precisely these criteria that the experts preferred and placed on the 2nd and 4th place in terms of significance in assessing the competitiveness of AC.

In the *second module*, companies were grouped by competitiveness using cluster analysis methods.

The classification dendrogram obtained using the Ward method is shown in Fig. 7.

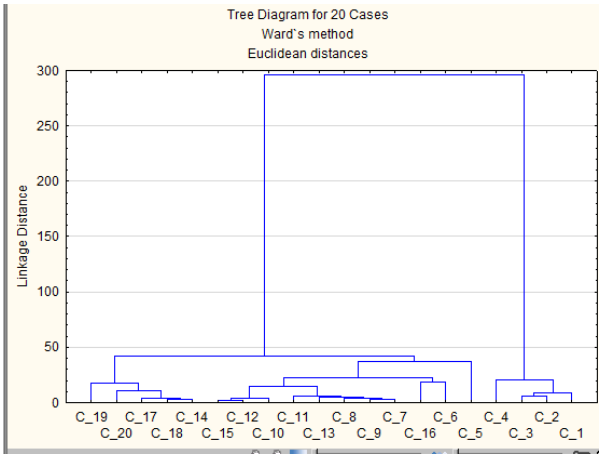


Fig. 7. Classification dendrogram

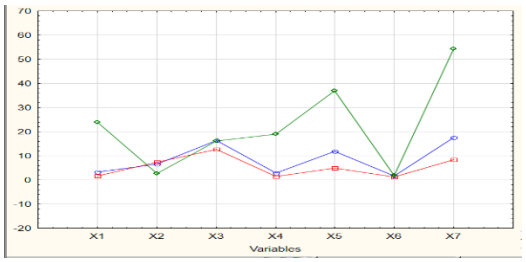
The above results (Fig. 7) allow us to conclude that the initial set of companies should be divided into three clusters. The composition of the clusters was determined using the k-means method. The results are shown in Fig. 8.

Case No.	Distance
C_1	3,146765
C_2	1,687622
C_3	1,132315
C_4	4,414896

Case No.	Distance
C_5	7,642282
C_6	4,272983
C_7	2,012152
C_8	1,838985
C_9	1,358687
C_10	1,550546
C_11	0,578167
C_12	1,937135
C_13	1,662322
C_15	2,362140

Case No.	Distance
C_14	1,147080
C_16	4,934782
C_17	1,620515
C_18	1,154768
C_19	4,815817
C_20	2,143464

a) Cluster composition



b) Average plot

Fig. 8. Clustering results based on the "k-means" method

As can be seen, the results of cluster analysis and expert analysis coincide. In the first cluster, KPMG International has the least low rating - 20.99, and the next ranking company, BDO Global, which is already in the second cluster, has a complex assessment of the competitiveness level of 11.64. That is, there is a very large gap between the ratings of the companies of the first and second cluster. The companies of the second and third clusters differ slightly in their characteristics. However, for such variables as Var3 - the number of offices, Var5 - the number of female partners, Var7 - the number of partner companies, for the firms of the second cluster, the values significantly exceed the indicators of the companies of the third cluster.

To assess the stability of the competitive positions of companies in the cluster in the third module (Fig. 1), a forecast of the rating of companies was carried out using the panel data model. The rating variable of the competitiveness of audit companies explaining the variables - lag values of competitiveness indicators was considered as the resulting variable. The following panel data model specifications were considered: a combined model, a model with a fixed effect. Enumerating the various options for the panel data model allowed us to choose a fixed-effect panel data model with this set of lag explanatory variables: $Var1_{t-1}$ - income, $Var3_{t-1}$ – number of offices, $Var7_{t-1}$ – number of partners. The value of the fixed effect (a_i) shown in Fig. 9, allows to conclude about the stable competitive position of the companies of the first cluster.

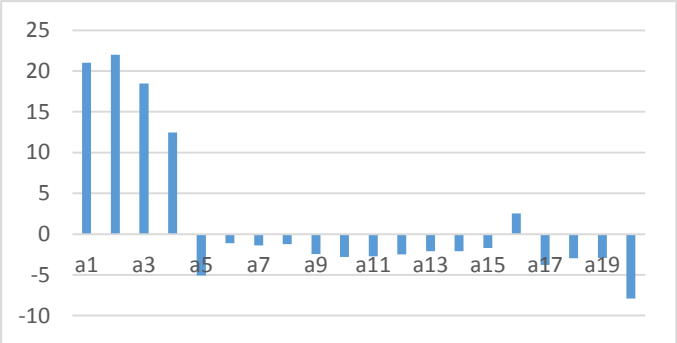


Fig. 9. Fixed effect values (a1-a20)

The forecast values of the rating score obtained on the basis of the panel data model with lag variables are given in table. 2.

Tab. 2. Predicted values of the integral indicator of the company's competitiveness level

Rank	Company	Integral indicator forecast	Rank	Company	Integral indicator forecast
1	Deloitte Touche Tohmatsu	25,55	12	TAG Alliances	5,95
2	PwC International	24,71	11	Baker Tilly International	6,37
3	EY Global	23,45	14	Nexia International	5,59
4	KPMG International	20,53	13	Moore Stephens International	5,69
5	BDO Global	11,99	15	HLB International	4,88
6	Geneva Group International	8,32	16	The Leading Alliances/ LEA Global	4,85
7	Crowe	7,15	17	Kreston International	4,67
8	RSM International	6,89	18	Prime Global	4,16
9	Praxity	6,85	20	Fiducial International	2,84
10	Grant Thornton International	6,61	19	BKR International	2,98

As can be seen from the table. 2, the deterioration of competitiveness indicators for the studied group of companies is forecasted. However, the composition of clusters in the forecast period remains stable; only the competitive positions of companies within the selected clusters change.

In the *fourth module* (Fig. 1), a model was developed for diagnosing and choosing a strategy to increase the competitiveness of a company using one of the methods of multidimensional comparison of alternatives - the web method. The results of the implementation of the model for the companies of the first cluster are shown in Fig. 10.

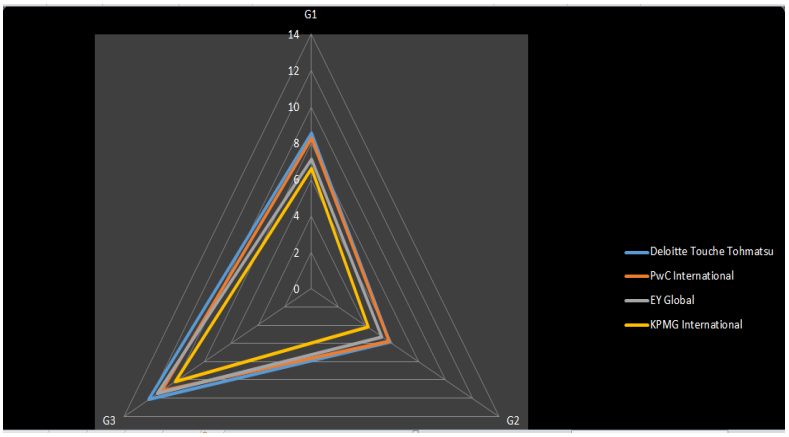


Fig.10. Chart - "web" of local integrated indicators of the competitiveness level (G1 – economic performance indicators; G2 – level of professionalism of employees, G3 – business reputation)

We see that all companies have close values of the G3 indicator - the business reputation of the audit organization. The gap in competitiveness levels in this area. The score is the smallest and is 1.19 times. We can also conclude that PricewaterhouseCoopers (PwC) does not take the first position and is inferior to Deloitte in assessing business reputation. However, the gap in the assessment of G2 - the level of professionalism of the employees of the audit organization - between Deloitte, which ranks first, and PwC is not very significant. However, PwC is lagging behind in economic indicators, so it is advisable to choose strategies that are primarily aimed at improving economic indicators.

To increase competitiveness, the following strategies should be used: regional diversification and expanding the range of countries and partners; implementation of a differentiated pricing policy for the provision of audit services; expanding the range of PwC services through consulting services, which will allow the customer company to optimize the number of consultancy companies and cooperate mainly with PwC; to study as much as possible and better the industries and problems of customer companies, to promote the implementation of effective industry solutions. If you adhere to these strategies, the company will be able to strengthen its competitive position, both in the breadth of services and in economic indicators through the implementation of a systematic approach to ensuring competitiveness.

Thus, the use of the proposed complex of models allows to choose an effective strategy for managing the competitiveness of audit companies.

IV Conclusions

Thus, the studies conducted in the work allow to draw the following conclusions:

a methodical approach to the formation of a set of models for assessing and analyzing the level of competitiveness of audit companies is proposed, which, based on Machine Learning methods such as factor, cluster, expert, regression analysis, panel data analysis methods, improves the validity of assessing the level of competitiveness of audit firms, identifies factors, having a dominant effect on the level of enterprise competitiveness, formulate recommendations on ensuring a high level of competitiveness audit company;

a complex of models for assessing and analyzing the competitiveness level of an audit company has been developed, which includes: a model for the formation of a diagnostic feature space; model of a complex assessment of the level of competitiveness; classification models of companies by competitiveness level; forecasting models of the enterprise competitiveness level; a model for diagnosing and choosing a strategy to increase the competitiveness of an enterprise;

the modeling results showed that in the group of the 20 largest audit companies, three clusters of homogeneous characteristics can be distinguished, which include 20%, 50%, and 30% of the firms from the number of analyzed companies, respectively. Moreover, the gap in average values of the level of competitiveness of the companies of the first and second cluster exceeds 300%. The companies of the second and third clusters differ, first of all, in terms of the number of offices and the number of partners. The predicted values of the competitiveness level obtained on the basis of the panel data model taking into account lag variables showed that the composition of the selected clusters will remain stable. However, there is a fairly strong change in the rating positions of companies in clusters. Diagnostics of the competitiveness level of the companies of the first cluster on the basis of local integrated assessments in such areas as economic indicators, the level of employees professionalism, business reputation, made it possible to draw a conclusion about the insignificant differentiation of companies in terms of business reputation and level of professionalism of employees. The most significant differences are observed in economic indicators. Therefore, strategies aimed at improving economic indicators should be considered as basic strategies for strengthening competitive positions. In particular, such as expanding the range of consulting services and strengthening industry specialization.

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