Technology for the Psychological Portraits Formation of Social Networks Users for the IT Specialists Recruitment Based on Big Five, NLP and Big Data Analysis

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Abstract. The specific features of the tasks of managing skilled human resources during recruiting, which allow to identify them as a task of multicriteria analysis and decision making in a fuzzy environment are highlighted in the article. A generalized conceptual model of decision-making in the recruitment tasks of IT specialists based on collected and analyzed data from social networks is proposed. It is substantiated that in order to increase the efficiency and transparency of solutions during recruiting, it is expedient to use multi-criteria optimization based on the TOPSIS method and show its advantages. The modification of the TOPSIS algorithm for recommending recruitment by qualified human resources on the basis of the analysis of user profiles in social networks for the Big Five model was proposed. The modification consists in integrating additional constituent management components into the decision-making algorithm, which provides calculation based on the analytical hierarchy process (AHP) criteria of the psychological state of IT specialists. Using the methods TOPSIS, AHP and scales for assessing the psychological state of skilled human resources, an example of recruitment has been used to make experimental calculations on the ranking of applicants, which demonstrated the efficacy of the proposed approach.

Keywords: Big Five, NLP, Big Data Analysis, Social Network, Quantitative Analysis, Recruitment, Content Analysis, TOPSIS, analytic hierarchy process, AHP.

1 Introduction

Today, professional recruitment is a necessary and necessary process in every organization in any sphere of activity: its financial performance depends on the quality and efficiency of the given process [1-13]. This is especially true for IT companies, in which the fast-growing increase in the number of different projects in the precise discussion of time spans requires continuous updating of the skilled workers of different directions. Most of the professions and specialties in this area are many - more than 30. Besides, in addition to the basic requirements for professionalism and the

education of IT specialists, the latest trend in recruiting is to take into account the psychological portrait of a future employee as a level of communicative, openness of experience, good faith, goodwill, leadership qualities, etc. Finding staff or recruiting is done using different approaches and sources of information, the main sources are:

- The internal database of the company or agency;
- Sites for job search and cooperation with recruiting agencies;
- Social capital (or search for candidates for acquaintance) and Mass-media;
- Social networks, forums, blogs, etc. [1-13];
- Employees of competitor companies, that is, the remuneration of specialists;
- Universities, that is, the involvement of young specialists from higher educational institutions.

This allows us to find professionals of a certain level for the corresponding position. But it does not guarantee solving problems, compliance with the human factor for the fulfillment of the respective official duties and the effectiveness of the work of the respective claimant. As well as the acquired professional knowledge and the experienced experience on the quality of work affects the psychological portrait of the very IT specialist. One of the modern tasks of analyzing the psychological state of personality when recruiting IT specialists is to analyze his profile in social networks (posts on forums, comments on events, activity in social networks, etc.). The most popular social networks for IT professionals are LinkedIn, Facebook, Twitter, Instagram, Google+, Youtube. Analysis of the level of activity in relevant social networks of relevant IT specialists and NLP analysis of the author's and content content of these individuals will enable to automatically form the profile of the psychological state of the applicant for the elected post. Ability to choose from a plurality of applicants, in addition to the level of competencies and even the psychological factors without subjectivity from the recruiter, will greatly improve the efficiency of recruitment for companies. Qualitative recruitment will not only save them time and resources, but will allow them to increase their own profits. The purpose of this study is to develop a technology for making managerial decisions in recruiting tasks in accordance with the above conceptual model and in verifying its effectiveness.

2 Influence of social networks for formation of psychological portrait of the person

Social networking service is a web site or other Internet service that allows users to create a public or semi-public questionnaire, make a list of users with whom they have a connection and view their own links list and lists of other users. The nature and nomenclature of connections may vary depending on the system. Unlike social networking services, the user is not in the center of the Internet community; the user's relation to other members of the community is in the foreground. The focus of the Internet community is on the user's contribution to achieving common goals, values and communication. In social networks, the user is in the center of the system and can belong to more than one group at a time [14-19].

Secondary connections in social networks are relatively weaker than secondary connections in Internet communities. For example, if you have several social links in the social network $User_2$, connections with unknown to him $User_2$ will be weaker than similar connections in the Internet community. In addition to providing useful services, social networking Internet services are also a number of dangers [20-22].

- Coordination of criminal gang activities.
- Distribution of propaganda and information operations.
- Infiltration of the circle of friends.

Analysis of social networks has a large potential for use in information operations, since it allows us to investigate the attitude, outlook and communication of a wide range of individuals, in particular [14-19]:

- Analysis of social networks can help to find important information about the user for their psychological analysis of recruiting. It also gives you the ability to direct information to your chosen audience and influence perceptions of reality, decision-making, or behavior of a particular group.
- Social networking portals allow you to quickly exchange texts, scenes, videos of various events in the process of their development. Watching this increases awareness of current events or track the distribution of quality information, their frequency to calculate the criterion of the model Big Five as a seam of ex-treversy, neuroticism, openness, annoyance and benevolence.
- The careful use of social networking portals can lead to secrecy disclosure. Instead, the analysis can help determine the level of trust in the applicant for a position where the notion of confidentiality is important.
- There have been cases where crowdsourcing and monitoring of social networks in Internet portals played an important role in the provision of humanitarian assistance, since they quickly provided important information. The regular participation of an individual in such events forms an appropriate opinion of him as a benevolent person.

Accordingly, content analysis can be used to find individuals in the process of recruiting (Fig. 1). Geocoded posts can complement the analysis, and help to assess the level of activity of such personality civility. Due to the analysis, it is possible to expand the analysis of the applicant for a post. The simpler classification of IT groups is sufficiently well describes the main lines of work at the lower (production) level of the IT company, that is, they are practically in all companies (test manager, project manager, business analyst, sysadmin, designer, team lead, architect, programmer, IT sales). Each group must possess not only relevant professional qualifications and experience, but also psychological features. According to the European e-competence Framework, the list of IT specialties forms 23 specialties, in particular [23]:

1. Account Manager,	13. ICT Trainer,
2. Business Analyst,	14. Network Specialist,
3. Business Information Manager,	15. Project Manager,

4. Chief Information Officer (CIO),
5. Database Administrator,
6. Developer,
7. Digital Media Specialist,
8. Enterprise Architect,
9. ICT Consultant,
10. ICT Operations Manager,
11. ICT Security Manager,
12. ICT Security Specialist,
16. Quality Assurance Manager,
17. Service Desk Agent,
18. Service Manager,
19. Systems Administrator,
20. Systems Analyst,
21. Systems Architect,
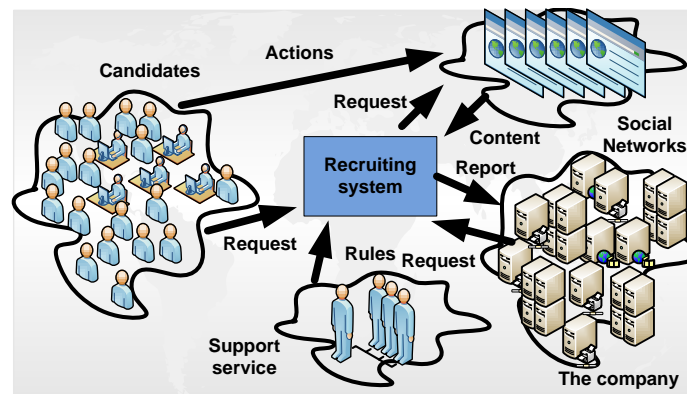22. Technical Specialist,
23. Test Specialist.

Fig. 1. The process of finding information about the applicant for a job at recruiting.

The list of professions somehow not got the following, which are even in Ukraine [23]:

1. Technical Lead,
2. Sales Manager,
3. Information Developer (Technical writer),
4. Designer,
5. Recruiter,
6. Human Resource Manager,
7. Data scientist,
8. Top Manager.

Although the hierarchy recommended in the main IT professions is the most commonly used in Ukraine [23]:

1. Postgraduate studies,
2. Systems Architector,
3. Senior Executive,
4. Senior Manager,
5. Manager,
6. Associate Manager,
7. Team Leader,
8. Senior Software Engineer,
9. Software Engineer,
10. Programmer,
11. Administrator,
12. Associate Software Engineer,
13. Recruiter,
14. Testers,
15. Assistant, assistant professor.

Even for the last list, any recruiter can be confused when performing his work - which of the candidate's best suits the psychological criteria for the recommended position is best. In addition, as a rule, recruits of the era do not have a degree in psychology. Therefore, additional automatic analysis of profiles of applicants in social networks in

absentia will reduce him time when the list of candidates for the rating is formed. This will work under the condition that, in cooperation with the IT cluster, a list of criteria for recruited posts will be formed and agreed upon. Next, it's a matter of working out large amounts of social networking data using Big Five, NLP and Big Data Analysis (Fig. 2) [24-37]. Analysis of posts in social networks, along with related metadata [38-43], can reveal future Timelifts. Image classification algorithms help you find out what kinds of images are popular on social networks, and, along with the link to the terrain, track changes in preferences and personal attitudes to different things [44-57]. However, recruiters are limited by national legislation and can not fully disclose the potential of analyzing social networks in relevant internet portals without the consent of the applicant [58-73].
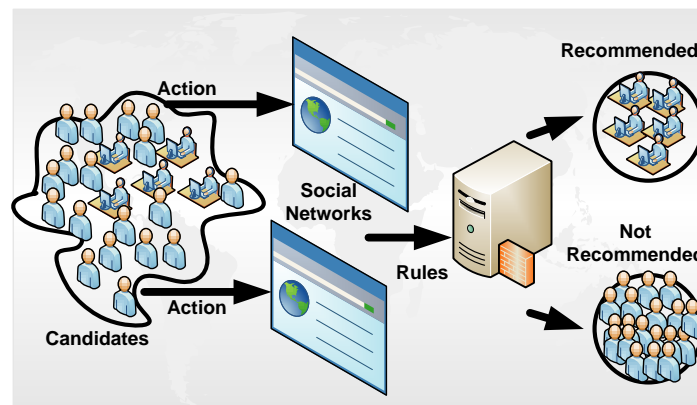

Fig. 2. The process of forming a recommendation for a post based on the analysis of candidate profiles in social networks.

3 Model Big Five for determination of the psychological state of personality

Regardless of its professionalism and level of experience, the Big Five model is used to determine the main features of a psychological portrait of a person. But it is usually used with the testing of these personalities. And on the sow of their answers build a corresponding psychological portrait. The modified version of the definition based on the Big Five model is the proposed method by the Chinese Bai Shuotian [6-7] - analysis of the profiles of Internet users of social networks, the frequency of clicks, posts, alarms, emoticons, etc. (Fig. 3). For more advanced analysis, methods of content analysis and NLP methods for collecting statistics based on the context-the emotional coloring of messages from a particular user, that is, the frequency of words with emotional coloration (negative, positive and neutral in relation to the total), are used. Recruitment algorithm based on the analysis of profiles in social networks.
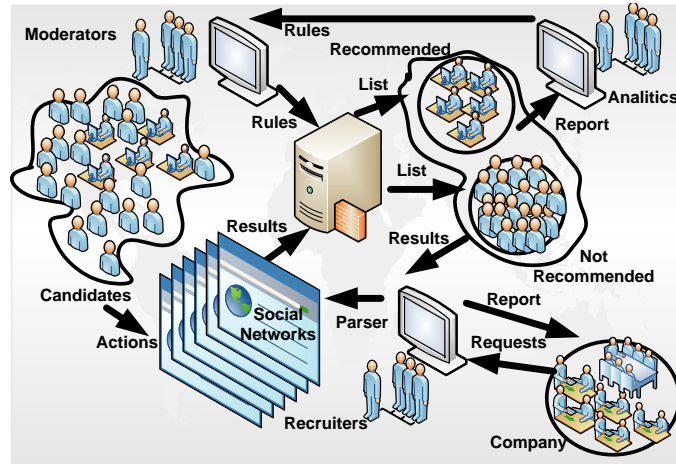
Fig. 3. Recruiting process based on the analysis of profiles in social networks

1. Periodic generalization of requirements for a position to formulate recommendations [41] of candidates for the model Big Five on the basis of a structured technique of the analytical hierarchy process (AHP, decision-making in a multicenter setting).
2. Identification of IT specialists as a user of social networks.
3. Automatic extraction of user profile data into social networks and its activity for a certain period of time (lyrics, posts, author's content, etc.) using modern methods of Big Data Analysis.
4. Analysis of the collected content by modern methods of NLP [23-37].
5. Formation of the profile of the psychological state of the IT specialist in the Big Five Medal based on the results obtained in the previous stage (submission of assessments according to the criteria on a certain scale).
6. Comparison of the received profile of the applicant with the requirements for the position and the provision of an in-depth report. In the case of several applicants for one position, the use of the TOPSIS method to form rating recommendations for the position of applicants in accordance with the requirements of deployed reporting [75].
7. The use of Machine Learning methods to study the system for recommending positions according to Big Five - analysis of user profiles in social networks.

Model Big Five is a hierarchical model of personality, which describes the five main features that make up the personality of a person. For the best memorization in the English literature, five rice are in the acronym OCEAN [1-13]:

- **Openness to experience.** The false perception of innovation, art, emotions, adventures, unusual ideas, curiosity and diversity of experience. Designed for gamers, web sites, animations, and more
- **Conscientiousness.** The tendency to be organized and reliable, demonstrate self-discipline, act obediently, strive to achieve and give preference to the planned, ra-

ther than spontaneous, behavior. High conscientiousness is often perceived as ob-stinacy and obsession. Inherent to programmers. Low conscientiousness is associ-ated with flexibility and spontaneity (inherent in business analysts), but it can also be manifested as failure and lack of reliability. This is a negative signal for many specialties, not just for IT business.

- **Extraversion.** Energy, positive emotions, sociability, and the tendency to seek stimulation in the company of others and talkativeness. Rice is inherent not only for Tollmasters, but also for managers, business analysts, coaches, tormenjedzhe-ram and designers. High extroversion is often perceived as seeking attention and domination. Low extroversion causes a protected, reflective personality that can be perceived as remote or self-absorbing (developers, datasansists, programmers, sys-tem architects, etc.). Extrovert IT specialists tend to be more dominant in a social setting, unlike introverted people who can act more shy and cautious in this envi-ronment.

- **Agreeableness.** The tendency to be sympathetic and co-operative, not suspicious and antagonistic to others. It is also an indicator of a trusting and altruistic charac-ter, as well as whether a person is generally well-nurtured or not. High coherence is often seen as naivete or obedience - good performers. A low figure is often an indi-cator of the competitiveness or complexity of a person (algorithmizers), which can be considered as amateurs arguing or unreliable.

- **Neuroticism.** The tendency to be prone to psychological stress. The tendency is easy to experience unpleasant emotions such as anger, anxiety, depression and vul-nerability. Neuroticism also refers to the degree of emotional stability and impulse control, and it is sometimes called emotional resistance. High stability manifests it-self as a stable and calm person (Timeliders), but it can be regarded as immovable and indifferent. Low stability turns out to be reactive and exciting personality, of-ten found in dynamic individuals (business analysts), but can be perceived as un-stable or dangerous. In addition, people with a higher level of neuroticism, as a rule, have worse psychological well-being.

Since the interpretation of results depends on the natural language that a person thinks, many countries of the world have their own versions of testing. The model is based on variables that are most widely spoken in the natural language through the use of a certain emotional color in the lexicon of the corresponding adjectives, nouns and rotations, as well as the frequency of their use. At the same time, the assumption is assumed that the natural linguistic person is formed:

$$M_{BF} = < C^{Ext}, C^{Agr}, C^{Cns}, C^{Nrt}, C^{Ops}, Ext, Agr, Cns, Nrt, Ops >, \qquad (1)$$

where the components of the tuple:

- extraversion (engagement): sociability, assertiveness or rest, passivity, that is $C^{Exp} = Exp(C, U^{Exp})$ through parameters U^{Exp} (u_1^{Exp} is sociability / sociability through the frequency and content of emoticons and liches at posts and friends' messages, u_2^{Exp} is perseverance / rest due to the frequency of reactions to the

actions of friends, u_3^{Exp} is activity / passivity due to the frequency of activity in the profile);

- benevolence (pleasure): kindness, trust, warmth or hostility, selfishness, distrust, that is $C^{Agr} = Agr(C, U^{Agr})$ through parameters U^{Agr} (u_1^{Agr} is kindness / hostility through reaction to new events, establishing new contacts and answering new queries. u_2^{Agr} is trust / distrust due to the response to the invitation, u_3^{Agr} is warmth / egoism through frequent posts about oneself in relation to posts about social events);
- conscientiousness (reliability): organization, thoroughness, reliability or carelessness, negligence, unreliability, that is $C^{Cns} = Cns(C, U^{Cns})$ through parameters U^{Cns} (u_1^{Cns} is organization / negligence due to the quality of author's posts, the degree of their chaos, u_2^{Cns} is solidity / serenity through the richness author posts, u_3^{Cns} is reliability / unreliability due to the reaction of friends to the author's events, the frequency of friends' greetings with the events, the frequency of answers to requests and the posts of friends);
- emotional stability: relaxation, balance, resistance or neuroticism is nervousness, depression, irritability, neuroticism, that is $C^{Nrt} = Nrt(C, U^{Nrt})$ through parameters U^{Nrt} (u_1^{Nrt} is relaxation / nervousness through the frequency and content of emoticons, nicknames and posts to friends' posts, u_2^{Nrt} is Balance / depression due to content content, emoticons, and likes, u_3^{Nrt} is stability / irritability due to the frequency of responses);
- culture, openness to experience: spontaneity, creativity or limited, intermediate, narrow interests, that is $C^{Ops} = Ops(C, U^{Ops})$, where C is content from user social networking profiles, U^{Ops} is rules for calculating the criterion, that is. $U^{Ops} = \{u_1^{Ops}, u_2^{Ops}, u_3^{Ops}, u_4^{Ops}\}$ (u_1^{Ops} is the frequency of occurrence of words related to kindness/anger; u_2^{Ops} is frequency of occurrence of words related to trust / distrust, u_3^{Ops} is the frequency of occurrence of words related to heat / hostility, u_4^{Ops} is the frequency of occurrence of words related to sincerity / egoism).

The following parameters are the main indicators for forming the criteria for social user behavior according to the Big Five model:

- frequency and content of emotional coloration of likes for a certain period of time;
- frequency and content of emotional coloration of emoticons for a certain period of time;
- frequency and content of emotional coloring of posts;
- the frequency and frequency of activities in the social network;
- average period of stay in social networks, taking into account the period (working time, non-working hours, season, etc.);

- participation and activity in groups;
- number of friends;
- frequency of greetings of friends;
- the presence / absence of pages, their number and frequency of updates;
- presence / absence of author's content (photos, videos, author's posts, etc.), its volumes and frequency / time of appearance;
- the presence / absence of information about yourself, the level of its completeness;
- the frequency and content of the vocabulary and the broadcasts of the applicant / author's / general content;
- the frequency and content of the comments of friends on the broad content of the applicant;
- proportionality of accessible public content to the closed view for all visitors.

This list can be continued, depending on the possibility of the social network itself. So in LinkedIn it is possible to further analyze the frequency of recommendations on the skills from friends (the level of trust of the surrounding to the applicant). Factors of the behavior model Big Five in research denote differently, but the overall content of the model is fairly stable and based on the following postulates []:

- all adult persons can be characterized by a specific combination of personality traits, influencing thoughts, feelings and behavior (on individuality);
- characteristics of the person being studied are endogenous basic tendencies (of origin);
- the features develop in the childhood, finally formed in adulthood and retain their immutability in the adapted subjects (on development);
- features are organized hierarchically, from narrow and specific to wide, generalized dispositions (about structure).

The described models are close to the theory of individuality. Theories of personality traits are intermediate between typological and idiographic (clinical) approaches to the study of individuality. However, for its use it is difficult to determine the correlation between different characteristics without the introduction of vertical and horizontal measurements, which are the basis of the hierarchy within the system of personality. Interpretation of rice as a situational sustained appearance also raises doubts. However, this does not forbid the use of the possibility of isolating and predicting personality traits. Today, the well-known corporation has developed an algorithm that defines features of the personality in English (Spanish) authoring text of 100 words or more. IBM Watson Personality Insights attempts to apply a linguistic analysis to determine the psychological portrait of its author along a piece of text [74]. The service itself is paid, it is offered for analysis of clients by blogs, tweets, and entries in the forum. But he has a demo where you can download a text of just one hundred words (it can be more, but one is the minimum). And the car, like a real oracle, will give a deployed personality trait. True, the text should be in English or Spanish [74].

- To get a psychological portrait, simply insert a piece of any text written by the person in question in the appropriate field, and then click on the "Analyze" button.

The program with a small delay gives a brief description, and when scrolling down the page you will find more detailed data. The text is analyzed for the presence of certain marked words, and the results are ordered by recognized psychological metrics, such as the Big Five - the assessment of personality on five characteristics, such as consciousness, friendliness, extraversion, emotionality and openness of experience.

- The service has APIs, open access documentation, and also a section on GitHub. According to [74] the results of the analysis of the text of Richard Branson under the heading "My idea of paradise" showed that the entrepreneur prefers imaginations rather than facts, believes in the best in people, trusts them, and in many of his actions is very independent. These data, if considered relevant, can be useful not only for analyzing the client base, but also for HR-specialists in evaluating applicants.

- However, the service users evaluate ambiguously. Quora has a related topic, where many participants believe that the service of accuracy of characteristics can be compared to horoscopes, they say, in any collection of very general phrases, everyone can see themselves. But subjective thought. Without a large number of statistical data, with close cooperation with psychologists, one can not fully confirm the effectiveness, efficiency and quality of the results. In parallel, with modern recruiting, the recruits themselves do not have a psychologist's education, and their subjectivity significantly influences the outcome of the formation of proposals for positions among applicants. It also does not solve the problem of qualitative selection of personnel. Therefore, companies often suffer losses and lose time searching for relevant professionals in the current fast-paced time and growing rates of IT business development. But a couple of drawbacks to using the method.

- The main thing in our opinion is the disadvantage of such a system - it is possible to pick up in advance or write a text that will be interpreted as beneficial to the applicant. Nowadays there is only one source of an independent, unique collection of content that has been collected over a long period of time by a specific personality, the user of social networks. As a person has not tried, she can not play a role for a long time (years), not showing himself in relationships with people around him in the same social network. The history of the user profile of a social network user is an objective information about his psychological state based on the Big Five model. Only appropriate methods of data extraction and NLP should be used to form the set of criteria for its psychological portrait for recruiting.

- Another disadvantage is that when creating requirements for the positions of IT professionals, the company usually uses other criteria such as communicative, responsible, leadership qualities, teamwork and creativity. This list may be expanded, but it is usually a fundamental indicator. By collaborating with representatives of an IT cluster with a specialist in psychology, this problem can be easily solved using, for example, a structured technique of the analytical hierarchy process (AHP, decision making in a multi-arterial setting) as shown in Fig. 4.

We will use the web resource http://victana.lviv.ua/matrytsia (Fig. 5) for a conditional example in the absence of statistical research in this area and active close cooperation

on these issues with the IT cluster and psychologists using approximate calculations (Fig. 6). In fig. 7. and Table 1 shows the results of calculations of the criteria for our conventional case.
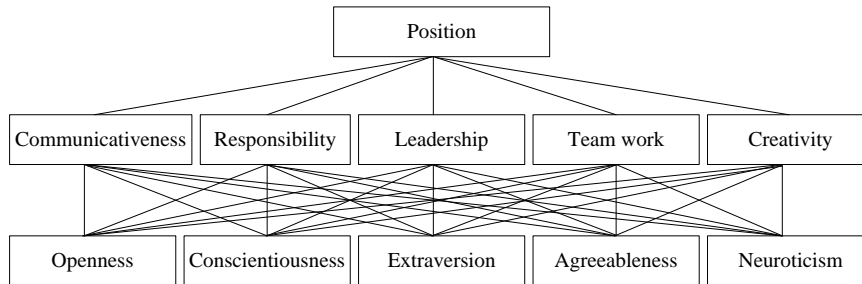

Fig. 4. Structured technique of AHP for calculation of job criteria by Big Five model

Fig. 5. Web Resource Interface for AHP

Fig. 6. An example of constructing a matrix of criteria for AHP

Матриця попарних порівнянь для рівня 2, рішення та узгодженість

	1	2	3	4	5	Вектор	x	Y
1	1	2	3	4	5	2.6051710846974	0.41741915999874	2.1222714992959
2	0.5	1	2	3	4	1.6437518295172	0.26337368472796	1.3309810792953
3	0.33	0.5	1	2	3	1	0.16022715838151	0.81051722165825
4	0.25	0.33	0.5	1	2	0.6083643418932	0.097476489762187	0.49274310145448
5	0.2	0.25	0.33	0.5	1	0.38385194963738	0.061503507129601	0.31297805798627

Lmax =	5.0694909596903
ІУ =	0.017372739225567
ВУ =	0.016403304619551

Очистити

Fig. 7. Results of calculation of criteria for our conditional example

Table 1 shows that criterion A (openness) for a candidate is more important than others, while criteria D (benevolence) and E (neuroticism) can even be neglected.

Table 1. Generalized Global Priorities

Criteria	1 0.417	2 0.263	3 0.160	4 0.097	5 0.062	Global priorities
A	0.417	0.417	0.417	0.417	0.417	0.417
B	0.263	0.263	0.263	0.263	0.263	0.263
C	0.160	0.160	0.160	0.160	0.160	0.160
D	0.097	0.097	0.097	0.097	0.097	0.097
E	0.062	0.062	0.062	0.062	0.062	0.062

4 The process of determining the suitability of a person's psychological state for an IT specialty

On the basis of a comprehensive approach to the accounting of the specifics of the processes of human resources management, a generalized conceptual model of decision-making in recruiting tasks will be provided by the following set of information:

- A set of feasible alternatives between applicants for a post $Cnd = \{cnd_1, cnd_2, \ldots, cnd_n\} = \{cnd_i, i = \overline{1,n}\}$;
- A set of criteria for choosing Big Five that characterize the psychological state of applicants / candidates (alternatives) – $U = \{U^{Ext}, U^{Agr}, U^{Cns}, U^{Nrt}, U^{Ops}\}$ or

$U = \{U_1, U_2, \ldots, U_m\} = \{U_j, j = \overline{1,m}\}$, where *m*=5, since there are only 5 model criteria Big Five;

- A set of subcriteria characterizing each of the criteria – $U_j = \{u_{j1}, u_{j2}, \ldots, u_{jT}\} = \{u_{jt}, t = \overline{1,T}\}$;
- The area of determining the values of each individual criterion – *Vcr*;
- A set of social networks where information about the applicant for the decision-making procedure is collected and analyzed – *Ssn*;
- A set of relationships between profiles in various Social Networks – *Rps*;
- The relationship between sets *Cnd*, *U* та *Ssn* – *Rss*;
- Linguistic expressions reflecting the degree of satisfaction of applicants to private criteria (degree of affiliation) – *Lrd*.
- Relations between criteria and private criteria – *Rcp*.

In order to achieve the goal as structured technique AHP, TOPSIS (The Technique for Order Preference by the Similarity to the Ideal Solution) has been selected in recruiting tasks, which allows to eliminate a number of disadvantages of existing instrumental approaches. The method is modified to the conditions of the accepted conceptual model of decision-making in recruiting tasks [75-80]. The main idea of the TOPSIS method is that the best bidder should have not only the greatest proximity to the ideal solution, but also beyond all other contenders for an unacceptable solution. Here, the best (optimal) solution is a vector that contains the maximum values for each criterion for all applicants, and the unacceptable (worst) solution is the vector containing the minimum values for each criterion. As follows from the essence of the TOPSIS method, using the latter can quite effectively solve the problem of fuzzy multicriteria optimization, which make up the mathematical basis of decision support in human resource management tasks. Under the multicriteria optimization in the decision-making theory, we mean the choice of the best solution among potential applicants. The TOPSIS method is one of the effective tools for promoting recruiting and experts in formulating their goals and subjective advantages, structuring the set of criteria, evaluating applicants in the decision making process in fuzzy mathematics, linguistic variables, fuzzy sets and fuzzy numbers. The solution of the optimization problem using TOPSIS involves the need to translate the values of qualitative linguistic variables, expressing the degree of satisfaction of one or another applicant to the criteria, in fuzzy numbers [75]. The fuzzy number is a fuzzy subset of a universal set of real numbers having a normal and convex membership function for which there is a carrier value, where the membership function is equal to one, while the function of membership decreases when the maximum or left moves from its maximum. According to [75] the fuzzy opinions of experts, for example, psychologists, formulated in terms of natural language, or independent indicators, calculated on the basis of analysis of social networks. These indicators can be described by fuzzy triangular and fuzzy trapezoidal numbers. In this paper, given the need to ensure the stability of the criteria to the boundaries of the interval of validity, an obscure trapezoidal number is used. Formation of judgments of the expert as a result of the analysis of the applicant's activity in social networks in the form of a fuzzy trapezoidal number in

practice is realized in this way. The investigated object according to the selected criterion is evaluated by the expert by a four-digit number $h = (h_1, h_2, h_3, h_4)$, where h_i are real numbers. The essence of this procedure is that the value of the criterion is in the range from h_1 to h_4, but most likely it is within the range from h_2 to h_3. If in the four the average numbers will be equal, that is $h_2 = h_3$, then a fuzzy trapezoidal number turns into an unclear triangular number. Using operations on membership functions based on the segment principle, operations on fuzzy numbers [75] are introduced. When using TOPSIS, some operations on fuzzy numbers should be taken into account. Let two fuzzy trapezoidal numbers be set as $\bar{h} = (h_1, h_2, h_3, h_4)$ and $\bar{g} = (g_1, g_2, g_3, g_4)$. Below are the operations of summation, the difference and the product of these numbers:

$$
\begin{aligned}
\bar{h} \oplus \bar{g} &= \left[h_1 + g_1, h_2 + g_2, h_3 + g_3, h_4 + g_4 \right], \\
\bar{h} - \bar{g} &= \left[h_1 - g_4, h_2 - g_3, h_3 - g_2, h_4 - g_1 \right] \\
\bar{h} \otimes \bar{g} &\cong \left[h_1 g_1, h_2 g_2, h_3 g_3, h_4 g_4 \right] \\
\bar{h} \otimes f &= \left[h_1 f, h_2 f, h_3 f, h_4 f \right]
\end{aligned}
\tag{2}
$$

The distance between two fuzzy trapezoidal numbers is determined from the expression [75]:

$$
w_o(\bar{h}, g) = \sqrt{\frac{1}{4} \left((h_1 - g_1)^2 + (h_2 - g_2)^2 + (h_3 - g_3)^2 + (h_4 - g_4)^2 \right)}.
\tag{3}
$$

If $\bar{h} = \bar{g}$, that is $\bar{h}$ and $\bar{g}$ equivalent, then $w_o(\bar{h}, \bar{g}) = 0$. To implement the method, it is necessary to operate with linguistic variables and their values, expressing verbal scales for measuring signs. At the same time, the levels are arranged in order of increasing intensity of the manifestation of these features. In this case, the number of values (gradations) of the linguistic variables is seven. Table 2 shows the 7-level values of the linguistic variable and their corresponding fuzzy trapezoidal numbers.

Table 2. Linguistic values and their corresponding fuzzy trapezoidal numbers

N	Scale	Linguistic values	Rating	False trapezoidal numbers
1	F	poorly	0-25	(0,0,1,2)
2	FX	unsatisfactorily	26-49	(1,2,2,3)
3	E	fairly	50-60	(2,3,4,5)
4	D	satisfactorily	61-70	(4,5,5,6)
5	C	добре	71-79	(5,6,7,8)
6	B	very good	81-87	(7,8,8,9)
7	A	perfectly	88-100	(8,9,10,10)

According to Table 2, numeric matching can be found for each value of the linguistic variable. For example, the numerical correspondence of the linguistic value "partially

good", which is one of the gradation of the measurement of properties, is determined by the 100-point rating system as (5, 6, 7, 8). We present an algorithm for multi-criteria optimization of recruiting tasks based on the TOPSIS method and the results of the analysis of the applicants' activity. $Cnd = \{cnd_i, i = \overline{1, n}\}$ in social networks $Ssn = \{s_l, l = \overline{1, v}\}$. Let the following components of recruiting tasks be known:

- $Cnd = \{cnd_i, i = \overline{1, n}\}$ is a set of candidate;
- $U = \{U_j, j = \overline{1, m}\}$ is a set of criteria by model Big Five;
- $U_j = \{u_{jt}, t = \overline{1, T_j}\}$ is a set of private criteria as sub-criteria of the Big Five model
- $Ssn = \{s_l, l = \overline{1, v}\}$ is a set of social networks;
- $rcp_j, j = \overline{1, m}$ are the coefficients of the relative importance of the criteria ($U = \{u_j, j = \overline{1, m}\}$);
- $rcp_{jt}, t = \overline{1, T}, j = \overline{1, m}$ are the coefficients of the relative importance of private criteria ($u_j = \{u_{jt}, t = \overline{1, T_j}\}$);
- $rps_l, l = \overline{1, v}$ is coefficients of reliability of social networks.

The purpose of the task is to rank the applicants on the basis of activity ratings in social networks, taking into account the reliability of the latter. The solution to the problem involves the following sequence of actions:

Step 1. To conduct multi-criteria optimization of recruiting tasks based on the TOPSIS method, it is necessary first of all to get rid of the hierarchical structuring of the criteria. To this end, based on the AHP Saati method, we use the coefficients of the relative importance of the criteria and the private criteria to determine the weights [75], which will be taken into account by the integral criterion $U = \{U_j, j = \overline{1, m}\}$. In a formalized form, the product rcp_j, where $\sum_{j=1}^{m} rcp_j = 1$ and $\sum_{t=1}^{T_j} rcp_{jt} = 1$, where is determined rcp_{jt}^{U} is the weight of the private criterion u_{jt} in the calculation of the integral criterion $U = \{u_j, j = \overline{1, m}\}$, that is $rcp_{jt}^{U} = rcp_{jt} \cdot rcp_j$. As a result, the two-level hierarchical structure of the selection criteria $U = \{U_j, j = \overline{1, m}\}$, characterizing the applicant for a position, is reduced to a one-step hierarchy. In the next steps for simplification of the indexes, all private criteria are combined in a single set *S*.

$$S = \{u_{jt}, j = \overline{1, m}, t = \overline{1, T_j}\} = \{u_z, z = \overline{1, Z}\}, \ z = T_{j-1} + t, \ j = \overline{1, m}, t = \overline{1, T_j}, T_0 = 0. (4)$$

Here Z is the total number of private criteria that characterize the applicant for a position, that is $Z = \sum_{j=1}^{m} T_j$. In this case, $rcp_z = rcp_{jt}^U$.

Step 2. Degrees of membership (matching) of applicants to private criteria are estimated linguistic values and are expressed by fuzzy trapezoidal numbers $Trn^l = (w_{iz}^l) = (e_{iz}^l, f_{iz}^l, g_{iz}^l, h_{iz}^l)$. So, for example, if the degree of satisfaction (affiliation) of the applicant cnd_i private criterion u_z on the basis of analysis of the applicant's activity in the social network l estimated value "good", then it is expressed as $w_{iz}^l = (7, 8, 8, 9)$, and if this assessment is "very good", then $w_{iz}^l = (8, 9, 10, 10)$ etc. As a result of the Big Five assessing the degree of membership of applicants for a job by private criteria, we obtain the following matrix:

$$Trn^l = [w_{iz}^l], l = \overline{1, q} \Leftrightarrow \{e_{iz}^l, f_{iz}^l, g_{iz}^l, h_{iz}^l\}, l = \overline{1, q} . \tag{5}$$

Step 3. This step involves preliminary calculation of the reliability ratios of social networks $rps_l, l = \overline{1, q}$. To this end, a modification of the method was introduced, which involves integrating into an algorithm an additional step, which involves calculating and introducing the reliability coefficients of social networks involved in the bidding process. From given the reliability coefficients of social networks $rps_l, l = \overline{1, q}$ matrix is formed

$$Trn^{rps_l} = [w_{iz}^{rps_l}], l = \overline{1, q} \Leftrightarrow \{e_{iz}^{rps_l}, f_{iz}^{rps_l}, g_{iz}^{rps_l}, h_{iz}^{rps_l}\}, l = \overline{1, q} . \tag{6}$$

Elements of this matrix are trapezoidal numbers that express the degree of satisfaction of the applicant cnd_i private criteria u_z taking into account the reliability of social networks and calculated as follows:

$$e_{iz}^{rps_l} = e_{iz}^l \cdot rps_l; \;\; f_{iz}^{rps_l} = f_{iz}^l \cdot rps_l; \;\; g_{iz}^{rps_l} = g_{iz}^l \cdot rps_l; \;\; h_{iz}^{rps_l} = h_{iz}^l \cdot rps_l. \tag{7}$$

Step 4. The single matrix is determined:

$$\begin{aligned} Trn^{rps_l} = [w_{iz}^{rps_l}], l = \overline{1, q} \Leftrightarrow \{e_{iz}^{rps_l}, f_{iz}^{rps_l}, g_{iz}^{rps_l}, h_{iz}^{rps_l}\}, l = \overline{1, q} \Rightarrow \\ \Rightarrow Trn_{iz} = [w_{iz}] \Leftrightarrow \{e_{iz}, f_{iz,} g_{iz}, h_{iz}\} \end{aligned} \tag{8}$$

The elements of this matrix are defined as follows:

$$e_{iz} = \{\min e_{iz}^{rps_l}, l = \overline{1,q}\}; \;\; f_{iz} = \frac{1}{q} \sum_{l=1}^{q} f_{iz}^{rps_l};$$

$$g_{iz} = \frac{1}{q} \sum_{l=1}^{q} g_{iz}^{rps_l}; \;\; h_{iz} = \{\max h_{iz}^{rps_l}, l = \overline{1,q}\}. \tag{9}$$

Step 5. Elements of the matrix $Tm_{iz} = [w_{iz}] \Leftrightarrow \{e_{iz}, f_{iz}, g_{iz}, h_{iz}\}$ multiply by the weight of the private criteria. As a result of this operation a weighted fuzzy matrix is constructed $Tm_{iz}^{rcp} = [w_{iz}^{rcp}] \Leftrightarrow \{e_{iz}^{rcp}, f_{iz}^{rcp}, g_{iz}^{rcp}, h_{iz}^{rcp}\}$ here:

$$e_{iz}^{rcp} = e_{iz} \cdot rcp_z; \quad f_{iz}^{rcp} = f_{iz} \cdot rcp_z; \quad g_{iz}^{rcp} = g_{iz} \cdot rcp_z; \quad h_{iz}^{rcp} = h_{iz} \cdot rcp_z. \quad (10)$$

Step 6. The resulting matrix is normalized. This method *Hsu* and *Cehn* is used [],on the basis of which are determined $h_z^+ = \max h_{iz}^{rcp}, i = \overline{1,n}$. Next on the basis of the expression:

$$Tm_{iz}^N = \left[w_{iz}^N \right] \Leftrightarrow \left\{ e_{iz}^N, f_{iz}^N, g_{iz}^N, h_{iz}^N \right\} \Leftrightarrow \left\{ \frac{e_{iz}^{rcp}}{h_z^+}, \frac{f_{iz}^{rcp}}{h_z^+}, \frac{g_{iz}^{rcp}}{h_z^+}, \frac{h_{iz}^{rcp}}{h_z^+} \right\}. \quad (11)$$

The elements of a normalized decision matrix are determined.
Step 7. Based on the weighted meanings, the ideal positive (best) solution is determined (IPS) Cnd^* . To this end, for everyone u_z, $z = \overline{1, Z}$ are chosing

$$h_z^* = \{\max h_{iz}^N, i = \overline{1, n}\} \quad (12)$$

matrix is formed

$$Cnd^* = [h_z^*] = [(h_1^*, h_1^*, h_1^*, h_1^*), ..., (h_Z^*, h_Z^*, d_Z^*, h_Z^*)] \quad (13)$$

According to the words (11) $h_z^* = 1$ for $\forall z$, that is, all elements of the matrix Cnd^* are equal to units.
Step 8. The ideal negative (worst) solution is calculated (INS) Cnd^- . To this aim, for everyone u_z, $z = \overline{1, Z}$ are chosing

$$e_z^- = \{\min e_{iz}^N, i = \overline{1, n}\} \quad (14)$$

and the following matrix is formed:

$$Cnd^- = [e_z^-] = [(e_1^-, e_1^-, e_1^-, e_1^-), ..., (e_Z^-, e_Z^-, e_Z^-, e_Z^-)] \quad (15)$$

Step 9. Using the formula (3), according to the individual values of each individual criterion, the distance of the applicants to IPS:

$$H_z^*(cns_i, Cnd^*) = \sqrt{\frac{1}{4}((e_{iz}^N - h_z^*)^2 + (f_{iz}^N - h_z^*)^2 + (g_{iz}^N - h_z^*)^2 + (h_{iz}^N - h_z^*)^2)} \quad (16)$$

On the basis of the obtained results a vector is formed $[H^*] = [H_1^*, ..., H_Z^*]$.
Step 10. By the individual values of each individual criterion, the distance of the applicants to INS:

$$H_z^-(cnd_i, Cnd^-) = \sqrt{\frac{1}{4}((e_{iz}^N - e_z^-)^2 + (f_{iz}^N - e_z^-)^2 + (g_{iz}^N - e_z^-)^2 + (h_{iz}^N - e_z^-)^2)} \quad (17)$$

On the basis of the obtained results a vector is formed $[H^-] = [H_1^-, ..., H_Z^-]$.

Step 11. Determine the distance of each of the applicants to IPS and INS:

$$H^*(cnd_i) = \sqrt{\sum_{z=1}^{Z}(H_z^*(cnd_i, Cnd^*))^2}; \quad D^-(cnd_i) = \sqrt{\sum_{z=1}^{Z}(H_z^-(cnd_i, Cnd^*))^2}. \quad (18)$$

Step 12. Calculates the integral index (coefficient of proximity) for each comparable bidder as the ratio of the calculated distance for him from the ideal worst decision to the sum of distances to the best and worst decisions:

$$H(cnd_i) = H^*(cnd_i) + H^-(cnd_i); \quad \alpha(cnd_i) = \frac{H^-(cnd_i)}{H(cnd_i)}. \quad (19)$$

In accordance with the value of the coefficient of proximity $\alpha(cnd_i)$ it is possible to rank applicants. So, the closer to the unit value of the coefficient of proximity $\alpha(cnd_i)$, the better the candidate is compared. The largest value of the integral indicator $\alpha(cvd_i)$ determines the best bidder, that is, the optimal solution. The least value $\alpha(cnd_i)$ matches the worst bidder.

5 Conclusions

In the conditions of the active development of innovative information technologies, human resources, including IT specialists, have become the main strategic resource of companies, which ensures their long-term competitiveness and achieve their goals. The emphasis in this matter is on recruiting IT specialists. In addition to the basic requirements for professionalism and IT education, the latest trend in recruiting is to take into account the psychological portrait of a future employee as a level of com-municativeness, openness of experience, good faith, goodwill, leadership qualities, etc. One of the modern tasks of analyzing the psychological state of personality when recruiting IT specialists is to analyze his profile in social networks (posts on forums, comments on events, activity in social networks, etc.). Therefore, the development of new conceptual approaches and promising IT management of human resources be-comes of special relevance and practical significance. In recruiting, the challenge of recruitment is of great importance, since, with the presence of qualified personnel, the company can function successfully. Therefore, the issues of the adoption of personnel decisions, free of subjectivity, are very relevant. The complexities faced by compa-nies in the process of identifying the applicant, the most acceptable requirements for a particular post in terms of professional suitability, and from the point of view of com-pliance with corporate style and psychological compliance, necessitate the develop-

ment and improvement of automated approaches for recruiting. The paper proposes a methodological approach to solving recruiting tasks based on the analysis of data on the applicant from social networks using multi-criteria optimization based on the TOPSIS method. The use of the TOPSIS method in human resources management tasks allows to increase the adequacy of the decisions made by ranking according to the degree of proximity to the ideal solution ensures the objectivity and transparency of the adopted managerial decisions and provides opportunities for expanding the scope of multicriteria optimization methods. The authors apply the TOPSIS method modification, which consists in integrating into the algorithm an additional step, which involves calculating and introducing the reliability coefficients of social networks involved in the procedure for evaluating the applicants' psychological state based on their activity with emotional coloration (neutral, positive and negative).

The advantages of the proposed approach to multicriteria optimization based on the modified TOPSIS method to support decision-making in recruitment are as follows:

- Absence of the need to compile a fuzzy rule base;
- Mathematical reasonableness and relative simplicity of calculations of integral indicators, allowing to carry out ranking of alternative solutions, to carry out further analysis and choice of the final solution;
- Lack of constraints on the number of applicants and the parameters of the formation of criteria for evaluation according to the activity in social networks, which characterize the object of research;
- Accounting in the algorithm of making decisions on the competence of the years of training involved in the decision-making process;
- Accounting for the hierarchical structure of the criteria describing the applicants;
- Ability to rank applicants according to their degree of proximity to the ideal solution.

The article presents a step-by-step demonstration of the possibilities of the proposed method in the process of multi-criteria analysis and decision-making on the example of the selection and recruitment task. Conducting alternative calculations for decision-making based on a ball assessment system and a comparative analysis of the results of the two methods shows the effectiveness of the proposed method. Using the described methodological approach as the mathematical basis of a computer system for decision support in recruiting tasks can become an effective tool for preparing and taking effective decisions in human resource management in IT business.

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