Fuzzy Multiperiod Model of Choosing Strategies for The Organization Interaction with Stakeholder Groups in The Stakeholder Network with Multiple "Power Centers"

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Abstract*: The article is devoted to the development of a fuzzy multiperiod model of choosing strategies for the organization interaction with stakeholder groups in the stakeholder network with multiple "power centers". Various interpretations of the plurality of "power centers" in the stakeholder network are reviewed in the article. The developed model allows to choose the most appropriate type of strategy for the interaction of a focal company with each stakeholder group, taking into account the change in the characteristics of relations among the network actors over time, including degrees of mutual influence. The model proposed in the article is described by the following distinctive features in comparison with the earlier developed models: firstly, the dependence of changes in the characteristics of relations between a pair of actors on changes not only in the properties of these actors but also in other actors of the network are taken into account in the article. In this case, the delay of changes in the characteristics of relations is assumed in comparison with changes in properties. Secondly, the Hamming distances between the "real" and "ideal" values of the advisability of applying types of strategies based on the characteristics of the relationship for each period within each scenario are calculated in the article. The model is described by the example of interaction between the regional University and the business community taking into account change of properties of the state.

Index Terms*: stakeholder network, power centers in the network, characteristics of relationships between stakeholders, stakeholder engagement strategies, multi-period model, deterministic equivalent, expected utility criterion, Hamming distances.

I. INTRODUCTION

Stakeholder networks [5–8] can be singled out in a variety of network types and forms of network interaction under review [1–4]. Any organization is associated with a stakeholder network representing an informal structure consisting of a variety of agents involved in the management process, as well as a variety of relationships defined on it – a set of relations among the agents [9]. Separate networks of relationships can be singled out as well, which serve various tasks existing in the organization activities. Different networks can have different structures, and decisions on the relationship management in such networks can be taken based on different criteria [10]. As an interfirm network (with some reservations), the stakeholder network is a complex system of explicit and implicit contracts among the formally independent economic agents aimed at optimal combination and use of resources, with a dominant relationship contract of an indefinite term [11, 12]. This assumes the establishment, support, and development of relationships that allow to coordinate the interests of individual stakeholders, adjust their individual strategies, and coordinate actions to achieve common goals for all stakeholders [13]. At the same time, it must be understood that each stakeholder has its own strategic goals, and these goals determine the choice of certain partners or networks of relationships [ibid.]. As such, goals of actors are at one pole, and goals of the entire network are at another pole. However, there are also goals at the level of dyads (dual pairs) [14]. However, there can also be goals at the level of individual networks of relationships that serve various tasks existing in the organization activities and can be viewed as subnets of the "large" stakeholder network. The contradictory nature of all these goals complicates the development of a universal management approach that is unified for the entire stakeholder network and aimed at maximizing the welfare of all the stakeholders [9]. As such, one of the most relevant and complicated problems is to align the interests of stakeholders in the network interfirm interaction [13]. Considerable attention in the studies devoted to the management of relationships in stakeholder networks is paid to issues of influence, power, and domination. The problems of the focal firm domination due to a serious resource of power are studied better, while influence due to a position in the network, when there are opportunities to influence other stakeholders in the network or the entire network, is studied less [10]. In this case, the organization tries to play a role of a network intermediary, managing resource (including information) flows among the stakeholders and receiving compensation for the transit of resources and access to additional information. As a result, an organization can

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extract relational rents of a specific kind, the nature of the occurrence of which differs from relational rents arising in the stakeholder-organization dyads [15]. Another field of research consists of issues related to tools for assessing the power and influence of stakeholders in various networks [10]. The incomplete contracts among the stakeholder network actors determine the risks of their failures and the loss of the welfare of the parties to these contracts. For protection, such agents should be endowed with certain property rights, including the final control rights. The resulting multiplicity of "power centers" means that the goals, strategies, and actions of companies depend on many stakeholders and are a result of alignment of their interests [16]. The multiplicity of "power centers" can also be reviewed from the standpoint of the position in the stakeholder network. Not just a focal organization but also other actors can play (or seek to play) the role of a network mediator. The ability to play this role depends on the position in the network described by a number of characteristics (parameters) [5]. The multiplicity of "power centers" in the stakeholder network can also be interpreted from the standpoint of the nontransitivity of mutual influence (power). This means that if a degree of mutual influence in some dyad (A, B) is shifted towards A (i.e. A has a certain power over B), while the degree of mutual influence in the (B, C) dyad is shifted towards B, then it does not follow that the degree of mutual influence in the dyad (A, C) is shifted towards A. A dyad reflecting the relationships between the two actors is the simplest unit of the network analysis. The study of networks using the dyad method yields information on the pairwise relations between the network agents but does not allow to review the activity of the network as a whole. Due to this, the researchers gradually moved towards studying triads, then tetrads, and later subgroups within the network, and networks as a whole. Conceptual issues arise at the level of triads, including, inter alia, transitivity of relations. In this case, the transition from dyads to higher order subgraphs (corresponding to subgroups within the network) necessitates an understanding of the influence of interactions in dyads on the entire subgroup as a unit of analysis, and vice versa [10].

Various models were previously proposed for choosing an organization's strategy of interaction with a specific group of stakeholders, which corresponded to the dyad level in the stakeholder network. Corresponding models were developed later, which took the interrelations of stakeholders into account [17, 18] – in other words, there was a transition from dyads to higher order subgraphs.

The goal of this article is to develop and test a multiperiod model for choosing strategies for organization interaction with stakeholder groups, with due consideration for changes in the degree of mutual influence among stakeholders.

II. PROPOSED METHODOLOGY

A. The Method section

The relations among the actors in the stakeholder network base on a resource exchange among them. Due to this, satisfaction with the resource exchange (i.e. satisfaction with the quality and quantity of resources received from the counterparty) is one of the most important characteristics of relationships. It was assumed that the quality and quantity of resources supplied by an actor depended on the severity of some of the actor's characteristics (properties, attributes) [19]. This article describes the relevant properties of the university and its main stakeholders, which determine the resource exchange among them. Besides, the properties of the university stakeholders, which determine the resource exchange among them, are described in the paper [20]. The properties of actors (along with the quality and quantity of resources they supply) are a subject of counterparties' expectations (following G. Kleiner, the authors understand the subject of expectations as the expected state or action of the object of expectations, where expectations can be explicit or implicit offers or requirements [21]). At the same time, on the one hand, a change in the counterparty's properties (i.e. its state) leads to a change in expectations for it (for its actions in terms of the quality and quantity of the resources it supplies). On the other hand, a change in the actor's properties is, inter alia, a consequence of the expectations of other network stakeholders aimed at it. These causal relationships in the stakeholder network served as a basis for models taking the relationships among stakeholders into account. It was assumed that the degree of change in expectations for the counterparty due to a change in some of its properties depended on the degree of mutual influence between the actor and the counterparty. With an equal degree of mutual influence, the degree of change in expectations equals to the degree of change in the property. This means that if these degrees of change are measured on a certain linguistic scale with subsequent conversion to fuzzy numbers, it can be assumed that the corresponding membership functions coincide. When the degree of mutual influence shifts towards the actor's greater power (over the counterparty), the estimates of expectations shift to a positive direction. Vice versa, if the degree of mutual influence is shifted towards greater power of the counterparty, expectations shift to a negative direction. Let us suppose that the change in expectations due to a change in the properties of the counterparty also depends on satisfaction with resources obtained from this counterparty. In the case of low satisfaction (high dissatisfaction), even a slight deterioration in properties can lead to a significant deterioration in expectations (even at an equal degree of mutual influence). Moreover, in the case of low satisfaction, even the lack of changes in properties can lead to a deterioration in expectations. Vice versa, with high satisfaction, the lack of changes in properties can lead to improved expectations. A fragment of the base of fuzzy rules for deriving the values of the linguistic variable of the change in expectations due to a change in the property of the counterparty, taking into account the degree of satisfaction with an equal degree of mutual influence, is provided in Table 1. It must be noted that satisfaction is evaluated only in relation to the resources obtained from the counterparty the quality and quantity of which depend on this property.

Table 1. Finding the values of the linguistic variable of changes in expectations when the property of the counterparty changes, taking into account the degree of satisfaction with an equal degree of mutual influence.

Estimate of satisfaction	Estimate of the change in property	Will worsen radically	Will worsen significantly	Will worsen insignificantly	Will not change	Will improve insignificantly	Will improve significantly	Will improve radically
Complete dissatisfaction		Will worsen radically	Will worsen radically	Will worsen radically	Will worsen significantly	Will not change	Will improve insignificantly	Will improve insignificantly
Significant dissatisfaction		Will worsen radically	Will worsen radically	Will worsen significantly	Will worsen insignificantly	Will not change	Will improve insignificantly	Will improve significantly
Moderate dissatisfaction		Will worsen radically	Will worsen significantly	Will worsen insignificantly	Will not change	Will improve insignificantly	Will improve significantly	Will improve significantly
Partial dissatisfaction and partial satisfaction	Estimate of the change in expectations	Will worsen radically	Will worsen significantly	Will worsen insignificantly	Will not change	Will improve insignificantly	Will improve significantly	Will improve radically
Moderate satisfaction		Will worsen significantly	Will worsen significantly	Will worsen insignificantly	Will not change	Will improve insignificantly	Will improve significantly	Will improve radically
Significant satisfaction		Will worsen significantly	Will worsen insignificantly	Will not change	Will improve insignificantly	Will improve significantly	Will improve radically	Will improve radically
Complete satisfaction		Will worsen insignificantly	Will worsen insignificantly	Will not change	Will improve significantly	Will improve radically	Will improve radically	Will improve radically

In this case, if the degree of mutual influence shifts towards the actor's greater power (over the counterparty), the estimates of expectations shift to a positive direction (towards the value "Will improve radically") in a similar way. Vice versa, if the degree of mutual influence shifts towards greater power of the counterparty, expectations shift to a negative direction (towards the value "Will worsen radically"). It must be noted that not one but several properties of one counterparty usually change simultaneously. Due to this, the change in expectations is defined as a convex combination of the corresponding fuzzy numbers, taking into account the weight coefficients of the properties, based on the proposed rule base and given membership functions [22]. In this case, the weight properties may also be fuzzy. A degree of desire for changes, which is a function of satisfaction and expectations regarding the counterparty, is another characteristic of relations among the actors in the stakeholder network. It is assumed that the lower the satisfaction is and the more negative the expectations are, the greater is the degree of desire for changes, and vice versa. A change in properties leads to a change in expectations and, therefore, to a change in the desire for changes. Due to this, it is proposed to consider the properties of actors as variables, when various scenarios of changes in relations in the stakeholder network are reviewed. As such, each scenario is a combination of some successive changes in the properties of stakeholders in the network, leading to consequences in the relations among them with a certain probability. The expectations of stakeholders to each other and to the organization, just as those of the organization to stakeholders can be recalculated within each scenario, as well as the corresponding degrees of desire for changes.

B. Model

The following fuzzy variables are considered:

1) quantifying estimate of the change in the *m*-th property of the *k*-th stakeholder in period *j* under scenario *l* (S_{1j}^{mkl}) and quantifying estimate of the change in the *m*-th property of the organization in period *j* under scenario *l* (S_{2j}^{mkl}) ($m=\overline{1,M_k},\ k=\overline{1,K},\ l=\overline{1,L},\ j=\overline{1,J}$);

2) weight of the *m*-th property of the *k*-th stakeholder in period *j* under scenario *l* (R_{1j}^{mkl}) and weight of the *m*-th property of the organization in period *j* under scenario *l* (R_{2j}^{mkl});

3) degree of the *k*-th stakeholder's satisfaction with the organization in period *j* under scenario *l* (U_{1j}^{kl}) and degree of the organization's satisfaction with the *k*-th stakeholder in period *j* under scenario *l* (U_{2j}^{kl});

4) quantifying estimate of the change in expectations of the *k*-th stakeholder about the organization in period *j* under scenario *l* (O_{1j}^{kl}) and quantifying estimate of the change in expectations of the organization about the *k*-th stakeholder in period *j* under scenario *l* (O_{2j}^{kl});

5) degree of desire for changes in the *k*-th stakeholder relationship with the organization in period *j* under scenario *l* (G_{1j}^{kl}) and degree of desire for changes in the organization's relationship with the *k*-th stakeholder in period *j* under scenario *l* (G_{2j}^{kl});

6) probability of the *l*-th scenario (p_l);

7) degree of mutual influence of the organization and the *k*-th stakeholder in period *j* under scenario *l* (V_j^{kl});

8) expediency of applying the *n*-th type interaction strategy to the *k*-th stakeholder in period *j* under scenario *l* (w_{nj}^{kl}) ($n=\overline{1,5}$).

Tables 2-6 show the term sets of the linguistic variables.

Table 2. Term set of the linguistic variable "estimate of satisfaction"

Value of the linguistic variable	Trapezoidal membership function
Complete dissatisfaction (LL)	(-5; -5; -4; -3)
Significant dissatisfaction (L)	(-4.5; -3.75; -2.25; -1.5)
Moderate dissatisfaction (ML)	(-3; -2.25; -0.75; 0)
Partial dissatisfaction and partial satisfaction (M)	(-1.5; -0.75; 0.75; 1.5)
Moderate satisfaction (MH)	(0; 0.75; 2.25; 3)
Significant satisfaction (H)	(1.5; 2.25; 3.75; 4.5)
Complete satisfaction (HH)	(3; 4; 5; 5)

Table 3. Term set of the linguistic variables "estimate of the change in expectations", "estimate of the change in property"

Value of the linguistic variable	Trapezoidal membership function
Will worsen radically (NH)	(-5; -5; -4; -3)
Will worsen significantly (NM)	(-4.5; -3.75; -2.25; -1.5)
Will worsen insignificantly (NL)	(-3; -2.25; -0.75; 0)
Will not change (NE)	(-1.5; -0.75; 0.75; 1.5)
Will improve insignificantly (PL)	(0; 0.75; 2.25; 3)
Will improve significantly (PM)	(1.5; 2.25; 3.75; 4.5)
Will improve radically (PH)	(3; 4; 5; 5)

Table 4. Term set of the linguistic variable "estimate of mutual influence"

Value of the linguistic variable	Trapezoidal membership function
Stakeholder's influence on the organization is radically greater than the organization's influence on stakeholder (SH)	(-5; -5; -4; -3)
Stakeholder's influence on the organization is significantly greater than the organization's influence on stakeholder (SM)	(-4.5; -3.75; -2.25; -1.5)
Stakeholder's influence on the organization is moderately greater than the organization's influence on stakeholder (SL)	(-3; -2.25; -0.75; 0)
Mutual influence of stakeholder and organization is much the same (NE)	(-1.5; -0.75; 0.75; 1.5)
Organization's influence on the stakeholder is moderately greater than the stakeholder's influence on organization (CL)	(0; 0.75; 2.25; 3)
Organization's influence on the stakeholder is significantly greater than the stakeholder's influence on organization (CM)	(1.5; 2.25; 3.75; 4.5)
Organization's influence on the stakeholder is radically greater than the stakeholder's influence on organization (CH)	(3; 4; 5; 5)

Table 5. Term set of the linguistic variable "estimate of degree of desire to change relationships"

Value of the linguistic variable	Trapezoidal membership function
Large (H)	(7; 8; 10; 10)
Above average (MH)	(5; 6; 8; 9)
Average (M)	(3; 4; 6; 7)
Below average (ML)	(1; 2; 4; 5)
Small (L)	(0; 1; 2; 3)
Extremely small probability (LL)	(0; 0; 1; 2)

Table 6. Term set of the linguistic variables "scenario probability", "property weight"

Value of the linguistic variable	Trapezoidal membership function
Large (H)	(0.7; 0.8; 1; 1)
Above average (MH)	(0.5; 0.6; 0.8; 0.9)
Average (M)	(0.3; 0.4; 0.6; 0.7)
Below average (ML)	(0.1; 0.2; 0.4; 0.5)
Small (L)	(0; 0.1; 0.2; 0.3)
Extremely small probability (LL)	(0; 0; 0.1; 0.15)

Table 7 presents a fragment of the fuzzy rule base for estimating the degree of desire for changes in the *k*-th stakeholder's relationships with the organization under scenario *l* and period *j* (G_{1j}^{kl}) by two factors. Rule base consists of 49 (7^2) rules. A similar rule base can be set for estimating the degree of desire for changes in the organization's relationships with the *k*-th stakeholder under scenario *l* and period *j* (G_{2j}^{kl}).

Table 7. Fragment of the fuzzy rule base

№ fuzzy rule	IF		THEN
	U_{1j}^{kl}	O_{1j}^{kl}	G_{1j}^{kl}
1	HH	PH	LL
5	HH	NL	L
25	M	NE	M
45	LL	PL	MH
49	LL	NH	H

A certain type of engagement strategy (the most suitable one, all other things being equal) can be chosen for each group of stakeholders, based on the analysis of relationship characteristics: satisfaction of demands, protection, impact, cooperation, restraint [23]. The "real" expediency of using strategy types is found for each of the five types of interaction strategies (satisfaction of demands, protection, impact, cooperation, restraint) under the l-th scenario and in the j-th period, using the following formulas:

$$w_{1j}^{kl} = \frac{5+G_{1j}^{kl}-v_j^{kl}}{20},\ w_{2j}^{kl} = \frac{10-\left|G_{1j}^{kl}-5\right|-v_j^{kl}}{15},\ w_{3j}^{kl} = \frac{5+G_{2j}^{kl}+v_j^{kl}}{20},\ w_{4j}^{kl} = \frac{25-G_{1j}^{kl}-G_{2j}^{kl}-\left|v_j^{kl}\right|}{25},\ w_{5j}^{kl} = \frac{10-\left|G_{2j}^{kl}-5\right|+v_j^{kl}}{15}. \quad (1)$$

The "ideal" expediency of applying strategy types is found for each of the five types of interaction strategies. To do so, the membership functions of the relationship characteristics (corresponding to the given values of the linguistic scales), for which coefficients w_nj^kl take the greatest values, are substituted in formulas (1). Then, the Hamming distance between the "ideal" and "real" value of the appropriateness of application of the strategy in the j-th period under the l-th scenario is calculated for each type of strategy (Table 8), using the following formula:

$$\rho_{nj}^{kl}\left(w_{nj}^{ukl}, w_{nj}^{pkl}\right) = \int_{-\infty}^{+\infty} \left|\mu_{w_{nj}^{ukl}}(x_h) - \mu_{w_{nj}^{pkl}}(x_h)\right| dx \quad (2)$$

where $\mu_{w_{nj}^{ukl}}(x_h)$ and $\mu_{w_{nj}^{pkl}}(x_h)$ are membership functions of the "ideal" and "real" appropriateness of application of the strategy types, respectively.

Table 8. Hamming distances

Scenarios (probabilities)	Periods		
	Period 1	...	Period *J*
Scenario 1 (p_1)	ρ_{n1}^{k1}		ρ_{nJ}^{k1}
…	...	...	...
Scenario *L* (p_L)	ρ_{n1}^{kL}	...	ρ_{nJ}^{kL}

The Hamming distances for each scenario can be reduced to one integral using the following formula:

$$\rho_n^{kl} = \frac{\sum_{j=1}^{J} \rho_{nj}^{kl} \cdot q_{nj}^{kl}}{\sum_{j=1}^{J} q_{nj}^{kl}} \quad (3)$$

where q_{nj}^{kl} is the factor describing the confidence of the expert (or decision-maker (DM)) in the characteristics of the relationships, based on which the Hamming distance in the *j*-th period is calculated for the *n*-th type strategy for the *k*-th stakeholder under the *l*-th scenario. The final choice of interaction strategy can be made on the basis of a generalized criterion found for each strategy type. The generalized criterion is a weighted sum of the partial criteria of the expectation and the standard deviation with weighting coefficients 1 and $-\lambda$ [24]. The value of λ describes the DM's risk proneness. When $\lambda > 0$, the DM is not prone to risk, since the estimate of a random variable obtained using the generalized criterion is less than its average value in this case, which describes a cautious person. When $\lambda < 0$, the opposite situation develops and the DM is prone to risk. Finally, when $\lambda = 0$, the DM is indifferent to risk, since the estimate of a random variable obtained using the generalized criterion coincides with its average value. It must also be noted that parameter λ reflects the subjective psychological qualities and is found from observations of the DM making decisions in risky situations. The interaction strategy can also be chosen based on the expected utility criterion (deterministic equivalent) [25]. Two approaches were used in the previously proposed multiperiod models of choosing strategies for the organization interaction with stakeholder groups. In the first approach, weighting coefficients of the expediency of interaction strategies were found for each scenario for each period, which were then reduced to one integral coefficient for each scenario [17]. In this case, it was assumed that the greater the number of the period was, the less was the experts' confidence in the estimates of the relationship characteristics, and hence the DM's confidence in the coefficients of the expediency of interaction strategies found for this period. According to another approach, fuzzy estimates of the relationship characteristics were reduced to one integral estimate for each scenario, and then the "real" values of the expediency of each type of strategy were found on their basis. The "ideal" values were found at the same time. Then the proximity of the "real" value to the "ideal" value was found as the Hamming distance between the corresponding fuzzy numbers [23]. In this case, the generalized criterion or the criterion of expected utility was found on the basis of the distances between the "real" and "ideal" values. According to both approaches, the experts in each scenario clearly or fuzzily estimated the relationship characteristics (or their changes) in each period. Due to the above, it is proposed to expertly estimate changes in the properties of actors, and then estimate (or calculate) changes in the relationship characteristics. In this case, it must be understood that the relationship characteristics will change with smaller or greater delay. As such, the following scheme is proposed for choosing the strategy of the organization interaction with stakeholder groups in the stakeholder network.

C. Flow Chart

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III. RESULTS

Let us review the use of a multiperiod model of choosing strategies for interaction with stakeholders by the example of the interaction of a regional university (the Vladivostok State University of Economics and Service, VSUES) with the business community. The VSUES is located in Vladivostok, the capital of the Primorsky region and the

Far Eastern Federal District of the Russian Federation. The Russian government has been giving priority to the development of the Far Eastern Federal District in recent years. Special attention, both from the state agencies and the commercial sector and investors, is paid to the performance of the priority social and economic development areas (PSEDA) and the Vladivostok Free Port (VFP). In the context of the PSEDA and VFP creation, the need increases for qualified personnel and applied research, which the university can provide. Let us review three possible scenarios of the university's interaction with business, with due consideration for the large-scale changes that occur in the regional economy and the world, as well as the place and role of the VSUES in the educational landscape of the Primorsky region. Scenario 1. The development of the regional economy is suggested under the first scenario. Creating unprecedented conditions of economic development of the territory (creating a comfortable environment for investors (both for novices and those who are already there), providing assistance through subsidies for promising types of business, ensuring business participation in the social facilities construction, etc.) will secure the development of the regional economy. The population outflow from the region will decrease. The business needs for qualified personnel, training and retraining, consulting and training services, applied research and development will grow. However, the development of the regional economy will be constrained by the current political and foreign economic situation. Scenario 2. Additional substantial improvement in the political and external economic conditions is suggested under the second scenario. The regional economy will develop at a faster pace. An inflow of skilled labor will be observed.

Scenario 3. The absence of any significant development of the regional economy, despite all the state efforts (creation of multiple special economic zones, etc.) is suggested under the third scenario. The nonzero probability of this scenario is due to the mismatch of long-lasting efforts and expectations, on the one hand, and the currently observed results, on the other hand. Graduates of universities will continue to massively leave to other more developed Russian regions in search of better living and employment conditions (high salaries, career prospects). The needs of regional businesses in qualified and trained graduates, as well as in the provision of consulting and training services of the university will not increase. The above scenarios are formed by successive changes in the properties of the state, business, and university. Some of the important properties of these stakeholder groups, weights of the properties, and the change of properties under the first scenario for the three periods are summarized in Tables 9 – 11. It has already been noted above that changes in properties form successive causal chains. For example, a change in the state policy in science and higher education and ensuring high rates of life expectancy in the region will lead to a decrease in the outflow of qualified staff from universities to commercial structures and other regions (or even reverse inflow). In turn, this will promote the improvement of the training and applied research quality, the growing demand for which from the business will also be caused by changes in the properties of the state. At the same time, the growth of business solvency (along with the growth of state funding) will contribute to modernization of facilities and resources in universities and hence improvement in the training and applied research quality, etc.

Table 9. Change in the properties of the state

Properties of the state	Property weight	Scenario 1		
		Period 1	Period 2	Period 3
State policy in science and higher education	Average	Will improve significantly	Will improve insignificantly	Will not change
State regulation of the pricing policy	Average	Will improve insignificantly	Will improve significantly	Will not change
Legal framework for investment climate	Average	Will improve radically	Will improve insignificantly	Will improve insignificantly
Securing guarantees to Russian and foreign investors	Average	Will improve significantly	Will not change	Will not change
Tax and customs benefits, investment loans provided to enterprises and other economic entities	Large	Will improve radically	Will improve insignificantly	Will improve insignificantly
Political stability and predictability of the region	Above average	Will not change	Will improve insignificantly	Will improve insignificantly
Securing high rates of life expectancy, high level of education and cultural life in the region	Average	Will improve insignificantly	Will improve significantly	Will improve significantly

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Table 10. Change in the properties of the business

Properties of the business	Property weight	Scenario 1		
		Period 1	Period 2	Period 3
Demand for graduates	Large	Will improve insignificantly	Will improve significantly	Will improve significantly
Demand for consulting and training services	Above average	Will not change	Will improve insignificantly	Will improve significantly
Solvency	Average	Will not change	Will improve insignificantly	Will improve significantly

Table 11. Change in the properties of the university

Properties of the university	Property weight	Scenario 1		
		Will not change	Will improve insignificantly	Will improve significantly
Staff qualification	Large	Will not change	Will improve significantly	Will improve insignificantly
Practice-integrated study	Large	Will not change	Will improve insignificantly	Will improve significantly
Modern facilities and resources	Average	Will not change	Will improve insignificantly	Will improve significantly
Applied research	Above average	Will not change	Will improve insignificantly	Will improve significantly

It can be easily seen that the properties of the university depending on changes in the properties of the state and business, as well as properties of the business depending on changes in the properties of the state, change with a delay. Similar property change chains can be built for the remaining two scenarios.

Then, using the bases of fuzzy inference rules, it can be shown how the expectations of the business community to the university in the first scenario change if one of the properties of the university changes, taking into account the degree of satisfaction and the degree of mutual influence (which, in turn, will also change by periods) (Table 12).

Table 12. Change in the expectations of the business community to the university

Property of the university	Staff qualification			
Period	Estimate of the change in property	Estimate of satisfaction	Estimate of mutual influence	Estimate of the change in expectations
Period 1	Will not change	Partial dissatisfaction and partial satisfaction	Mutual influence of stakeholder and organization is much the same	Will not change
Period 2	Will improve insignificantly	Partial dissatisfaction and partial satisfaction	Mutual influence of stakeholder and organization is much the same	Will improve insignificantly
Period 3	Will improve significantly	Moderate satisfaction	Stakeholder's influence on the organization is moderately greater than the organization's influence on stakeholder	Will improve significantly

The change in expectations, taking changes in other properties into account, can be found in a similar manner. It can also be noted that the change in expectations can be found as a convex combination of the corresponding fuzzy numbers, taking the weighting factors of the properties into account and based on the proposed rule base and specified membership functions, because not one but several properties change in the counterparty. The fuzzy characteristics of the relationship between the university and the business community, including the degree of desire for change in relationships obtained on the basis of the fuzzy inference rules, are provided in Table 13.

Table 13. Fuzzy characteristics of the relationship between the university and the business community

Scenarios	Scenarios (probabilities)	Periods	Fuzzy characteristics of the relationship between the university and the business community						
			U_{1j}^{kl}	O_{1j}^{kl}	U_{2j}^{kl}	O_{2j}^{kl}	V_j^{kl}	G_{1j}^{kl}	G_{2j}^{kl}
Scenario 1	Above average	1	M	PL	M	PL	NE	M	M
		2	M	PL	MH	PM	CL	M	ML
		3	MH	PM	H	PM	CL	ML	L
Scenario 2	Average	1	MH	PM	MH	PM	SL	ML	ML
		2	MH	PH	H	PM	SL	L	L
		3	H	PM	H	PH	SM	LL	LL
Scenario 3	Average	1	M	NL	ML	NL	NE	M	M
		2	ML	NL	ML	NM	NE	M	MH
		3	L	NM	L	NM	NE	H	H

The calculated Hamming distances between the "ideal" and "real" values of expediency for each type of strategy in period *j* under scenario *l* are provided in Table 14.

Table 14. The calculated Hamming distances for each type of strategy in period *j* under scenario *l*

Scenarios	Periods	q_{nj}^{kl}	Types of engagement strategies				
			Satisfaction of demands	Protection	Impact	Cooperation	Restraint
Scenario 1	1	0.90	0.40	0.35	0.40	0.32	0.37
	2	0.80	0.43	0.44	0.43	0.30	0.36
	3	0.70	0.45	0.34	0.44	0.21	0.47
Scenario 2	1	0.80	0.43	0.28	0.45	0.24	0.48
	2	0.70	0.44	0.14	0.46	0.16	0.50
	3	0.60	0.43	0.31	0.51	0.15	0.62
Scenario 3	1	0.85	0.40	0.35	0.40	0.32	0.37
	2	0.75	0.41	0.35	0.34	0.38	0.47
	3	0.65	0.25	0.10	0.26	0.41	0.52

The Hamming integral distances, as well as the calculated mathematical expectations ($E\rho_n^k$) and standard deviations ($\sigma\rho_n^k$) for each strategy type are provided in Table 15.

Table 15. Hamming integral distances

Scenarios	Types of engagement strategies				
	Satisfaction of demands	Protection	Impact	Cooperation	Restraint
Scenario 1	0.424	0.377	0.422	0.281	0.396
Scenario 2	0.433	0.242	0.470	0.187	0.526
Scenario 3	0.360	0.277	0.339	0.366	0.446
$E\rho_n^k$	0.408	0.307	0.412	0.278	0.450
$\sigma\rho_n^k$	0.031	0.059	0.051	0.069	0.054

Let us consider the problem of two-criterion optimization, where $E\rho_n^k$ and $\sigma\rho_n^k$ act as partial criteria, to choose the most appropriate type of interaction strategy. A generalized criterion is used to solve this problem, which is a weighted sum of the partial criteria $\frac{1}{E\rho_n^k}$ and $\sigma\rho_n^k$ with weighting coefficients 1 and $-\lambda$:

$$\eta(E\rho_n^k, \sigma\rho_n^k) = \frac{1}{E\rho_n^k} - \lambda\sigma\rho_n^k \qquad (4)$$

Let us find the optimal strategy using the generalized criterion. In this case,

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$$\eta(E\rho_1^k,\sigma\rho_1^k)=\frac{1}{0.408}-0.031\lambda$$
$$\eta(E\rho_2^k,\sigma\rho_2^k)=\frac{1}{0.307}-0.059\lambda$$
$$\eta(E\rho_3^k,\sigma\rho_3^k)=\frac{1}{0.412}-0.051\lambda$$
$$\eta(E\rho_4^k,\sigma\rho_4^k)=\frac{1}{0.278}-0.069\lambda$$
$$\eta(E\rho_5^k,\sigma\rho_5^k)=\frac{1}{0.450}-0.054\lambda.$$

Let us find the lower limit of the risk proneness measure λ^0 and the upper limit of the risk proneness measure λ^* to establish the ranking of the strategy types according to the generalized criterion, using the following formulas:

$$\lambda^0=min\left\{\frac{\frac{1}{E_{i1}}-\frac{1}{E_{i2}}}{\sigma_{i1}-\sigma_{i2}}\right\},\lambda^*=max\left\{\frac{\frac{1}{E_{i1}}-\frac{1}{E_{i2}}}{\sigma_{i1}-\sigma_{i2}}\right\}, \quad (5)$$

where (E_{i1},σ_{i1}) and (E_{i2},σ_{i2}) are the expectation and the standard deviation of two fixed alternatives to a_{i1}, a_{i2}. In this case, $E_{i1}<E_{i2}$ and $\sigma_{i1}>\sigma_{i2}$. The following values were obtained: $\lambda^0=29.3$, $\lambda^*=213.4$. As such, the following zones can be selected: (0; 29.3) is a zone of small risk proneness (zone of little caution), (29.3; 213.4) is a zone of uncertainty, and (213.4; $+\infty$) is a zone of great risk proneness (zone of great care). If the risk proneness measure for the DM is $0\le\lambda<29.3$, the ranking of the strategy types for him or her coincides with their ranking by the reciprocal of the expectation value. In this case, the cooperation strategy will be optimal. If the risk proneness measure for the DM is $\lambda>213.4$, the ranking of the strategy types for him or her coincides with their ranking by the risk index (standard deviation). In this case, the request satisfaction strategy will be optimal. Let us consider the case when risk proneness measure for the DM falls into the zone of uncertainty. Assume, for example, $\lambda=40$. Then $\eta(E\rho_1^k,\sigma\rho_1^k)=1.19$, $\eta(E\rho_2^k,\sigma\rho_2^k)=0.89$, $\eta(E\rho_3^k,\sigma\rho_3^k)=0.37$, $\eta(E\rho_4^k,\sigma\rho_4^k)=0.82$, $\eta(E\rho_5^k,\sigma\rho_5^k)=0.05$.

The resulting ranking is $\eta(E\rho_1^k,\sigma\rho_1^k)\succ\eta(E\rho_2^k,\sigma\rho_2^k)\succ\eta(E\rho_4^k,\sigma\rho_4^k)\succ\eta(E\rho_3^k,\sigma\rho_3^k)\succ\eta(E\rho_5^k,\sigma\rho_5^k)$

In this case, the request satisfaction strategy will be the most expedient.

IV. CONCLUSION

The proposed fuzzy multiperiod model of choosing strategies for the organization interaction with stakeholder groups in the stakeholder network with multiple "power centers" allows to choose the most appropriate type of strategy for the interaction of a focal company with each stakeholder group, taking into account the change in the characteristics of relations among the network actors over time, including degrees of mutual influence. A distinctive feature of the model is the dependence of changes in the characteristics of relations between a pair of actors on changes not only in the properties of these actors but also in other actors of the network. In this case, the delay of changes in the characteristics of relations is assumed in comparison with changes in properties. Another significant difference from the previously developed models is that the Hamming distances between the "real" and "ideal" values of the advisability of applying types of strategies are calculated based on the characteristics of the relationship for each period within each scenario. The model proposed in the article was tested on the example of the interaction between a regional university and businesses, taking into account the changes in the properties of the state. In this example, the choice of the most appropriate type of strategy is based on a generalized criterion.

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