CHAPTER 6

Development of models and methods for assessing green skills in the labor market ecologization environment

Masuma Mammadova
Tetyana Baydyk
Zarifa Jabrayilova
Huseyn Gasimov
Turkan Alibeyli

Abstract

The modern world is faced with an unprecedented number of interconnected environmental problems, the key ones being environmental pollution, climate change, loss of biodiversity, depletion of natural resources. One of the most serious environmental problems of our time, affecting all aspects of life on Earth, is global climate change, caused mainly by anthropogenic factors. The negative impacts of the deepening climate crisis on the sustainable economic development of countries around the world have created a real threat to humanity in recent decades and have led the world community to recognize the need to transition to a green economy as a way to solve these problems. Green transformation, which involves the transition to sustainable and environmentally friendly technologies, leads to serious changes in the labor market, in particular, it causes changes in the sectoral structure of employment, rapid growth of green jobs in various sectors of human activity and, accordingly, the need for green skills necessary to use new technologies. The implementation of the green policy leads to the elimination of a number of professions and specializations and the emergence of new priority professions and specializations in the labor market, focused on the restoration of ecological systems and careful interaction of man with the environment. New professions and specializations requiring the acquisition of green skills generate a discrepancy between the demand for human resources of the required profile and their supply. This, in turn, actualizes the problem of effective selection of personnel with the necessary skills and determines the need to develop models and methods for assessing the supply and demand for specialists, providing an opportunity to assess the compliance of

 DOI: 10.21303/978-9908-9706-6-0.ch6

the proposed skills with the requirements of vacant green jobs. This chapter proposes a methodological approach to intelligent management of supply and demand in the green segment of the labor market. Fuzzy multi-criteria methods for supporting decision-making have been developed, allowing, in the context of green professions and specialties, to determine the degree of compliance of the proposed skills with the level of required green skills. Models and algorithms for supporting decision-making to identify the degree of "greenness" of the proposed skills to the requirements of green jobs are proposed, taking into account the multivariate nature of the coordination of supply and demand.

Keywords

Green jobs, green skills, intelligent management of supply and demand, greenness degree of the proposed skills.

6.1 Introduction

Ecological systems (ecosystems) are natural communities of living organisms (animals, microorganisms, plants, etc.) and the environment (air, water, soil, forests, climate, etc.), functioning together as a unit. Their state determines the well-being of the planet and man [1]. Ecological systems are quite vulnerable to anthropogenic impacts, and subject to pollution and depletion. The state of the ecosystem has a significant impact on the climate, biodiversity, and human health. A particularly serious environmental problem of modern time is climate change, which manifests itself through such indicators as global warming, rising (lowering) sea levels, water bodies, increased frequency and intensity of extreme weather events such as droughts, floods, hurricanes, forest fires, and other emergencies.

In recent decades, humanity has particularly felt that the uncontrolled production and use of traditional energy, emissions of which account for 75% of all greenhouse gases polluting the atmosphere, are leading the world to a catastrophe. Not by coincidence the issues of reducing the global climate change and the environmental problems, developing a "green economy" and clean energy, providing each inhabitant of the planet with the access to clean energy were the discussion topics at the annual general debate of the 76th Session of the UN General Assembly with the participation of leaders of states and governments of 193 member-countries, September 21–27, 2021, New York. Countries specific commitments were made to reduce the hydrocarbon share and "decarbonization" of energy industry in the following ten years in order to implement the Paris Climate Agreement, which is a legal international treaty on climate change [2].

To date, all UN member countries have ratified the Paris Agreement, which sets the goal of preventing global temperatures from rising by more than 2°C. Each country has committed to Nationally Determined Contributions (NDCs) to reduce greenhouse gas emissions. In this regard, the ever-growing demand for energy in the world is accelerating the gradual transition of nation-states to green energy. The implementation of NDCs includes commitments to reduce greenhouse gases in the energy, agriculture, transport, and other sectors.

However, national commitments and sectoral priorities for implementing the Paris Agreement tend to underestimate the role of skills development. The key role of human capital in preventing environmental disaster is often overlooked when developing policies and plans to support the transition to a green economy. This increases the skills shortage and impairs the skills mismatch in the emerging green segment of labor market. Therefore, most companies face difficulties in recruiting professionals with the necessary green skills for the available green vacancies.

According to a study by Cedefop (European Centre for the Development of Vocational Training), professions requiring a transition to green skills accounted for around 40% of the total number of online job advertisements in the EU between 2020 and 2022 [3]. The European Commission estimates that an additional 884,000 jobs could be created in the EU by 2030 with the climate goals of the European Green Deal [4]. This estimate takes into account job losses in sectors such as coal mining or polluting industries and job growth in areas such as renewable energy, agriculture, the circular economy [5, 6]. At the same time, sectors such as transportation and storage, water supply, agriculture, renewable energies, energy storage and waste management, which are critical to the transition to a green economy, are experiencing labor shortages [4].

An analysis of data on developing and transition countries conducted by the International Renewable Energy Agency (IRENA) found out that the renewable energy sector alone would employ 13.7 million people in 2022, compared to 7.3 million in 2012. IRENA estimates that the large investments required to meet climate objectives could create many millions of additional jobs in the coming decades [7].

LinkedIn data, covering 48 countries and 930 million users worldwide, also shows that the demand for green jobs is growing almost twice as fast as the availability of workers with the necessary skills to fill these vacancies. In 2023, 7.3% of job postings on LinkedIn were for a green job or required green skills, in 2024, that figure rose to 7.7% [8].

According to the International Labor Organization (ILO) estimations, if countries take measures to achieve the goals set in the Paris Agreement, about 24 million green jobs will be created worldwide by 2030, with the majority of them in Asian countries. Moreover, approximately 6 million jobs are estimated to be closed. Taking into account the losses, the net increase in jobs will be 18 million [9].

As follows from the statistics above, the problem of increasing demand for human resources with skills supporting the green transition is quite relevant for all regions and countries all over the world. Growing demand for new green skills requires adaptation to new environmental requirements, changing the thinking and lifestyle of each person to make informed decisions to reduce negative impacts on the environment and improve the environmental situation [10, 11].

The process of ecosystem recovery promotes the emergence of new areas of employment, the creation of green jobs, makes the problem of effective selection of personnel with green skills relevant and determines the need to develop models and methods for assessing green skills and green jobs.

6.2 Related work

Successful implementation of net zero policies requires measures to eliminate the mismatch between supply and demand for skills in the green segment of the labor market. In this context, it is first necessary to clarify what the terms "green jobs" and "green skills" mean. Further, taking into account the content of these two conceptual concepts, it is possible to review the main areas of research devoted to identifying the relationship between the green transition and the corresponding skills.

The literature review shows that today specialized international organizations and research institutes have adopted various definitions and methodological approaches to analyze and identify green jobs and green skills. However, the lack of a single generally accepted definition and the heterogeneity of methodological frameworks lead to significant differences in the results of studies, especially when trying to quantify green jobs and determine the necessary green skills. Moreover, a number of green skill indicators are assessed only by qualitative characteristics that cannot be described using traditional methods. Therefore, the degree of "greenness" attributed to various profiles of professions and positions can vary significantly depending on the field of activity. The adoption of a unified definition is even more difficult at the international level, since each country has its own specific political and economic context, intellectual potential and methodological approach to defining these concepts. Currently, very few countries have monitored and assessed the green skills market. Taking these factors into account, the authors of this paper refer to definitions proposed by leading international organizations.

According to the ILO definition, "green jobs are decent jobs that contribute to preserve or restore the environment, be they in traditional sectors (manufacturing, construction etc.) and in new, emerging green sectors (renewable energy, energy efficiency)". They are divided into two categories [12]:

1) jobs that design and produce goods or provide services that benefit the environment, such as green buildings, clean transportation and renewable energy, sustainable food;

2) jobs that contribute to more environmentally friendly processes in the production of any product or service, e.g. increasing water or energy efficiency, improving recycling systems etc.

In accordance with the US Green Economy Program, initiated in 2009, the online Occupational Information Network O*NET developed a methodology for data collection based on the use of scientific journals, commissioned reports, industry white papers, and government technical reports on green and non-green issues and identified approximately 100 professions included in the green economy. To identify green economic sectors, green occupations, and green tasks, their potential to reduce harmful impacts on the environment (e.g., by the reduction of the use of fossil fuels, the decreasing pollution and greenhouse gas emission, the developing renewable sources of energy) was taken into account. Using this definition, the experts classify occupations into three general categories, which are also included in the O*NET taxonomy [13]:

1) existing occupations that are expected to be in high demand due to the Green Increased Demand;

2) occupations the task content of which will undergo significant changes due to the greening of the economy (Green-Enhanced Skills);

3) New & Emerging Green. Currently, the number of occupations included in the green category by O*NET is 204.

In the European Union, the definition of green skills proposed by Cedefop is used to identify green jobs, occupations and skills. According to this definition, green skills are understood as "knowledge, abilities, values and attitudes needed to live, work and act in economies and societies seeking to reduce the impact of human activity on the environment" [14].

The systematization of knowledge and skills related to the green transition in the EU is carried out within the framework of ESCO (European Skills, Competences, Qualifications and Occupations) and is based on the definition of green skills proposed by Cedefop. ESCO works as a dictionary, describing, identifying and classifying professional occupations and skills relevant for the EU labor market and education and training [15], and includes the identified green skills and green jobs in its taxonomy. The taxonomy also defines which skills and knowledge concepts are essential or optional for a particular occupation's green economy and identifies green transition skills that can be applied across different occupations.

The identification of green professions and skills was performed through a group expert assessment of the skill requirements specified in vacancies and the processing of online vacancies using machine learning algorithms. The resulting ESCO skills base was divided into three groups [16, 17]:

1) brown skills, which are defined as knowledge and skills that increase the impact of human activity on the environment;

2) white skills, which do not increase nor reduce the impact of human activity on the environment;

3) green skills, which reduce the impact of human activity on the environment.

Currently, the ESCO taxonomy contains 381 green skills, 185 knowledge concepts and 5 transversal skills.

Skills for the green economy consist of:

– **specific skills**, required to adapt or implement standards, processes and services to protect ecosystems and biodiversity, and to reduce energy, materials and water consumption;

– **transversal skills** (digital, interdisciplinary, entrepreneurial, sustainable management, communication and negotiation skills**)**, linked to sustainable thinking and acting, relevant to all economic sectors and occupations;

– **highly specialized skills**, required to develop and implement green technologies such as renewable energies, sewage treatment or recycling. Skills for the green economy are also referred to as skills for green jobs, skills for the green transition or green skills.

According to [18], the transition to a green economy will lead to a reduction in jobs in sectors with high levels of emissions and environmental pollution, while new green jobs will be created in cleaner industries and will cause large changes in the demand for green professional skills.

In the study [19], the authors came to the following conclusion:

a) the rate of implementation of green technologies in various sectors of the economy and their impact on skill requirements are difficult to quantify;

b) the level of changes in the demand for professional skills depend on the specific characteristics of individual sectors.

In [20, 21], the authors estimate the lack of skills in green sectors as a vulnerable factor holding back the implementation of innovations and technologies.

The studies [22–24] estimate the share of US jobs that would benefit from the transition to a green economy using the online database O*NET and its definition of green jobs.

An analysis of green jobs has revealed differences in the degree of greenness. This suggests that the term greenness should be considered as a continuum rather than a binary characteristic. Greenness measures for four general green skill categories (engineering and technical science, operation management and monitoring) are proposed [22, 24].

In order to draw policy stakeholders' attention to the breadth of green skills needed to achieve climate justice, the authors propose a skills framework for the green economy [25]. They show the conceptualization of green skills through a gender and adolescent lens in the greening, sustainable development and education areas.

In the discussion paper [26], given that the green transition is set to accelerate over the next decade and trigger structural changes in EU labor markets, it is provided descriptive data on regions and demographic groups expected to be most affected by shifts between sectors, firms and occupations, and discusses the policy implications.

In [27] the results of observation of development of green jobs in Scotland are obtained using a hybrid approach. The authors conclude that the most important is not the total number of jobs, but the types of green jobs created and the spread of their impact on the economy.

A. Sulich, L. J. Kozar analyze Green Competences within Green Human Resource Management on the basis of the literature review [28]. The authors give various definitions of green competencies and examines their connection with the context of the problem being solved.

A review of the literature on the analysis of the impact of skills on the green transition has yielded several conclusions:

1. One of the obstacles to assessing the impact of the green transition on demand (green jobs) is the difficulty of identifying the skills needed for the green transition.

2. Research related to the transition to a green economy mainly focuses on identifying green occupations (jobs), skills and employment forecasts.

3. The ad hoc studies of occupations and skills conducted to date, due to their small number and methodological differences, do not complement each other and therefore cannot provide an up-to-date picture of the changing demand for skills.

4. The most valuable information on green jobs and green skills is collected at the sectoral level, which makes it possible to set targets for each individual industry.

5. Research and policy initiatives rarely take into account the human resources needed to support the green transition. This increases uncertainty in assessing the supply and demand for the relevant skills.

6. The pace of green technology adoption across sectors and its impact on human resource requirements with green skills are difficult to assess quantitatively and qualitatively.

7. Methods for assessing the match of skills offered to green workplace need to be developed to select workers with the required green skills.

6.3 Objective and general statement of the problem

Taking into account the findings, let's accept the existence of designated green occupations and skill sets across various sectors of the economy. The aim of the present study is to determine the compatibility of the set of skills offered by the applicant with the set of green skills characterizing green jobs (vacancies) in the recruitment process for green jobs and to evaluate the degree of "greenness" of the applicant's skills.

The conducted review and listed conclusions identify the problem of management of the green demand and green supply in the green labor market as semi-structured and difficultly formalized tasks [29, 30]. Obviously, for the solution of such problems, the use of intelligent methods and technologies based on fuzzy logic, is most effective. In this interpretation, solution of the management problem labor market assumes:

– selection of the most demanded green professional groups and specialties on the labor market;

– identification of requirements for green professional and personal competencies of specialists demanded on the labor market most in the context of each professional group or specialty;

– development of situational models of supply and demand in ever-changing labor market;

– comparison and evaluation of fuzzy situation of supply and demand in the current situation;

– deciding on the choice of a policy for their compliance.

The labor market can be referred to socio-economic ("soft") systems for its properties. This market is a social system as its key resources include people, intellectual potential, personal and psychophysiological qualities, the preferences of the latter, without which the management of the social system will be ineffective [30]. The success of a specialist in performing professional duties depends on his/her intellectual potential, the degree of certain professional and personal competencies, the willingness to adequately apply them at a particular workplace, the desire and ability to improve and regularly update his/her knowledge and experience in the professional field in accordance with the functional requirements to the latter. In this context, the approach to the labor market as an intellectual environment seems promising, in which knowledge, skills and abilities act as a commodity [31], for the formalization of which the theory of fuzzy sets is used [32].

As follows from the above, in order to assess and identify the degree of consistency between supply and demand in the context of various professional groups and specialties, it is necessary to solve two problems:

Problem 1 – identifying supply and demand for green professional groups and specialties needed in the labor market.

Problem 2 – identifying supply and demand for professional skills, specific to certain green specialty, and personal competencies for specialists in the context of each professional group or specialty, considered from the standpoint of individual subjects of the labor market (specialists and employers) and their behavioral strategies.

6.3.1 Problem statement 1

It is possible to assume that there are a predetermined number of green professional groups and specialties identified by examining the structure of the labor market [33]. It is required to assess the need for professional groups and specialties, their ranking (streamlining) from the most promising to low demand from the positions of demand in the green segment of labor market. It is possible to note that the ordering of the list of professional groups and specialties takes into account the demand for a particular green specialty as a whole, and not as the probability of employment of each specialist or graduate.

Problem solution 1.

Variant A. The method for fuzzy multicriteria individual expert decisions on the choice of priority professional groups and specialties.

Let's consider the method for selecting and arranging the alternatives of professional groups (or specialties) in the case when the criteria assessments of one expert are set as the degree of satisfaction of alternatives characterizing them (criteria, properties). The decision-making process in this case is reduced to a rational choice of alternatives, taking into account a set of features and preferences of an individual expert or decision maker, who are the same person here.

Let $X = \{x_1, x_2, ..., x_n\} = \{x_i, i=\overline{1,n}\}$ be a set of alternatives, which are the list of green specialties to be considered. $K = \{k_1, k_2, ..., k_m\} = \{k_j, j=\overline{1,m}\}$ denotes a set of criteria (features, properties) characterizing the alternatives. It is necessary to choose the best alternatives (green specialties) out of the evaluated ones, i.e., the most required specialties in the labor market from the standpoint (preferences) of an expert.

In this case, a specific alternative (green professional group or green specialties), on the one hand, is characterized by the relation of the criteria with the specified alternative, i.e., by the assessment of the green alternative for all criteria, on the other hand, by the relation of preference with this alternative for each of the criteria. This means that a fuzzy set can be defined for m criteria $K = \{k_1, k_2, \ldots, k_m\} = \{k_j, j = \overline{1,m}\}$ chosen for the assessment of the green alternatives.

$K = \{\mu_k(x_1)/x_1, \mu_k(x_2)/x_2, \ldots, \mu_k(x_n)/x_n\}$, where the membership function $\mu_k(x_i) \in [0,1]$ is the assessment of the alternative x_i for the criterion K, which characterizes the degree of satisfaction of the alternative x_i with the concept determined by the green criterion K.

The degree of satisfaction of the set of alternatives X with the green criteria $K = \{k_j, j = \overline{1,m}\}$ is determined by the set of membership functions $\mu_{k_j}(x_i): X \times K \to [0,1]$, $j = \overline{1,m}$, where $\mu_{k_j}(x_i)$ expresses the degree of satisfaction of the alternative x_i to the green criterion k_j. The best alternative, in this case, is that which satisfies all green criterion, i.e., both k_1 and $k_2, \ldots, k_m$, i.e. $\Omega = k_1 \cap k_2 \cap \ldots \cap k_m$.

Then the rule for choosing the best (non-dominated) alternative can be written as the intersection of the corresponding fuzzy sets and reduced to a multicriteria problem of fuzzy mathematical programming, for the solution of which the generalized Bellman-Zadeh approach is applied [33, 34].

Variant B. The method for fuzzy multi-criteria group decision on the choice of the most priority green professional groups and specialties.

Let $X = \{x_1, x_2, \ldots, x_n\} = \{x_i, i = \overline{1,n}\}$ be a set of alternatives, out of which it is necessary to choose the best one by the degree of greenness. $K = \{k_1, k_2, \ldots, k_m\} = \{k_j, j = \overline{1,m}\}$ is a set of criteria, features or indicators characterizing the greenness of alternatives.

The set of acceptable alternatives is represented by a two-dimensional matrix, in which the degree of satisfaction of the alternative x_i with the green criterion k_j is determined by the membership function $\varphi_{k_j}(x_i): X \times K \to [0, 1]$.

Set of experts G is formed by the decision maker (company manager), who is guided by his/her own opinion on the level of their competence in the field of greenness assessment. For each of the experts $g \in G$, a fuzzy preference relation is defined on the set of alternatives X, i.e., the membership function of the form $\psi: X \times X \times G \to [0,1]$. Certainly, in the process of multi-criteria assessment of alternatives, experts proceed from their own preference relations. The value $\psi(x_i, x_j, g)$

is interpreted as the degree of preference of the alternative x_j to the alternative x_i, through the prism of the preferences of the expert g and is determined as follows

$$\psi(x_i,x_j,g)=\begin{cases}1-\left[\varphi(x_j,g)-\varphi(x_i,g)\right], & \text{if } \varphi(x_j,g)\geq\varphi(x_i,g),\\ 1, & \text{if } \varphi(x_j,g)\leq\varphi(x_i,g),\end{cases} \tag{6.1}$$

where $\varphi(x_i, g) = \min\{\varphi_{k_j}(x_i,g), j=\overline{1,m}\}$.

Using the expression (6.1) of each expert, a matrix of fuzzy green preference relations of alternatives is determined.

On the other hand, the decision maker (DM) unequally evaluates the competence of experts invited by them to assess alternatives. This factor is represented by the coefficient of competence of experts: $\gamma(g) \to [0,1]$, taking into account the expression

$$v(g_1,g_2)=\begin{cases}1-\left[\gamma(g_2)-\gamma(g_1)\right], & \text{if } \gamma(g_2)\geq\gamma(g_1),\\ 1, & \text{if } \gamma(g_2)\leq\gamma(g_1),\end{cases} \tag{6.2}$$

from which v: $G \times G \to [0,1]$ is determined – fuzzy relation of expert competence. The value $v(g_1, g_2)$ is understood as the degree to which, in the opinion of the DM, the expert g_1 is more competent than the expert g_2.

Afterwards, the problem is reduced to a rational choice of alternatives from the set X, taking into account the information described above. According to [35] $\psi^{n.d.}(x_i, g)$ defined as a fuzzy subset of non-dominated alternatives, corresponding to a fuzzy preference relation $\psi(x_i, x_j, g)$ with fixed $g \in G$

$$\psi^{n.d.}(x_i,g)=1-\sup_{x_j\in X}\left[\psi(x_j,x_i,g)-\psi(x_i,x_j,g)\right]. \tag{6.3}$$

The alternatives that give the largest possible value of the membership function $\psi^{n.d.}(x_i, g)$ on the set X coincide with the individual solution of the g-th expert.

Further, the fuzzy relation $v(g_1, g_2)$ is generalized to the class of fuzzy subsets of the set G. The induced (generalized) fuzzy relation on the set X is defined as follows

$$\eta(x_i,x_j)=\sup_{g_1,\,g_2\in G}\min\left\{\psi^{n.d.}(x_i,g_1),\psi^{n.d.}(x_j,g_2),v(g_1,g_2)\right\}. \tag{6.4}$$

This fuzzy preference relation is the result of a "convolution" of a family of fuzzy relations $\psi(x_i, x_j, g)$ into a single resulting fuzzy preference relation, taking into account information about the competence of experts in a given subject area.

Induced preference relations on the set X make it possible to proceed to the problem of choosing alternatives with a single preference relation by defining the corresponding set of non-dominated alternatives

$$\tilde{\eta}^{n.d.}(x_i) = 1 - \sup_{x_j \in X} \left[\eta(x_j, x_i) - \eta(x_i, x_j) \right]. \tag{6.5}$$

Finally, from the expression

$$\eta^{n.d.}(x_i) = \min\left\{ \tilde{\eta}^{n.d.}(x_i), \eta(x_i, x_j) \right\} \tag{6.6}$$

the corrected fuzzy set of non-dominated alternatives is determined and an alternative is chosen that delivers the maximum of the $\eta^{n.d.}(x)$ function

$$\eta^{n.d.}(x) = \sup_{x_j \in X} \eta(x_i), \tag{6.7}$$

which is the most effective alternative. The selected alternative is the resulting group choice decision and coincides with one of the individual decisions.

Based on the approach proposed in [33], an empirical experiment is described for obtaining a regulated list of specialties for the ICT professional group and determining the most priority specialties.

6.3.2 Problem statement 2

In accordance with the concept of intelligent supply and demand management [30, 31], the labor market is viewed as an intellectual space in which its main subjects interact. These subjects represent the demand (employers) and supply (specialists in various fields).

In the context of green transition, green skills/competencies of specialists that integrate the personified intellectual potential of the latter, expressed by a set of professional (green) and personal competencies, are considered as a product in the labor market.

It is required to develop the tools for managing the coordination of supply and demand in the context of various professional groups, individual professions and specialties that are in demand in the green segment of the labor market most. Moreover, an effective balancing involves the development of approaches, models and methods for assessing supply and demand of skills in the green segment of the labor market and making the best management decisions (strategies and measures) to minimize the imbalance between supply and demand for green skills in various labor sections (according to the hierarchy in management, vocational qualification, competence, quantity, quality, etc.).

It is possible to assume that the demand in the labor market is defined by the set:

– $V=\{V_i\}, i=\overline{1,k}$, expressed in terms of the number of vacancies;

– $L=\{l_j\}, j=\overline{1,n}$ – a set of personal features (characteristics) required from a candidate to a particular green position (job, workplace);

– $C=\{c_f\}, f=\overline{1,m}$ – a set of green skills/competencies, which a candidate must have for a vacancy (specific or super-specific for a profession, transversal (universal), i.e., necessary for all professions);

– $U=\{u_\gamma\}, \gamma=\overline{1,p}$ – a set of conditions offered to the applicants to green vacant jobs.

The demand model $V=(L, C, U)$ can be described by three matrices $V_L=\left\|l_{ij}\right\|_{k,n}$, $V_C=\left\|c_{if}\right\|_{k,m}$ and $V_U=\left\|u_{i\gamma}\right\|_{k,p}$, where each $i=\overline{1,k}$ of the row (V_i) characterizes individual green vacancy in the green segment of the labor market; columns:

– l_j, where $j=\overline{1,n}$ displays a constantly expanding base of personal features, allowing to keep systematically developing green skills up to date;

– c_f, where $f=\overline{1,m}$ – a set of green skills/competencies that characterize the employer's skill requirements for a green workplace;

– u_γ, where $\gamma=\overline{1,p}$ conditions offered to the applicants to a specific green vacant job.

The matrix elements V_L (i.e., l_{ij}, where $i=\overline{1,k}$, $j=\overline{1,n}$), V_C (i.e., c_{if}, where $i=\overline{1,k}, f=\overline{1,m}$) and V_U (i.e., $u_{i\gamma}$, where $i=\overline{1,k}$, $\gamma=\overline{1,p}$) express the employer's requirements for the level of indicators l_j, c_f, u_{i_γ} characterizing the offered green vacancy V_i. Requirements for the level of possessing green skills by the applicants are described in the form of linguistic variables and their values. The latter correspond to verbal rating scales representing the intensity of the possession of greenness of indicators (for example, extremely high, high, medium, satisfactory, low) [32–36].

Accordingly, the degree of conformity of the vacancy V_i by the indicators l_{ij}, c_{if} and u_{kp} is defined as fuzzy sets with membership functions

$$\mu_{l_j}(V_i): V\times L\to[0,1],\ \mu_{c_f}(V_i): V\times C\to[0,1],\ \mu_{u_\gamma}(V_i): V\times U\to\left[0,1\right]. \tag{6.8}$$

It is possible to assume that the supply in the labor market is given as set of specialists $S=\{S_g\}, g=\overline{1,q}$ looking for work and applying to a particular green vacancy; $L=\{l_j\}, j=\overline{1,n}$ – a set of actual competencies characterizing the specialists; $C=\{c_f\}, f=\overline{1,m}$ – a set of actual competencies of each individual applicant to a green vacancy; $U=\{u_\gamma\}, \gamma=\overline{1,p}$ – a set of preferences of the specialist expressed as his/her requirements for the green vacancy.

The supply model $S = (L, C, U)$ is also given as three matrices: $S_L = \|l_{gj}\|_{q,n}$, $S_C = \|c_{gf}\|_{q,m}$ and $S_U = \|u_{g\gamma}\|_{q,p}$, where each row (S_g) $(g = \overline{1,q})$ characterizes individual candidates to proposed green vacancies in the job market; columns l_j, c_f, u_γ $(j = \overline{1,n}, f = \overline{1,m}, \gamma = \overline{1,p})$ represent the constantly expanding base of personal features, competencies and requirements of the specialist for a green vacancy.

The matrix elements S_L (i.e., l_{gj}, where $g = \overline{1,q}$, $j = \overline{1,n}$), S_C (i.e., c_{gf}, where $g = \overline{1,q}$, $f = \overline{1,m}$) and S_U (i.e., $u_{g\gamma}$, where $g = \overline{1,q}$, $\gamma = \overline{1,p}$) represent the level of a specialist's possession of individual green features that are specified by linguistic variables and their values.

The degree of compliance of a certain specialist S_g, $g = \overline{1,q}$ to the criteria l_j, c_f and u_γ is defined by the membership function

$$\mu_{l_{gj}}(S_g): S \times L \to [0,1],\ \mu_{c_{gf}}(S_g): S \times C \to [0,1],\ \mu_{u_{g\gamma}}(S_g): S \times U \to \left[0,1\right].$$

In fact, there are two sets of fuzzy situations describing the conditions of demand for green skills $\tilde{V}_i$ and supply $\tilde{S}_g$ in the green segment of the labor market:

$$\tilde{V}_i = \left\{\left\langle \mu_{l_{gj}}(V_i)\right\rangle, \left\langle \mu_{c_{gr}}(V_i)\right\rangle, \left\langle \mu_{u_{gz}}(V_i)\right\rangle\right\} = \left\{\mu_{V_i}(y)/y\right\}, \tag{6.9}$$

$$\tilde{S}_g = \left\{\left\langle \mu_{l_{gj}}(S_g)\right\rangle, \left\langle \mu_{c_{gr}}(S_g)\right\rangle, \left\langle \mu_{u_{gz}}(S_g)\right\rangle\right\} = \left\{\mu_{S_g}(y)/y\right\}. \tag{6.10}$$

Here, set $\tilde{V}_i = \{\mu_{V_i}(y)/y\}$, $i = \overline{1,k}$ represents fuzzy reference green situation, and set $\tilde{S}_q = \{\mu_{S_q}(y)/y\}$, $g = \overline{1,q}$ represents fuzzy real green situation.

Problem solution 2.

Multi-scenario approach to decisions on the correspondence of supply and green demand, i.e., offered skills for the specialists in the context of each individual professional group or specialty.

The procedure of fuzzy similarity situations is used to correspond the supply and demand for the identified priority professions or specialties. The procedure of pattern recognition involves the following steps:

– real situations are determined (search patterns of specialists) in accordance with the green indicator's values that characterize each applicant for the announced green vacancy (supply), real situations are determined (search patterns of specialists);

– reference situations are determined (search patterns of requests) in accordance with the green indicators' values that characterize the employer's requirements to the applicant for the vacancy (demand);

– degree of green similarity of the reference situation to each real situation is calculated in accordance with the chosen measure of assessment of similarity between two fuzzy situations;

– real situation is revealed, which has the greatest green proximity rate with the reference situation. In other words, a decision is made on the green correspondence of supply and demand to the requirements of the employer (decision-maker (DM)).

The work [37] reviews various measures to determine the proximity rate between two fuzzy situations, involving single-stage or multistage measurement procedures. The case study uses the degree fuzzy inclusion of a situation $\tilde{S}_g$ in a fuzzy situation $\tilde{V}_i$, and the degree of fuzzy equality of $\tilde{S}_g$ and $\tilde{V}_i$ as the measure of identifying the proximity rate of demand (fuzzy reference situations) and supply (fuzzy real situations).

The degree of fuzzy inclusion of a fuzzy situation $\tilde{S}_g$ in a situation $\tilde{V}_i$ is determined based on the following formula

$$\mu(\tilde{S}_g,\tilde{V}_i)=\&\mu(\mu_{S_g}(y),\mu_{V_i}(y))=\underset{y\in Y}{\&}(\max(1-\mu_{S_g}(y),\mu_{V_i}(y)))=$$
$$=\min(\max(1-\mu_{S_g}(y),\mu_{V_i}(y))). \qquad (6.11)$$

The situation $\tilde{S}_g$ is considered fuzzy inclusive in the situation $\tilde{V}_i$ ($\tilde{S}_g\subseteq\tilde{V}_i$), if the degree of inclusion of $\tilde{S}_g$ in a situation $\tilde{V}_i$ is not less than the inclusion threshold ($\psi\in[0.6, 1]$ determined by the management conditions), i.e. $\mu(\tilde{S}_g,\tilde{V}_i)\geq\psi$.

The degree of fuzzy equality $\tilde{V}_i$ and $\tilde{S}_g$ is defined by the following formula

$$\mu(\tilde{S}_g,\tilde{V}_i)=\vee(\tilde{S}_g,\tilde{V}_i)\&\vee(\tilde{V}_i,\tilde{S}_g)=\&\mu(\mu_{S_g}(y),\mu_{V_i}(y)=$$
$$=\min_{y\in Y}\left[\min(\max(1-\mu_{S_g}(y),\mu_{V_i}(y)),\max(1-\mu_{V_i}(y),\mu_{S_g}(y)))\right]. \qquad (6.12)$$

Situations $\tilde{S}_g$ and $\tilde{V}_i$ are considered to be fuzzy equal $\tilde{S}_g\approx\tilde{V}_i$, if $\mu(\tilde{S}_g,\tilde{V}_i)\geq\psi$, $\psi\in\left[0.7,1\right]$, where ψ is a certain threshold of fuzzy equality of situations.

After the completion of the process of recognizing the most acceptable green similarity of the pair of "fuzzy reference pattern – fuzzy real pattern" in terms of proximity rate, there may be several possible scenarios among the sets of real search patterns of specialists (supply) and reference green search patterns of the query (demand) [30, 31]:

Scenario 1. One vacancy (employer's request) – one applicant (specialist), i.e., "one fuzzy reference pattern – one fuzzy real pattern".

In this case, if the degree of fuzzy similarity of the two situations (i.e., $\tilde{S}_g$ and $\tilde{V}_i$) is not less than the threshold accepted by the employer (for example, $\psi\in[0.6, 1]$), then a hiring decision is made.

A flowchart of the decision-making process on the correspondence between supply and demand for Scenario 1 is shown in **Fig. 6.1**.

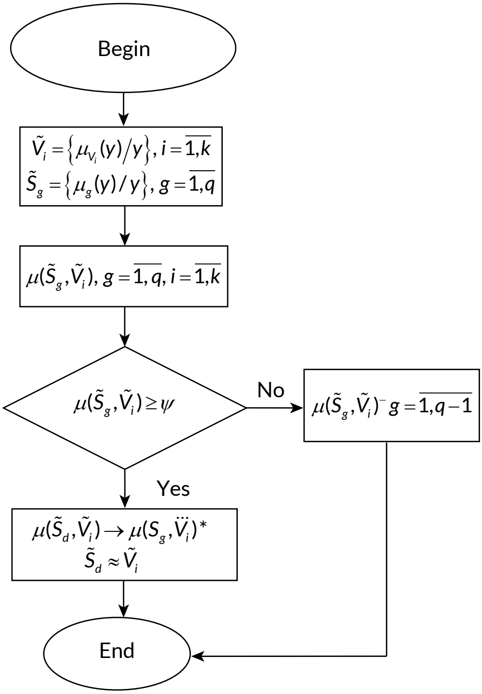

Fig. 6.1 Flowchart of the decision-making process on the correspondence between supply and demand for Scenario 1

Scenario 2. A few applicants (specialists) are eligible to the employer in accordance with the accepted measure of the similarity of the two fuzzy situations, i.e. "one fuzzy reference pattern – many fuzzy real patterns". That is, in this case, there is a set $\{\mu(\tilde{S}_g, \tilde{V}_i), g = \overline{1,\eta}, \eta \leq q)\}$, the elements of which satisfy the following condition: $(\mu(\tilde{S}_g, \tilde{V}_i), g = \overline{1,\eta}) \geq \psi$.

In this case, the employer, acting as an expert (DM), can be offered various methods for decision making:

Scenario 2.1. The task of making decisions on the correspondence of supply and demand is reduced to the comparison of the proximity of the reference and real situations in terms of the degree of possession of the criteria that characterize a certain professional group or specialty. The best alternative (applicant) is that, who has the greatest proximity rate by the coincidence of criteria and the degree of their possession.

In this case, the sought is the real situation, which provides the maximum value in terms of the degree of reference similarity, i.e.

$$\mu(\tilde{S}_d,\tilde{V}_i)^* = \max(\mu(\tilde{S}_g,\tilde{V}_i),\, g=\overline{1,\eta},\, \tilde{S}_d \in \left\{\tilde{S}_g,\, g=\overline{1,\eta}\right\}. \qquad (6.13)$$

Scenario 2.2. The task of decision making is reduced to a multicriteria choice of the best solution (alternative), taking into account the relative importance of the criteria characterizing the specialists [38].

In this case, the task of decision-making is implemented in accordance with the following steps:

Step 1. The coefficients of relative importance of the indicators shall be defined [38, 39].

Assume that:

– $\omega_j,\, j=\overline{1,n}$ – coefficients of relative importance of indicators characterizing the criterion *L*;

– $\omega_f, f=\overline{1,m}$ – coefficients of relative importance of indicators characterizing the criterion *C*;

– $\omega_\gamma, \gamma=\overline{1,p}$ – coefficients of relative importance of indicators characterizing the criterion *U*.

Step 2. Based on the aggregation of the degrees of possession of individual indicators (i.e. $\mu_{l_{gj}}(\tilde{S}_g,\tilde{V}_i),\, j=\overline{1,n},\, \mu_{c_{gf}}(\tilde{S}_g,\tilde{V}_i), f=\overline{1,m},\, \mu_{u_{g\gamma}}(\tilde{S}_g,\tilde{V}_i),\, \gamma=\overline{1,p}$), the specific specialists $S_g, g=\overline{1,\eta}$ determine the degree of similarity of fuzzy real situations (supply) with the reference situation (demand) by the following step [40]:

Step 2.1. Based on the "convolution" $\mu_{l_{gj}}(\tilde{S}_g,\tilde{V}_i),\, j=\overline{1,n}$, the degree of similarity between real and reference situations is determined by personal characteristics (*L*)

$$\mu_L(\tilde{S}_g,\tilde{V}_i)=\sum_{j=1}^{n} w_j \mu_{l_j}(\tilde{S}_g,\tilde{V}_i).$$

Step 2.2. Based on the "convolution" $\mu_{c_{gf}}(\tilde{S}_g,\tilde{V}_i), f=\overline{1,m}$ – the degree of similarity between real and reference situations is determined in terms of competences (*C*)

$$\mu_C(\tilde{S}_g,\tilde{V}_i)=\sum_{f=1}^{m} w_f \mu_{c_f}(\tilde{S}_g,\tilde{V}_i).$$

Step 2.3. Based on the "convolution" $\mu_{u_{g\gamma}}(\tilde{S}_g, \tilde{V}_i), \gamma = \overline{1, p}$ – the degree of similarity between real and reference situations is determined through the prism of the requirements for the vacancy *U*

$$\mu_U(\tilde{S}_g, \tilde{V}_i) = \sum_{\gamma=1}^{p} w_\gamma \mu_{u_\gamma}(\tilde{S}_g, \tilde{V}_i).$$

Step 2.4. Based on the obtained results and coefficients of relative importance *L*, *C* and *U* – w_L, w_C, w_U, the similarity rates of the real situation with the reference ones are determined

$$\mu_w(\tilde{S}_g, \tilde{V}_i) = \omega_L \cdot \mu_L(\tilde{S}_g, \tilde{V}_i) + \omega_C \cdot \mu_C(\tilde{S}_g, \tilde{V}_i) + \omega_U \cdot \mu_U(\tilde{S}_g, \tilde{V}_i).$$

Step 3. Fuzzy real situation with the maximum value is chosen

$$\varphi(\tilde{S}_g, \tilde{V}_i)^* = \max\left\{\varphi(\tilde{S}_g, \tilde{V}_i), g = \overline{1, \eta}\right\}.$$

The selected fuzzy real situation corresponds to the search pattern of the applicant, who has the greatest degree of similarity with the reference pattern of the vacancy, and is accepted as the best solution.

Scenario 2.3. The list of evaluation criteria is extended, and the input situations are re-defined (re-examined) and the recognition procedures are repeated.

A flowchart of the decision-making process on the correspondence between supply and demand for Scenario 2 is presented in **Fig. 6.2**.

According to this proposed algorithm, empirical experiments are implemented to solve the problem of hiring a programmer-engineer in [31] and a pediatrician in [38].

Scenario 3. "Many fuzzy reference patterns – one fuzzy real pattern". In this case, there is an inverse task: a subset of fuzzy reference situations (alternatives) is presented, which is represented, out of which a specialist has to make a choice according to his/her preferences. In this case, a professional is DM. According to the preferences of the latter, there can be the variants of Scenario 3 listed below.

Scenario 3.1. The proximity rate of the claims of the specialist with the green criteria characterizing the employment in the certain green specialty shall be compared, and decision shall be made on the greatest coincidence of the degree of possession of the criteria.

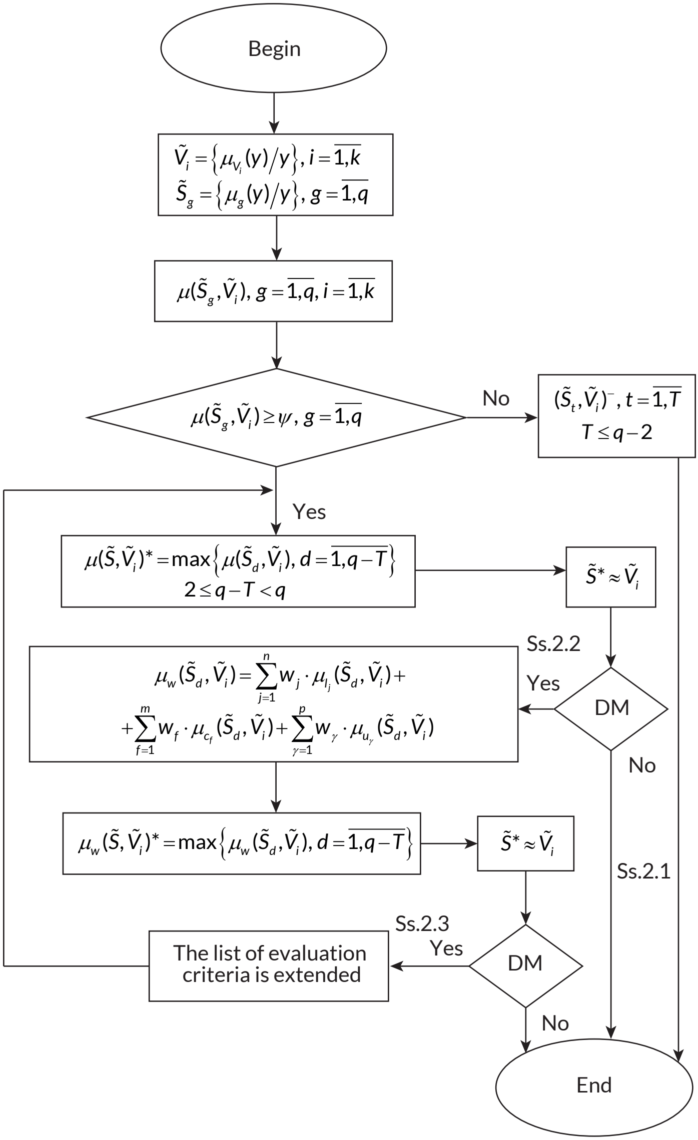

Fig. 6.2 Flowchart of the decision-making process on the correspondence between supply and demand for Scenario 2

The task of decision-making is reduced to the comparison of the similarities between real and standard situations in terms of the proximity rate of the conditions offered by employers and the claims of the applicant. The best vacancy has the greatest degree of similarity by the coincidence of green criteria that characterize the conditions offered by employers, and the applicant's claims. Thus, it is possible to assume that:

$$\mu(\tilde{S}_d, \tilde{V}_z) = \max\left\{\mu(\tilde{S}_g, \tilde{V}_z), z = \overline{1,f}, g = \overline{1,q}\right\}, V_z \in \left\{V_i, i = \overline{1,k}\right\},$$
$$S_d \in \left\{S_g, g = \overline{1,q}\right\}, 2 \le f < k.$$

In this case, the pair with the maximum value of the degree of fuzzy similarity situations is defined by the following formula

$$\mu(\tilde{S}_d, \tilde{V}_z)^* = \max\left\{\mu_U(\tilde{S}_d, \tilde{V}_z), z = \overline{1,f}\right\}.$$

The fuzzy reference green situation is accepted as the best solution, which is corresponding to the green search pattern of the vacancy that has the greatest degree of green similarity with the applicant's real pattern.

Scenario 3.2. The task of decision-making shall be reduced to the multi-objective task of choosing the best solution, taking into account the relative importance of green criteria characterizing the preferences of a specialist (*U*), expressed in the form of his/her requirements for a specialized green vacancy.

In this case, if $\omega_\gamma, \gamma = \overline{1,p}$ is the coefficients of the relative importance of green indicators characterizing the criterion *U*, then a fuzzy reference situation that has the greatest degree of similarity (greenness) with the applicant's real pattern is determined based on the following formula

$$\mu(\tilde{S}_d, \tilde{V}_z)^* = \max\left\{\sum_{\gamma=1}^{p} w_\gamma \cdot \mu_{u_\gamma}(\tilde{S}_d, \tilde{V}_z), z = \overline{1,f}\right\}.$$

The selected pair is taken as the best solution.

Scenario 3.3. The list of green criteria for the workplace assessment shall be expanded, furthermore, the input situations shall be re-defined (re-examined) and the recognition procedure shall be repeated using formulas (6.11) or (6.12).

A flowchart of the decision-making process on the correspondence between supply and demand for Scenario 3 is presented in **Fig. 6.3**.

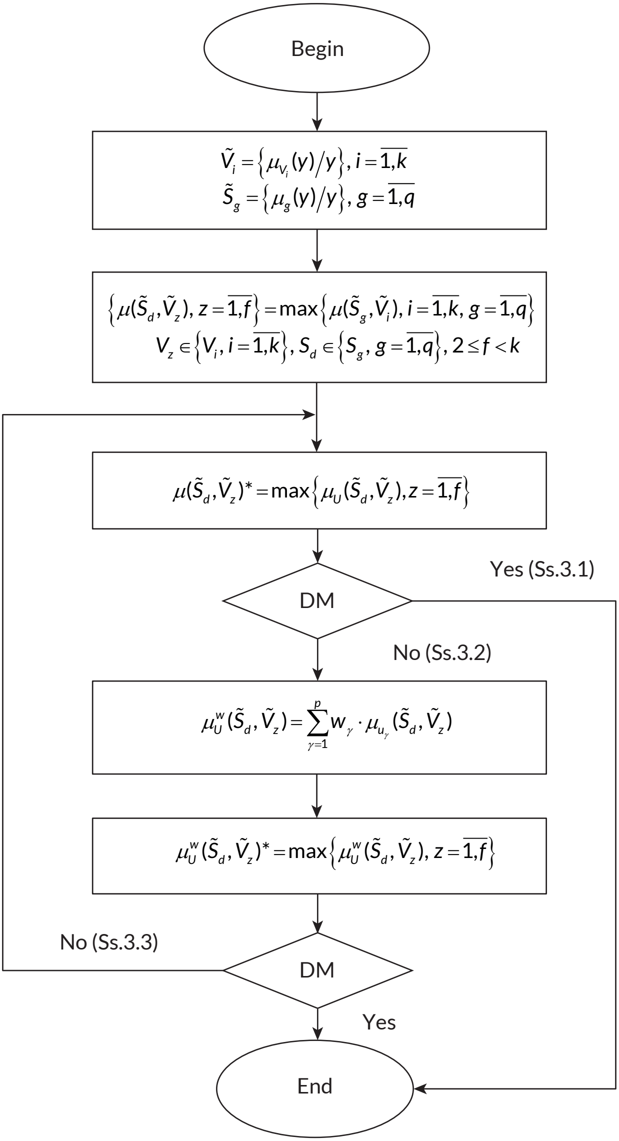

Fig. 6.3 Flowchart of the decision-making process on the correspondence between supply and demand for Scenario 3

6.4 Example of implementation of the methodology for hiring a specialist for a green vacancy

Let's consider the application of the proposed methodology using the example of solving the problem of real selection and hiring for a specific green vacancy of an IT engineer for land resources management.

Let a vacancy of an IT engineer for land resources management be – V, for which four IT specialists are applying – S_1, S_2, S_3, S_4. Let's consider the stages of implementing the problem of making decisions on selecting candidates for this vacancy from four applicants, using the degree of their fuzzy equality to determine the proximity of two situations:

Stage 1. Definition of a reference situational model of a vacancy, which comes down to the selection of indicators characterizing the employers' requirements for the vacancy. To form a system of indicators characterizing vacancies, information on hiring an IT engineer for land resources management from recruiting sites is used [8, 41].

Indicators system for vacancy V:

Personal qualities (L):

– communication skills (l_1);

– systemic thinking (l_2);

– work on yourself, desire to develop (l_3).

Competencies, knowledge and skills (C):

– level of professional knowledge in the specialty "IT engineer for land resource management" in accordance with the university diploma (c_1);

– knowledge of the development of GIS platforms to maintain a land registry and accounting, monitor (c_2);

– knowledge in the field of geodesy, remote sensing, geographic information systems (c_3);

– practical skills in using the capabilities of geographic information systems for land resource management (c_4).

Requirements and conditions of the vacancy (U):

– minimum 1 year of practical work (u_1);

– certificate in the course of green transition in land resource management (u_2);

– fluency in the national and English languages (u_3).

Stage 2. To determine the degree of possession of individual indicators by applicants, it is necessary to formalize the indicators, i.e., it is necessary to operate with linguistic variables and their values [32]. **Table 6.1** demonstrates 5-level values of the linguistic variable "communicability" and the corresponding ranges of change of fuzzy degrees of possession of this indicator in the interval [0, 1].

Table 6.1 Fuzzification of the indicator "communicability"

Gradations of the indicator "communicability"	Linguistic assessment	The range of change of fuzzy degrees in the interval [0, 1]
Very sociable	Excellent	[0.95–1]
Communicative	Good	[0.8–0.94]
Weakly sociable	Normal	[0.5–0.79]
Unsociable	Satisfactory	[0.26–0.49]
Withdrawn	Bad	[0–0.25]

Stage 3. Linguistic assessments of candidates for vacancy *V* are given in **Table 6.2**.

Table 6.2 Linguistic assessments of candidates for vacancy *V*

Indicators characterizing the vacancy *V*	Applicants			
	S_1	S_2	S_3	S_4
Personal qualities (*L*):				
Communication skills (l_1)	Excellent	Good	Good	Normal
Systemic thinking (l_2)	Good	Good	Good	Good
Work on yourself, desire to develop (l_3)	Good	Good	Good	Good
Competencies, knowledge and skills (*C*):				
Level of professional knowledge in the specialty "IT engineer for land resource management" in accordance with the university diploma (c_1)	Excellent	Excellent	Good	Excellent
Knowledge of the development of GIS platforms to maintain a land registry and accounting, monitor (c_2)	Good	Good	Normal	Good
Knowledge in the field of geodesy, remote sensing, geographic information systems (c_3)	Excellent	Excellent	Good	Good
Practical skills in using the capabilities of geographic information systems for land resource management (c_4)	Good	Excellent	Good	Normal
Requirements and conditions of the vacancy (*U*):				
Minimum 1 year of practical work (u_1)	Good	Good	Excellent	Excellent
Certificate in the course of green transition in land resource management (u_2)	Good	Good	Excellent	Excellent
Fluency in the national and English languages (u_3)	Excellent	Excellent	Good	Good

Table 6.3 presents the degrees of possession of the candidates with the indicators characterizing the vacancy V.

Table 6.3 Degrees of possession of the candidates with the indicators (membership function values) characterizing the vacancy V

Indicators characterizing the vacancy V	Applicants			
	S_1	S_2	S_3	S_4
Personal qualities (L):				
Communication skills (l_1)	0.97	0.88	0.82	0.65
Systemic thinking (l_2)	0.89	0.85	0.89	0.82
Work on yourself, desire to develop (l_3)	0.87	0.80	0.70	0.90
Competencies, knowledge and skills (C):				
Level of professional knowledge in the specialty "IT engineer for land resource management" in accordance with the university diploma (c_1)	0.98	0.95	0.82	0.97
Knowledge of the development of GIS platforms to maintain a land registry and accounting, monitor (c_2)	0.90	0.84	0.75	0.88
Knowledge in the field of geodesy, remote sensing, geographic information systems (c_3)	0.95	0.97	0.80	0.82
Practical skills in using the capabilities of geographic information systems for land resource management (c_4)	0.82	0.95	0.90	0.70
Requirements and conditions of the vacancy (U):				
Minimum 1 year of practical work (u_1)	0.90	0.94	0.97	0.96
Certificate in the course of green transition in land resource management (u_2)	0.82	0.82	0.97	0.95
Fluency in the national and English languages (u_3)	0.95	0.95	0.80	0.88

Based on **Table 6.3** and formula (6.10), fuzzy real situations are formed, i.e. fuzzy images of applicants for vacancy V:

$$\tilde{S}_1 = \begin{Bmatrix} 0.97/l_1; 0.89/l_2; 0.87/l_3; 0.98/c_1; 0.9/c_2; 0.95/c_3; \\ 0.82/c_4; 0.9/u_1; 0.82/u_2; 0.95/u_3 \end{Bmatrix},$$

$$\tilde{S}_2 = \begin{Bmatrix} 0.88/l_1; 0.85/l_2; 0.8/l_3; 0.95/c_1; 0.84/c_2; 0.97/c_3; \\ 0.95/c_4; 0.94/u_1; 0.82/u_2; 0.95/u_3 \end{Bmatrix},$$

$$\tilde{S}_3 = \begin{Bmatrix} 0.82/l_1; 0.89/l_2; 0.7/l_3; 0.82/c_1; 0.75/c_2; 0.8/c_3; \\ 0.9/c_4; 0.97/u_1; 0.97/u_2; 0.8/u_3 \end{Bmatrix},$$

$$\tilde{S}_4 = \begin{Bmatrix} 0.65/l_1; 0.82/l_2; 0.9/l_3; 0.97/c_1; 0.88/c_2; 0.82/c_3; \\ 0.7/c_4; 0.96/u_1; 0.95/u_2; 0.88/u_3 \end{Bmatrix}.$$

The reference fuzzy image of vacancy V is described as follows

$$\tilde{V} = \{1/l_1; 1/l_2; 1/l_3; 1/c_1; 1/c_2; 1/c_3; 1/c_4; 1/u_1; 1/u_2; 1/u_3\}.$$

Stage 4. Using formula (6.12), the degrees of fuzzy equality of the reference $\tilde{V}$ and real situations $\tilde{S}_1, \tilde{S}_2, \tilde{S}_3, \tilde{S}_4$ are determined:

– by personal indicators (L):

$$\mu_L(\tilde{V},\tilde{S}_1)=0.87;\ \mu_L(\tilde{V},\tilde{S}_2)=0.8;\ \mu_L(\tilde{V},\tilde{S}_3)=0.70;\ \mu_L(\tilde{V},\tilde{S}_4)=0.65;$$

– in terms of competencies (C):

$$\mu_C(\tilde{V},\tilde{S}_1)=0.82;\ \mu_C(\tilde{V},\tilde{S}_2)=0.84;\ \mu_C(\tilde{V},\tilde{S}_3)=0.75;\ \mu_C(\tilde{V},\tilde{S}_4)=0.7;$$

– through the prism of vacancy requirements (U):

$$\mu_U(\tilde{V},\tilde{S}_1)=0.82;\ \mu_U(\tilde{V},\tilde{S}_2)=0.82;\ \mu_U(\tilde{V},\tilde{S}_3)=0.8;\ \mu_U(\tilde{V},\tilde{S}_4)=0.88.$$

Based on the results obtained, the degree of fuzzy equality $\mu(\tilde{V},\tilde{S}_g)$, $g=\overline{1,4}$ of the reference image of vacancy V and search images of real situations $\mu(\tilde{V},\tilde{S}_g)$, $g=\overline{1,4}$ is determined:

$$\mu(\tilde{V},\tilde{S}_1)=\mu_L(\tilde{V},\tilde{S}_1)\&\mu_C(\tilde{V},\tilde{S}_1)\&\mu_U(\tilde{V},\tilde{S}_1)=0.87\&0.82\&0.82=0.82,$$

$$\mu(\tilde{V},\tilde{S}_2)=\mu_L(\tilde{V},\tilde{S}_2)\&\mu_C(\tilde{V},\tilde{S}_2)\&\mu_U(\tilde{V},\tilde{S}_2)=0.8\&0.84\&0.82=0.8,$$

$$\mu(\tilde{V},\tilde{S}_3)=\mu_L(\tilde{V},\tilde{S}_3)\&\mu_C(\tilde{V},\tilde{S}_3)\&\mu_U(\tilde{V},\tilde{S}_3)=0.7\&0.75\&0.8=0.7,$$

$$\mu(\tilde{V},\tilde{S}_4)=\mu_L(\tilde{V},\tilde{S}_4)\&\mu_C(\tilde{V},\tilde{S}_4)\&\mu_U(\tilde{V},\tilde{S}_4)=0.65\&0.7\&0.88=0.65.$$

Stage 5. The results obtained correspond to Scenario 2.1, i.e., in terms of the degree of fuzzy equality of the reference situation $\tilde{V}$ and real situations $\tilde{S}_1, \tilde{S}_2, \tilde{S}_3, \tilde{S}_4$, the closest is the real situation $\tilde{S}_1$ with the value $\mu(\tilde{V},\tilde{S}_1)=0.82$.

Thus, the real search image of the applicant S_1 has the maximum degree of proximity to the reference search image of the vacancy V and is the best solution.

6.5 Discussion of research results

The green transition, its demands for professional groups and specialties cause some changes in the structure of professions, the formation of the green segment of the labor market, the creation of workplaces requiring different degrees of greenness, the diverse greenness rates of the skills offered for these vacancies, and the creation of numerous uncertain green demand-supply relationships. In order to eliminate this uncertainty and reveal the real situation, this article proposed a comprehensive approach to intelligent management of human resources in the green segment of the labor market.

The new approach proposed in this article was based on:

1) fuzzy multicriteria assessment and ranking of alternatives for determining priority green professional groups and specialties;

2) decision-making methods in the context of priority specialties, allowing to take into account the entire spectrum of real and potential relationships between supply and demand in the labor market. The decision-making methods are based on fuzzy situational analysis and pattern recognition. The developed methods and algorithms for multi-scenario assessment of supply and demand, based on fuzzy situational analysis and pattern recognition, make it possible to make decisions on the degree of green compliance of supply and demand in the context of specific green professions or specialties from the standpoint of satisfying both the employer's requirements and the claims of specialists.

6.6 Conclusion

1. A new comprehensive approach to intelligent human resource management in the green segment of the labor market was proposed, allowing for the entire spectrum of real and potential relationships between green demand and green supply.

2. Multi-criteria individual and collective decision-making methods were developed referring to fuzzy relational model to determine the priority of green occupational groups and specialties in a dynamically changing labor market in green environment.

3. The problem statement of decision-making on the coordination of supply and demand for specialists in the context of a specific priority green profession or

specialty was presented, which was reduced to fuzzy pattern recognition. Pattern recognition was based on fuzzy situational analysis and determination of the green proximity rate of fuzzy situations. The degree of their fuzzy inclusion and fuzzy equality were used as the measures for assessing the proximity rate of two fuzzy situations.

4. Possible scenarios of the relationship between supply and demand were proposed, for each of which appropriate methods and algorithms for making decisions on the green compliance of supply and demand in the context of green professions and specialties most in demand in the labor market were developed.

5. The task can be developed by expanding the set of possible scenarios for matching supply and demand and developing appropriate decision-making methods.

6. A step-by-step implementation of the methodology for multi-scenario supply and demand management was implemented using the example of solving the problem of real selection and hiring for a specific green vacancy.

7. The proposed methodology for assessing green skills in the labor market ecologization environment is invariant for human resource management in various segments of the green economy, provided that it was adapted to the characteristics of the segment under study.

References

1. Ecosystem Definition. Available at: https://www.biologyonline.com/dictionary/ecosystem
2. The Paris Agreement. Available at: https://unfccc.int/process-and-meetings/the-parisagreement/the-paris-agreement
3. Skills in transition. The way to 2035 (2023). Cedefop. Available at: https://www.cedefop.europa.eu/files/4213_en.pdf
4. Employment and Social Developments in Europe (ESDE). Report 2023 (2023). European Commission. Available at: https://op.europa.eu/webpub/empl/esde-2023/executive-summary.html
5. Baydyk, T., Mammadova, M., Velasco, G., Kussul, E. (2024). Improvement of solar concentrator structure. Eastern-European Journal of Enterprise Technologies, 2 (8 (128)), 38–45. https://doi.org/10.15587/1729-4061.2024.301538
6. Kussul, E., Baydyk, T., Mammadova, M., Rodriguez, J. L. (2022). Development of a model of combination of solar concentrators and agricultural fields. Eastern-European Journal of Enterprise Technologies, 6 (8 (120)), 16–25. https://doi.org/10.15587/1729-4061.2022.269106

7. Renewable Energy and Jobs – Annual Review 2023. IRENA (2023). Geneva: Abu Dhabi and International Labour Organization. Available at: https://www.irena.org/Publications/2023/Sep/Renewable-energy-and-jobs-Annual-review-2023
8. Global Green Skills Report 2024 (2024). Linkedin. Available at: https://elettrico-magazine.it/wp-content/uploads/2024/12/Global-Green-Skills-Report-2024_compressed.pdf
9. World employment and social outlook: Greening with Jobs (2018). Geneva: International Labour Organization, X, 189. Available at: https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_628654.pdf
10. Skills for a green economy. A report on the evidence (2011). HM Government, 34. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/32373/11-1315-skills-for-a-green-economy.pdf
11. Mammadova, M. G., Jabrayilova, Z. G. (2024). Identify the degree of greenness of the proposed skills with the requirements of green jobs based on fuzzy logic. Technology transfer: fundamental principles and innovative technical, 27–30. https://doi.org/10.21303/2585-6847.2024.003575
12. Monica, C. (2023). Green jobs, green economy, just transition and related concepts: A review of definitions developed through intergovernmental processes and international organizations. International Labor Organization, 48. Available at: https://www.ilo.org/sites/default/files/wcmsp5/groups/public/%40ed_emp/%40emp_ent/documents/publication/wcms_883704.pdf
13. Dierdorff, E. C., Norton, J. J., Drewes, D. W., Kroustalis, C. M., Rivkin, D., Lewis, P. (2015). Greening of the World of Work: Implications for O*NET ® -SOC and New and Emerging Occupations. Available at: https://www.onetcenter.org/reports/Green.html
14. Green skills and environmental awareness in vocational education and training (2012). CEDEFOP. Luxembourg: Publications Office of the European Union. Available at: https://www.cedefop.europa.eu/files/5524_en.pdf
15. About ESCO. Available at: https://esco.ec.europa.eu/en/about-esco
16. Francesca, R. (2024). The future of work in the green transition. Available at: https://www.etf.europa.eu/en/green2024-futureofskills
17. Larsen, C., Kipper, J., Porep, D., Walter, A., Kampe, C., Höhne, M., Kleine-Rueschkamp, L. (Eds.) (2023). Pathways of Greening Labour Markets. European Training Foundation. https://doi.org/10.5771/9783957104236
18. Assessing and Anticipating Skills for the Green Transition: Unlocking Talent for a Sustainable Future, Getting Skills Right (2023). Paris: OECD Publishing. https://doi.org/10.1787/28fa0bb5-en

19. Job Creation and Local Economic Development 2023: Bridging the Great Green Divide (2023). Paris: OECD Publishing. https://doi.org/10.1787/21db61c1-en
20. Keese, M., Marcolin, L. (2023). Labour and social policies for the green transition: A conceptual framework. OECD Social, Employment and Migration Working Papers, No. 295. Paris: OECD Publishing. https://doi.org/10.1787/028ffbeb-en
21. Rutzer, C., Niggli, M., Weder, R. (2020). Estimating the green potential of occupations: a new approach applied to the U.S. labor market. Working papers 2020/03. Available at: https://ideas.repec.org/p/bsl/wpaper/2020-03.html
22. Bowen, A., Kuralbayeva, K., Tipoe, E. L. (2018). Characterising green employment: The impacts of ‘greening' on workforce composition. Energy Economics, 72, 263–275. https://doi.org/10.1016/j.eneco.2018.03.015
23. Vona, F., Marin, G., Consoli, D., Popp, D. (2018). Environmental regulation and green skills: An empirical exploration. Journal of the Association of Environmental and Resource Economists, 5 (4), 713–753. Available at: https://sciencespo.hal.science/hal-03471569v1
24. Consoli, D., Marin, G., Marzucchi, A., Vona, F. (2016). Do green jobs differ from non-green jobs in terms of skills and human capital? Research Policy, 45 (5), 1046–1060. https://doi.org/10.1016/j.respol.2016.02.007
25. Kwauk, C. T., Casey, O. M. (2022). A green skills framework for climate action, gender empowerment, and climate justice. Development Policy Review, 40 (S2). https://doi.org/10.1111/dpr.12624
26. Vandeplas, A., Vanyolos, I., Vigani, M., Vogel, L. (2022). The Possible Implications of the Green Transition for the EU Labour Market. https://doi.org/10.2765/583043
27. Connolly, K., Allan, G. J., McIntyre, S. G. (2016). The evolution of green jobs in Scotland: A hybrid approach. Energy Policy, 88, 355–360. https://doi.org/10.1016/j.enpol.2015.10.044
28. Sulich, A., Kozar, L. J. (2024). Green competences: A review and future research in the context of green human resource management. Economics and Environment, 89 (2), 713. https://doi.org/10.34659/eis.2024.89.2.713
29. Simon, H. A. (1973). The structure of ill structured problems. Artificial Intelligence, 4 (3-4), 181–201. https://doi.org/10.1016/0004-3702(73)90011-8
30. Mammadova, M. H., Jabrayilova, Z. G. (2019). Methods Managing for Matching of Supply and Demand on the IT Specialists. Automatic Control and Computer Sciences, 53 (2), 148–158. https://doi.org/10.3103/s0146411619020044
31. Mammadova, M. H., Jabrayilova, Z. G. (2020). Application of Fuzzy Pattern Recognition in the Recruitment of IT Specialists. Studies in Fuzziness and Soft Computing. Cham: Springer, 9–22. https://doi.org/10.1007/978-3-030-47124-8_2

32. Zadeh, L. A. (1975). The concept of a linguistic variable and its application to approximate reasoning – II. Information Sciences, 8 (4), 301–357. https://doi.org/10.1016/0020-0255(75)90046-8
33. Mammadova, M. (2019). Methods for fuzzy demand assessment for it specialties. EUREKA: Physics and Engineering, 4, 23–33. https://doi.org/10.21303/2461-4262.2019.00939
34. Bellman, R., Zadeh, L. A. (1970). Decision-making in fuzzy environment. Management Science, 17 (4), 141–164. Available at: https://www.jstor.org/stable/2629367
35. Orlovsky, S. A. (1978). Decision-making with a fuzzy preference relation. Fuzzy Sets and Systems, 1 (3), 155–167. https://doi.org/10.1016/0165-0114(78)90001-5
36. Moshkovich, H. M., Mechitov, A. I. (2013). Verbal Decision Analysis: Foundations and Trends. Advances in Decision Sciences, 2013, 1–9. https://doi.org/10.1155/2013/697072
37. D'Aniello, G. (2023). Fuzzy logic for situation awareness: a systematic review. Journal of Ambient Intelligence and Humanized Computing, 14, 4419–4438. https://doi.org/10.1007/s12652-023-04560-6
38. Mammadova, M., Jabrayilova, Z. (2017). Development of a multi-scenario approach to intelligent management of human resources in the field of medicine. Eastern-European Journal of Enterprise Technologies, 2 (3 (86)), 4–14. https://doi.org/10.15587/1729-4061.2017.95216
39. Saaty, T. L., Vargas, L. G. (2013). The Analytic Network Process. Decision Making with the Analytic Network Process. Decision Making with the Analytic Network Process. International Series in Operations Research & Management Science, vol. 195. Boston: Springer, 1–40. https://doi.org/10.1007/978-1-4614-7279-7_1
40. Abbasov, A. M., Mamedova, M. H., Orujov, G. H., Aliev, H. B. (2001). Synthesis of the methods of subjective knowledge representations in problems of fuzzy pattern recognition. Mechatronics, 11 (4), 439–449. https://doi.org/10.1016/s0957-4158(00)00027-1
41. IT-inzhener po upravleniiu zemelnymi resursami. Atlas novykh professii i kompetentcii v Respublike Kazakhstan. Available at: https://atlasbt.enbek.kz/profession/220