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Optimization of Interaction with Counterparties: Selection Game Algorithm under Uncertainty

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Abstract: The purpose of this study is to develop a comprehensive algorithm for optimizing the interaction of economic entities with counterparties, taking into account the uncertainty of market conditions and the variety of behavioral strategies of participants. The developed algorithm aims to increase the stability and efficiency of the interactions between the economic entity under study and its counterparties, minimizing risks and optimizing cooperative and competitive strategies within the framework of existing market relations. The methodology uses game theory to devise interaction strategies using mutual influence indices, non-cooperative game principles, and payment matrices. The model analyzes various interaction scenarios with counterparties by using payment matrices and considering both competitive and cooperative conditions. The research methodology is supplemented by the calculation of integral estimates based on a set of financial and economic indicators, enabling the assessment of the impact of various interaction strategies on the overall efficiency of an economic entity. After testing the developed models, a set of data was obtained, which can be used to optimize strategic planning and manage the interaction of economic entities with counterparties. The developed algorithm is an effective tool for improving the operational analysis of enterprises, primarily in industrial sectors.

Keywords: game theory; non-cooperative games; payment matrices; multicriteria analysis; integral estimates; interaction with counterparties; strategic planning; business modeling

MSC: 90B50; 91A35; 91B06

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1. Introduction

Economic space generates a high uncertainty and contributes to the formation of dynamism in market processes. In such conditions, the issues of effective interaction between economic agents, including enterprises and their counterparties, become relevant. For this purpose, it is advisable to develop economic and mathematical models that contribute to the rationalization of management, taking into account factors of the instability and uncertainty of the external environment [1–4].

From the perspective of managing economic systems, the effective interaction between economic entities is relevant for key sectors of the national economy, particularly for the engineering complex, the stability of which depends on the stability of connections between various counterparties. The effectiveness of processes for managing interactions with external agents directly affects business operations and strategic prospects of enterprises [5,6]. In the face of constantly changing supply chains and unstable market conditions, the development of new approaches and algorithms is necessary to optimize cooperative and competitive strategies [7–15].

Existing solutions for interactions with business partners are currently largely static and involve some options for assessing participants in cooperation, ranking them from best to worst. In the case of working with a real complex socio-economic system, which is an enterprise, such an approach is quite simple and primitive, which, ultimately, will often be reflected in the inconsistency and unreliability of the measures and forecasts being developed. In our work, we will try to level out this aspect by modeling some aspects of human psychology in our decisions, taking the apparatus of game theory as a fundamental basis.

This research aims to develop an algorithm that integrates game theory, multicriteria analysis, and statistics to optimize economic entity interactions under uncertainty. The approach proposed in this work is based on the use of game-theoretic criteria, which allows us to take into account various strategies of the behavior of counterparties of an economic entity to form effective interaction strategies.

Additionally, the work uses the author's tools to highlight the mutual influence between counterparties, which allows us to assess the impact of various strategies on the overall efficiency of an economic entity. Based on the construction of payment matrices, it becomes possible to analyze and interpret possible interaction scenarios. Thus, the results of this study are of practical significance for management and strategic planning, allowing entities to increase operational efficiency by minimizing risks and optimizing relationships with key counterparties.

To increase the clarity and awareness of this topic to the reader, we will briefly explain the following terms, which we will use in this manuscript:

- Game-theoretic approach—in accordance with this approach, the participants in the interaction try to self-organize in such a way that in the event of a force majeure situation, they do not suffer irreparable damage (reach a state of equilibrium).
- Integral estimates—synthetic estimates of complex objects, obtained by condensing various multifaceted indicators that characterize them into an indicator represented by one single number.
- Non-cooperative games—a situation where the parties of the interaction primarily pursue their own personal selfish goals, without trying to unite with other participants to solve their problem.
- Payment matrices—results presented in a tabular form and representing the ratio of actions of two interacting or opposing parties.
- Modeling of integral estimates—selection of a scheme for condensing various heterogeneous indicators characterizing a complex object into a single monosyllabic indicator.

2. Literature Review and Theoretical Analysis

The challenges of the modern economic space are associated with the transformation of interaction chains, forcing economic entities to adapt to market dynamics. To adapt to new realities and maintain competitiveness at a high level, it is necessary to ensure rational interactions with counterparties. To implement effective management of interaction processes and counteract these challenges, this study proposes to develop and apply a gaming algorithm for selecting counterparties, taking into account the uncertainty of market conditions and the strategic interests of the participants. Building an integrated approach allows one to increase the stability and efficiency of the interactions. We will analyze the key theoretical issues that form the basis of this study, as follows:

2.1. Game-Theoretic Approach to Interaction Optimization

As part of optimizing the interaction with counterparties, it is permissible to present the actions of the subjects in a game format. Game theory itself provides tools for analyzing the strategies of participants and predicting possible outcomes [16]. Basic principles of game theory, such as the concept of the Nash equilibrium, can be applied to determine optimal strategies under conditions of uncertainty [17,18].

A mathematical tool for analyzing the strategic interactions of the players involved is game theory. Optimization using gaming tools helps manage risk situations where the stochastic approach is untenable [19]. In particular, on the basis of game situational conditions, it is possible to optimize the actions of agents depending on the state of the external environment, for example, when making investment decisions or in the presence of a number of alternative strategies [20,21]. In general terms, within the framework of this approach, we do not simply choose the best option but focus on our viability after the onset of any critical situation.

The consideration of game theory under conditions of uncertainty from the perspective of optimization measures in business allows us to identify key aspects of business aimed at adapting to the variability of market conditions, which, in business practice, contributes to the development of effective interaction strategies [22,23]. The transformation of game theory into an economic tool and its integration made it possible to develop applied approaches for managing various economic aspects [24,25].

In many ways, adaptive actions in conditions of variability in the external environment make it possible to form sustainable strategies for effectively responding to changes through the strategic elaboration of the potential consequences of the player's actions. This approach allows for greater flexibility and a fair justification for the relationships between decisions and results [26]. The mathematical basis, in turn, contributes to the formation of systems for collecting asymmetric information to rationalize the actions of subjects in the external environment. A complex of external information and data about a cooperative or non-cooperative game allows us to clarify the strategy format [27,28].

2.2. Multicriteria Analysis

Multicriteria analysis plays a key role by taking into account a variety of decision-making criteria. In the context of interactions with counterparties, where the various goals and interests of the parties are of high importance, the use of multicriteria approaches in the gaming algorithm contributes to a more complete understanding and optimization of strategies [1,29]. Thus, it becomes possible to take into account many aspects, forming more comprehensive interaction strategies. In this case, parameters should be set for each aspect, and specific factors should be identified, for example, based on data mining and digital models [30,31].

Since multicriteria analysis is a structured method, it makes it possible to take into account the complex nature of the interaction between economic entities and their counterparties [5,6]. In this context, it becomes possible to analyze and weigh the various interaction criteria involved in decision-making. Moreover, each criterion takes into account the various goals and interests of the parties [32–34]. The implementation of this approach contributes to a detailed understanding of the processes of interactions between parties and contributes to more informed strategic decisions in a dynamic business environment [35,36].

The implementation of this approach involves considering the situation of interest from different angles and sides. This is especially true for systems of a social nature (economics and sociology), where they, in turn, are extremely extensive and multifaceted.

2.3. Mathematical Statistics in Interaction Optimization

Mathematical statistics provide tools for modeling and analyzing uncertainty in economic processes. When integrated with applied game theory, it becomes possible to analyze the strategic behavior of agents, setting the trajectories of their actions. The use of data processing and the analysis of various scenarios of uncertainty in economic processes makes it possible to solve issues of business, economics, law, and public policy [37,38]. Based on identified patterns in the data, it becomes possible to make adjustments to strategies, including those based on previous trends and the analysis of past interactions with counterparties [22].

The instrumental processing of collected information on economic entities and the introduction of specialized algorithms for selecting counterparties makes it possible to evaluate and distribute factors by taking into account the likelihood of their implementation according to factor states [1,27,39]. This approach also presents a way to use predictive analytics based on objective data, which helps economic entities predict possible scenarios and make informed decisions in conditions of increased risk and uncertainty [40–42]. For example, the presence of a basis for the intellectual development of an economic entity allows us to model a selection of counterparties based on a system of accounting for interests [7,12,36,43].

Mathematical statistics are thus applicable to many aspects of human life. Its development is due to the widespread use of computers and the writing of appropriate computing programs for them. Human activity and the spheres of its management have various numerical characteristics and estimates, which, in turn, are the fuel for statistical tools.

2.4. Interaction with Counterparties: From Theory to Practice

It is worth considering that the actual conditions of interactions with counterparties may be different. It is possible to adapt simulation modeling to explain the various states between counterparties in the process of making economic decisions. Gaming strategies increase business flexibility and adaptability, but the requirements for monitoring external changes to predict many alternative scenarios also increase [44,45]. The theory of multicriteria analysis implies the need to manage multiple criteria when interacting with counterparties. The practical application of multicriteria approaches in relationship management allows us to focus on various aspects of the interaction, taking into account the interests of various parties [5,6]. The transition from a game basis to specific practical actions on issues of interactions with counterparties includes the implementation of game strategies in business processes, which makes it possible to take into account the state of variability with an unclear number of optimal states in a given interaction. The development of an algorithm that takes into account the full range of variables allows one to adapt information to the needs of decision-making.

Further work involves combining the three approaches outlined above, essentially embodying the hybrid modeling paradigm. To some extent, this practice is described as the most promising and progressive in modeling and controlling complex systems [46–48]. We present the general ideas of the approaches discussed above and the concept we are developing in the table below (Table 1).

Table 1. Approaches to managing cooperation between economic agents.

Approach	General Idea
1. Game theory	Searching for equilibriums stable to shocks and beneficial to all participants in the interaction.
2. Multicriteria analysis	Observation of an object from various sides and positions to characterize it.
3. Mathematical statistics	Tracking of quantitative trends, dynamics, outliers, and recurring fluctuations.
4. Hybrid approach	Integration of different heterogeneous tools adapted for narrow, local, and specific tasks to solve a more global problem.

We would also like to note that the ideas we have conceived for implementation are, in some respects, similar to those presented in a recent article by a small group of Canadian researchers [49]. The article focuses more on computer simulations with different starting model parameters. We decided to implement the modeling of more realistic and reliable trades between the interacting parties.

3. Research Methodology

Based on the theoretical background, a research methodology was developed. The methodology is based on aspects of interactions between economic entities. To adapt the theoretical developments of the authors to the conditions of practical implementation, the aspects of the economic activities of enterprises in the mechanical engineering industry were taken into account. In particular, if we consider the direct interaction of an enterprise with its counterparties in the engineering complex, then, the strategic plan should take into account the need for extensive actions in certain key areas of the interaction: suppliers of basic resources (P), primary buyers of products (U), intermediary companies (K), and support resource providers (L) [5,6,50]. For the clarity of visualizing potential interactions between the listed areas, let us present them in the form of a system (as shown below, in the totality of the objects under study, the suppliers as a whole can be divided into main and auxiliary categories):

$$\begin{cases} \begin{cases} P = \{p_1,\ p_2,\ p_3,\ \ldots\} \\ L = \{l_1,\ l_2,\ l_3,\ \ldots\} \end{cases} \\ U = \{u_1,\ u_2,\ u_3,\ \ldots\} \\ K = \{k_1,\ k_2,\ k_3,\ \ldots\} \end{cases}. \quad (1)$$

The result of this approach may be the adaptation of game modeling to build an algorithm in order to optimize the interaction of an economic entity with specific counterparties. The selection of counterparties is carried out according to specified groups, which is combined with their influence on the functionality of the machine-building enterprise. In order to maximize the competitiveness of engineering enterprises, it is necessary to maximize the efficiency of production and economic activities by identifying and accounting for counterparties for the interaction. Strategy planning should take into account aspects of the interaction at different stages of reproduction, implying adjustments to operational and strategic plans in connection with changes in the production system or market conditions.

Directly constructing a game algorithm to implement the interaction between counterparties requires a number of complex steps, but the use of modern technological capabilities makes it possible to effectively integrate game mechanisms into the strategic planning system of economic entities. Consequently, it becomes possible to take into account a complex of data to build algorithmic actions aimed at synergistic impact, reducing risks when implementing strategic decisions.

In conditions of market dynamics, uncertainty gives rise to a diverse probability of the occurrence of various events and actions of players, posing an objective task of conducting a multi-probability analysis. Game tools are justified if there are dependencies and conditions of action between participants in the economic process. For machine-building enterprises, it is permissible to use a set of methods and approaches to build sound plans. Consequently, the research methodology takes into account various directions for modeling, defining methods and models for decision-making under conditions of incomplete information and uncertainty.

3.1. Mutual Influence Indices

In many ways, the success of gaming interactions is associated with the presence of the mutual influence between economic entities. For this purpose, we introduce an index of mutual influence, which is a method that allows for the adaptation of game criteria. Based on stable connections between economic entities, the mutual influence index allows us to take into account the synergy from the cooperation between counterparties. The introduction of an index into the final matrix improves the quality of management decisions, taking into account the complex relationships between the subject and its elements. The result of this is the selection of the most significant counterparties from the many alternatives available on the market (Figure 1).

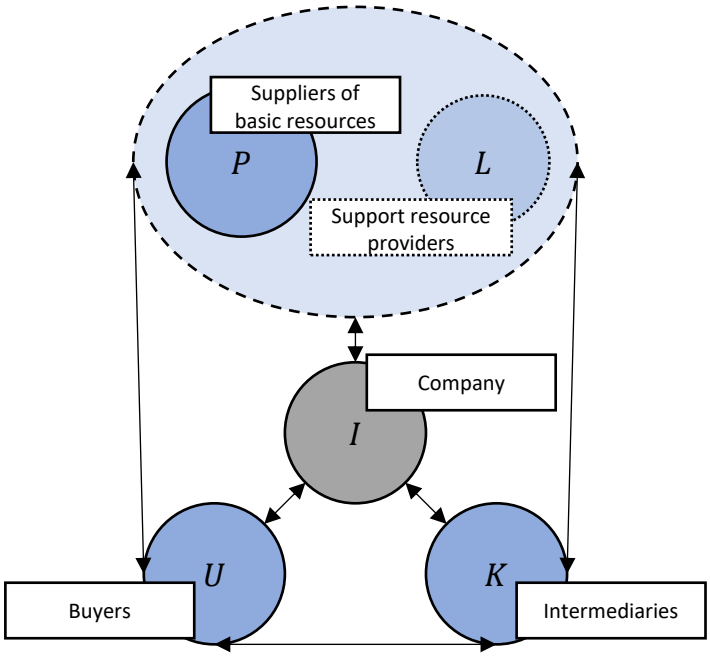

Figure 1. Interaction between market participants.

As shown in the figure, there is an interaction between all the objects (the gray node I indicates the integral assessment of a machine-building enterprise). The auxiliary suppliers L and their association with the main suppliers P are noted. In this regard, they can be considered either as a separate link in the existing network (which makes the assessment more accurate and reliable but less simple from a computational point of view) or as an adjustment to the main ones (here, accordingly, sacrificing rigor, we obtain a simplified but operational result).

Assessing potential risks by taking into account the mutual influence index expands the possibilities for choosing the optimal options for the interaction with the counterparties. The mutual influence index allows one to evaluate the effect of "cooperation" in the game, which allows one to adapt the tools and create a game algorithm for assessing stable connections between economic entities. The resulting algorithm is aimed at optimizing the planning system. Despite the limitations of the gaming algorithm in determining the final number of player strategies, the use of statistical information and retrospective analysis makes it possible to select effective counterparties and establish stable relationships.

3.2. Risk and Cooperation Coefficients

When developing strategies for intercorporate interactions, there is a noticeable error in reducing their effectiveness due to the incompetence of partners or, conversely, the possibility of increasing the final efficiency due to the stable connections and loyalty of counterparties. Such conditions can be taken into account in the game algorithm for selecting counterparties. To maximize the effectiveness of interaction strategies between enterprises, we propose applying the risk coefficient R and cooperation coefficient C, taking into account the uncertainty of the obtained efficiency values without a retrospective analysis of the interaction parameters. These coefficients can be calculated based on a sample of interaction parameters, adapting them to the specific actions of counterparties.

$$R = \sum \beta_R k_R, \tag{2}$$

where k_R is the potential possible damage from the occurrence of any incident (in accordance with empirical practice) and β_R is the adjustment of the damage after expert discussion of the current situation.

$$C = \sum \beta_C k_C, \tag{3}$$

where k_C is the potential positive effect of cooperative interactions and β_C is the adjustment of the effect after expert discussion of the current situation.

The final efficiency E is given as follows:

$$E = C - R. \tag{4}$$

3.3. Key Modeling Indicators

We propose analyzing the following financial and economic aspects: the structure of the enterprise's property with the sources of its formation, business activity (turnover), and financial results. These indicators are used in this methodology to determine the prospects of an economic entity and identify potential trajectories and opportunities for implementing the interaction (Table 2). The considered set of ratings and metrics serves as the basis for the analysis of the financial and economic activities of companies and is conditioned by the historical practice of its conduct and management.

Table 2. Financial and economic aspects of the enterprise (resulting indicators).

Structure of the Enterprise's Property and Sources of Its Formation	Business Activity (Turnover)	Financial Results
• current assets; • stocks; • accounts receivable; • cash and cash equivalents; • borrowed funds; and • accounts payable.	• asset turnover; • working capital turnover; • inventory turnover; • accounts receivable turnover; • accounts payable turnover; • capital turnover; • capital productivity; etc.	• net profit; • revenue; • *EBIT*; • return on sales; • return on assets; • return on capital employed; etc.

The indicators listed below in the table, in general, are used together to forecast the probability of bankruptcy of a particular company. Consequently, the probability of the organization collapsing may indicate its current resilience to economic shocks and, accordingly, its level of strength. More details about this can be found in the following article [51].

The indicators that serve as metrics for determining the optimal assessment of the interaction with a particular counterparty may be as follows:

- the average cost of production;
- the average discount on products;
- the costs of cooperation;
- the time needed to search for a counterparty;
- the time of conclusion of the contract;
- the dates of transactions;
- the reliability of the counterparty;
- the product quality;
- the remoteness of the supplier; and
- the possibility of obtaining a deferred payment.

The presented list of indicators, to some extent, is publicly available to be filled in with real numerical data and can be extracted from the internet through ordinary browser searches. Additionally, specialized software tools can be used, which are briefly discussed

in another work [52]. Unlike the company's own state, data on counterparties will always be partially hidden or distorted. That is why the possibility of obtaining them is one of the key conditions for building the list of indicators by which we will conduct the assessment later.

The list of statistical estimates can be expanded, which should hypothetically lead to greater accuracy of the calculated results realized by the algorithm. In addition to financial indicators, assessments characterizing the information or intellectual capital of the company can be used [53].

3.4. Game Interaction Algorithm

After the database is formed, it becomes possible to build an algorithm for selecting the counterparties, taking into account incomplete information. This algorithm is based on the tools of mathematical statistics, the methodology of aggregated integral estimates, and the apparatus of game theory. The following stages of the implementation of the algorithm are distinguished below:

3.4.1. Development of a Set of Indicators for Assessing the Performance of Enterprises

Within the framework of the implemented economic practice, three blocks of indicators are formed, which will determine the financial, economic, and production aspects of the enterprise's activities.

$$Y_1 = \left\{ y_1^1,\ y_1^2,\ \ldots,\ y_1^6 \right\}, \tag{5}$$

where Y_1 is the structure of the enterprise's property and the sources of its formation. The other parameters (the values of all the indicators of this block should not differ greatly from a specific value, which is determined by the empirical practice of the researcher and can vary depending on the situation) are as follows:

y_1^1 is the share of current assets, in %. The optimal value is 45%.
y_1^2 is the share of inventories in current assets, in %. The optimal value is 60%.
y_1^3 is the share of accounts receivable in current assets, in %. The optimal value is 15%.
y_1^4 is the share of cash and cash equivalents in current assets, in %. The optimal value is 20%.
y_1^5 is the share of borrowed funds in the structure of liabilities, in %. The optimal value is 45%.
y_1^6 is the share of short-term liabilities in the structure of borrowed funds, in %. The optimal value is 45%.

$$Y_2 = \left\{ y_2^1,\ y_2^2,\ \ldots,\ y_2^7 \right\}, \tag{6}$$

where Y_2 is the business activity (turnover) and the other parameters are as follows:

y_2^1 is the asset turnover, in days. The best value is the smallest value.
y_2^2 is the turnover of the working capital, in days. The best value is the smallest value.
y_2^3 is the inventory turnover, in days. The best value is the smallest value.
y_2^4 is the accounts receivable turnover, in days. The best value is the smallest value.
y_2^5 is the turnover of short-term liabilities, in days. The best value is the largest value.
y_2^6 is the equity capital turnover, in days. The best value is the smallest value.
y_2^7 is the capital productivity, in rub./rub. The best value is the largest value.

$$Y_3 = \left\{ y_3^1,\ y_3^2,\ \ldots,\ y_3^7 \right\}, \tag{7}$$

where Y_3 are the financial results and the other parameters are as follows:

y_3^1 is the net profit, in million rubles. The best value is the largest one.
y_3^2 is the revenue, in million rubles. The best value is the largest one.
y_3^3 is the *EBIT*, in million rubles. The best value is the largest one.
y_3^4 is the return on sales to net profit, in %. The best value is the largest one.
y_3^5 is the return on assets, in %. The best value is the largest one.

y_3^6 is the return on capital employed, in %. The best value is the largest one.
y_3^7 is the return on sales to gross profit, in %. The best value is the largest value.
These blocks can be combined into one single score, denoted by a vector, as follows:

$$I = \{Y_1,\ Y_2,\ Y_3\}. \tag{8}$$

3.4.2. Selection and Assessment of Counterparties

In the market, an enterprise works with many counterparties, which can be designated through the following vector:

$$G = \{g_1,\ g_2,\ \ldots,\ g_n\}, \tag{9}$$

where G is the set of potential counterparties for the interaction.

In accordance with the capabilities of the Internet information space, as well as by direct request to the counterparty in order to obtain the necessary data, the data can be assessed using a combination of the following indicators:

$$g_j = \{x_1,\ x_2,\ \ldots,\ x_{10}\}, \tag{10}$$

where x_1 is the average cost of production, in rub. The best value is the smallest value.

x_2 is the average discount on products, in %. The best value is the largest value.

x_3 represents the costs of cooperation, in thousand rubles. The best value is the smallest value.

x_4 is the time needed to search for a counterparty, in days. The best value is the smallest value.

x_5 is the time of contract conclusion, in days. The best value is the smallest value.

x_6 represents the dates of transactions (profitable or unprofitable, for example, when the enterprise does not have excess funds and requires a loan). The best value is the largest value.

x_7 is the reliability of the counterparty. The best value is the largest value.

x_8 is the product quality. The best value is the largest value.

x_9 is the distance of the supplier, in km. The best value is the smallest value.

x_{10} is the possibility of obtaining a deferred payment, in days. The best value is the largest value.

3.4.3. Modeling of Integral Estimates

Based on the selected indicators, two integral assessments are modeled, which will characterize the enterprises under study and the counterparties with which they may interact.

In such a context, there is a need to evaluate various objects that have many individualized characteristics expressed in different units of measurement. In economics, the problem is further aggravated by the fact that the indicators used for evaluation have an implicit meaning, i.e., depending on the person using them, they are interpreted differently. Additionally, the problem is aggravated by the fact that the obtained result must be accessible and easy to interpret. Integral assessments may be a possible solution.

From many different and seemingly unrelated characteristics, we obtain one single number that can be classified or correlated with any level. This approach also allows one to compare and correlate complex socio-economic objects.

1. Data scaling

This procedure involves bringing indicators recorded in different units of measurement to some conditionally identical dimensional scale. There are two main options for such procedures: standardization and normalization.

- Standardization

$$\widetilde{x_i} = \frac{x_i - \overline{x}}{\sigma(x)}, \tag{11}$$

where x_i is the actual observation value;

$\overline{x}$ is the average for all the observations; and

$\sigma(x)$ is the standard deviation according to the observations.

According to the formula above, the transformed data for the group will give a mathematical expectation equal to 0 and a variance equal to 1. In general terms, various indicators are converted to a dimension with such properties.

- Normalization

In this situation, the set of estimates for the indicator is generally locked on the interval $[0,\ 1]$. Depending on the nature of the indicator under consideration, various formulas may be used to carry out this procedure.

$$\widetilde{x}_i = \frac{x_i - x_{\min}}{x_{\max} - x_{\min}}, \tag{12}$$

where $x_{\max}$ and $x_{\min}$ are the maximum and minimum values according to observations.

This formula serves to normalize an indicator (the higher, the better).

$$\widetilde{x}_i = \frac{x_{\max} - x_i}{x_{\max} - x_{\min}}. \tag{13}$$

This formula is for normalizing indicators that have the best value when minimizing them.

$$\widetilde{x}_i = 1 - \frac{\left|x_i - x_{\text{opt.}}\right|}{\max\left\{\left(x_{\max} - x_{\text{opt.}},\ x_{\text{opt.}} - x_{\min}\right)\right\}}, \tag{14}$$

where $x_{\text{opt.}}$ is the best value of the indicator.

According to the formula, the further the normalized observation is from the ideal, the worse it is.

2. Weighting factors

Modeling the weights of the indicators included in the integral indicator is quite a difficult and fundamental task when developing such assessments. Correctly selected weighting coefficients will allow us to evaluate the situation under study as it really is. At the same time, this position has a manipulative aspect, according to which biased metrics can be obtained. Below are three options for their calculation, with a brief explanation of the advisability of using one or another method.

- Equivalent indicators

The simplest option for constructing an integral assessment is the summation of scaled indicators multiplied by equally distributed weights between them. The formula for finding them is as follows:

$$w_j = \frac{1}{n}, \tag{15}$$

where n is the number of indicators used to model the integral assessment.

This option, due to its simplicity, is not appropriate when an object is assessed according to a very large number of indicators. If they are correlated, then, the same characteristic will be taken into account several times in the overall assessment.

- For the first principal component

This method was highly developed and popularized by S.A. Ayvazyan and tested on the example of a regional assessment of the quality and lifestyle of the population of the Russian Federation [54]. In a similar way, an assessment of the scientific and technological potential of the regions was carried out in Russia [55], as well as the state of the forest stand of Huanglong Mountain [56].

In [57], the problem of the adequacy and reliability of integral assessments was raised, and a variant of their possible verification was proposed. The existence of this problem was written in an accessible form [58].

The essence of the methodological framework lies in the analysis of the main components. Let us say that from the initial indicators, we model a certain aggregated estimate, according to which it is possible to restore the original ones in such a way that the sum of unrecovered balances is minimal. Provided that the original values are restored through linear regression from the aggregated indicator, the sum of squared residuals will be minimal if the coefficients in front of the indicators that form the integral indicator by summing them are taken in accordance with the values of the eigenvector of the first principal component.

To normalize these coefficients (their sum will be equal to 1), when working with standardized data, they need to be squared:

$$w_j = {u_j}^2. \tag{16}$$

The data are taken in their original form. Then, the square of the coefficients are divided by the corresponding eigenvalue:

$$w_j = \frac{1}{\lambda}{u_j}^2, \tag{17}$$

where u_j is the value of the eigenvector corresponding to the indicator j and λ is the eigenvalue of the first principal component.

However, the problem here is that the most correlated indicators receive the most weight. When modeling an integral assessment, this is reflected in the repeated consideration of the same factor. The solution may be to construct an aggregated indicator using a correlation matrix (another development option is presented in [59]).

- According to the correlation relation

As mentioned earlier, socio-economic indicators are often interpreted ambiguously, which is why the same processes and phenomena can be characterized by different assessments that quantitatively express the same thing. Such indicators for modeling an integral assessment lead to the duplication of accounting for the same thing several times.

This problem can be solved to some extent by calculating the linear Pearson pair correlation coefficient. To do this, use the sample to find a classic correlation matrix for the indicators selected to create an integral assessment. Then, for each indicator, calculate the sum of squares of its correlations with other indicators. The larger the amount, the less unique and significant the indicator is. Its weight can be determined as the share of the inverse value indicated above in the aggregate of similar estimates for other indicators:

$$w_j = \frac{\dfrac{1}{\sum_i \left(r_i^j\right)^2}}{\sum_j \dfrac{1}{\sum_i \left(r_i^j\right)^2}}, \tag{18}$$

where r_i^j is the correlation coefficient between indicators j and i.

Instead of squares, modules can be taken, which, to some extent, is interpreted more clearly. The disadvantage is that with a small amount of data, the resulting weights will be biased. With squares, convergence to the true values is faster.

3. Modeling the interaction of an enterprise with contractors

To maximize efficiency, one should diversify the interaction with counterparties, that is, select several participants in joint activities and distribute one's limited resource among them. To do this, by relying on the interaction matrix, it is necessary to select the lines that we will focus on from it, select the number of counterparties with whom we want to interact, and select the criterion [60], in accordance with which the counterparties for the interaction are determined.

This stage is quite complex and subjective. In practice, the selection of the designated parameters and their subsequent adjustment will be based on one's business experience, business sector, and changing economic conditions caused by the rapid development of digital technologies.

None of the criteria listed below is better or worse than the others. A high level of understanding of the subject of research is required for their use; so, one can choose a specific theoretical game principle.

- Laplace criterion

$$\max_i \sum_j h_i^j, \tag{19}$$

where $\max_i$ is the maximum value of the Laplace criterion among the years of operation of the enterprise selected for consideration and h_i^j is the assessment of the enterprise's interaction with the counterparty j per year i.

According to the criterion, the most favorable year is selected, and the resource is distributed in accordance with the set of best estimates for a given number of counterparties.

- Bayes–Laplace criterion

If there is information about the frequency of successful interactions with the counterparties, then the Laplace criterion can be modified into the Bayes–Laplace criterion:

$$\max_i \sum_j p_j h_i^j, \tag{20}$$

where p_j is the probability of successful interactions with the counterparty j in accordance with the frequency of working with him in the past.

- Extreme optimism criterion

$$\max_i \max_j a_i^j, \tag{21}$$

where a_i^j is the sum j of the combination of interaction estimates for a given number of counterparties per year i.

- Wald criterion

$$\max_i \min_j h_i^j. \tag{22}$$

- Hurwitz criterion

$$\max_i \left(\alpha \left(\frac{\max_j a_i^j}{l} \right) + (1 - \alpha) \min_j h_i^j \right), \tag{23}$$

where α is the estimate of optimism on the interval $[0, 1]$ and l is a specified number of counterparties with whom we want to interact.

- Savage criterion

For this criterion, it is necessary to recalculate the considered years of the interaction matrix in accordance with some estimate of the loss that can be obtained without choosing the best counterparty:

$$r_i^j = \max_i h_i^j - h_i^j. \tag{24}$$

The criterion itself is as follows:

$$\min_i \max_j r_i^j. \tag{25}$$

4. Review of the counterparties

The review of the counterparties is based on the modification of the model, taking into account a game component or premise. Hypothetically, when interacting with certain counterparties, they will build a certain dictate regarding us, i.e., create conditions that are less favorable for us and more favorable for themselves. Accordingly, the interaction with other counterparties may become a priority.

In this regard, we will recalculate the interaction distribution, reducing the integral estimates of the selected counterparties by the corrected standard deviation s. We decide to leave or replace the participants with whom we want to cooperate based on old and new interaction assessments, choosing the best ones.

The adjustment of integral estimates can be increased, for example, to 3 s (in accordance with the three-sigma rule). This is appropriate step to take if we confidently assume that the counterparties available for selection are unreliable, thereby introducing more serious risks into the interaction model.

4. Research Results

At the first stage, initial data on the analyzed enterprise were collected, which makes it possible to test the model on a real subject (Table A1).

Next, data on potential counterparties were analyzed (Table A3). Ten suppliers of the main resource were selected from the analyzed mechanical engineering enterprise.

According to the methodology of integral assessments and the available initial data, the following results were obtained (Tables A2 and A4). Most of the calculations were carried out using the *Excel 2108* spreadsheet editor. The main component was found using the *Python* library—*scikit-learn*, using the *sklearn.decomposition.PCA* class.

In accordance with the calculated integral estimates, a payment matrix of interactions between the enterprise and the contractors was constructed. The following are aggregated indicators calculated using the correlation ratio (Table 3).

Table 3. Interaction between the enterprise and the contractors.

		$I_{corr.}$	**3.1215**	**3.3789**	**3.7664**	**4.1206**	**4.9105**	**5.0514**	**5.1314**	**5.2228**	**5.6950**	**6.4135**
		Normal	**0**	**0.0782**	**0.1959**	**0.3035**	**0.5434**	**0.5862**	**0.6105**	**0.6383**	**0.7817**	**1**
$I_{corr.}$	**Normal**	**Counter** / **Years**	g_8	g_6	g_2	g_7	g_9	g_5	g_4	g_{10}	g_3	g_1
5.4801	1	2021	0	0	0	0	0.1599	0.2942	0.3621	0.4333	0.7208	1
5.3513	0.9514	2014	0.0486	0.0527	0.0604	0.0697	0.2493	0.3771	0.4416	0.5094	0.7829	0.9514
5.3018	0.9328	2017	0.0672	0.0729	0.0836	0.0965	0.2836	0.4089	0.4722	0.5386	0.8068	0.9328
5.2270	0.9045	2018	0.0955	0.1036	0.1187	0.1371	0.3355	0.4571	0.5184	0.5829	0.8429	0.9045
5.2263	0.9043	2019	0.0957	0.1038	0.1190	0.1374	0.3360	0.4575	0.5188	0.5832	0.8432	0.9043
5.0476	0.8369	2013	0.1631	0.1769	0.2028	0.2341	0.4600	0.5724	0.6292	0.6888	0.9294	0.8369
4.4695	0.6189	2012	0.3811	0.4134	0.4739	0.5471	0.8611	0.9442	0.9862	0.9697	0.7918	0.6189
3.5155	0.2593	2016	0.7407	0.8036	0.9212	0.9365	0.4771	0.4422	0.4246	0.4062	0.3316	0.2593
3.1104	0.1065	2020	0.8935	0.9693	0.8889	0.7172	0.1960	0.1817	0.1745	0.1669	0.1363	0.1065
2.8279	0	2015	1	0.9152	0.7564	0.5643	0	0	0	0	0	0

0—The worst interaction option and 1—the best interaction option.

In the rows and columns of the table presented above, under the heading "Normal", the corresponding integral $I_{corr.}$ estimates are normalized according to one of the normalization formulas presented in this work. The values of the interaction matrix are calculated from the idea that the best counterparty will predominantly perform effectively only if the score indicates our high solvency (other sustainable partnership schemes are hypothetically possible). Based on this, to calculate the required estimates, another normalization formula can be used, where $x_{opt.}$ is the corresponding normalized integral assessment of the counterparty and x_i is an aggregate indicator of the state of the enterprise, which is calculated for a specific year.

According to the Laplace criterion, one should focus on 2020 (its value is 4.43). In accordance with this, the distribution of contracts will be between counterparties g_6, g_8, and g_2 in a ratio of 0.35 : 0.32 : 0.32.

In the case of extreme optimism, the best experience also occurred in 2020 (its value is 2.75). In accordance with it, the subject must interact with the same counterparties, i.e., g_6, g_8, and g_2, in the same ratio, i.e., 0.35 : 0.32 : 0.32.

According to the Wald criterion, one should focus on the year in which the best of the worst estimates of the interaction are recorded. Once more, this year was 2020 (Wald criterion—0.11), according to which the distribution should be realized between counterparties g_6, g_8, and g_2 in a ratio of 0.35 : 0.32 : 0.32.

The Hurwitz criterion is a generalization of the extreme optimism and Wald criteria. In this case, $\alpha = 0.5$; the value of the required indicator reached a maximum again in 2020 (Hurwitz criterion—0.51), which means that the interaction between counterparties g_6, g_8, and g_2 is proposed to be carried out in a ratio of 0.35 : 0.32 : 0.32.

According to the Savage criterion, 2019 was the best year (its value is 0.81). The distribution of contracts will be carried out after normalizing the estimates, i.e., r_i^j, using one of the indicated formulas in accordance with the three new best values obtained. The potential counterparties will thus be g_1, g_3, and g_{10}, and the proportion of the distribution between them will be 0.40 : 0.37 : 0.24. A summary of the calculations is presented below (Table 4).

Table 4. Distribution of interactions with counterparties.

Laplace criterion (2020)—4.43.		
g_6	g_8	g_2
0.35	0.32	0.32
Extreme optimism criterion (2020)—2.75		
g_6	g_8	g_2
0.35	0.32	0.32
Wald criterion (2020)—0.11		
g_6	g_8	g_2
0.35	0.32	0.32
Hurwitz criterion (2020) at $\alpha = 0.5$—0.51		
g_6	g_8	g_2
0.35	0.32	0.32
Savage criterion (2019)—0.81		
g_1	g_3	g_{10}
0.40	0.37	0.24

Then, the interaction distribution was recalculated, as a result of which the integrated estimates of the selected counterparties were reduced by the corrected standard deviation ($s = 1.0538$). The new distribution is as follows (Table 5).

Table 5. Distribution of interactions with counterparties after the revision.

Laplace criterion (2020 → 2019)—4.43 → 5.08		
g_6	$g_8 \rightarrow g_3$	$g_2 \rightarrow g_1$
0.35	0.32 → 0.33	0.32
Extreme optimism criterion (2020)—2.75 → 2.79		
g_6	$g_8 \rightarrow g_2$	$g_2 \rightarrow g_8$
0.35 → 0.34	0.32 → 0.34	0.32
Wald criterion (2020)—0.11		
g_6	$g_8 \rightarrow g_2$	$g_2 \rightarrow g_8$
0.35 → 0.34	0.32 → 0.34	0.32
Hurwitz criterion (2020) at $\alpha = 0.5$—0.51 → 0.52		
g_6	$g_8 \rightarrow g_2$	$g_2 \rightarrow g_8$
0.35 → 0.34	0.32 → 0.34	0.32
Savage criterion (2019 → 2020)—0.81 → 0.88		
g_1	$g_3 \rightarrow g_6$	$g_{10} \rightarrow g_3$
0.40 → 0.34	0.37 → 0.34	0.24 → 0.32

→ An indication of a change in the values of the criteria downwards, a change in the year under consideration to a more distant one from the current point in time, and a change in the counterparty and the distribution of the interaction with it remaining unchanged or worsening. → An indication of reverse changes →.

In accordance with all of the above, under Section 4, the following diagram of the algorithm of actions of the enterprise management in selecting counterparties for the interaction can be constructed (Figure 2).

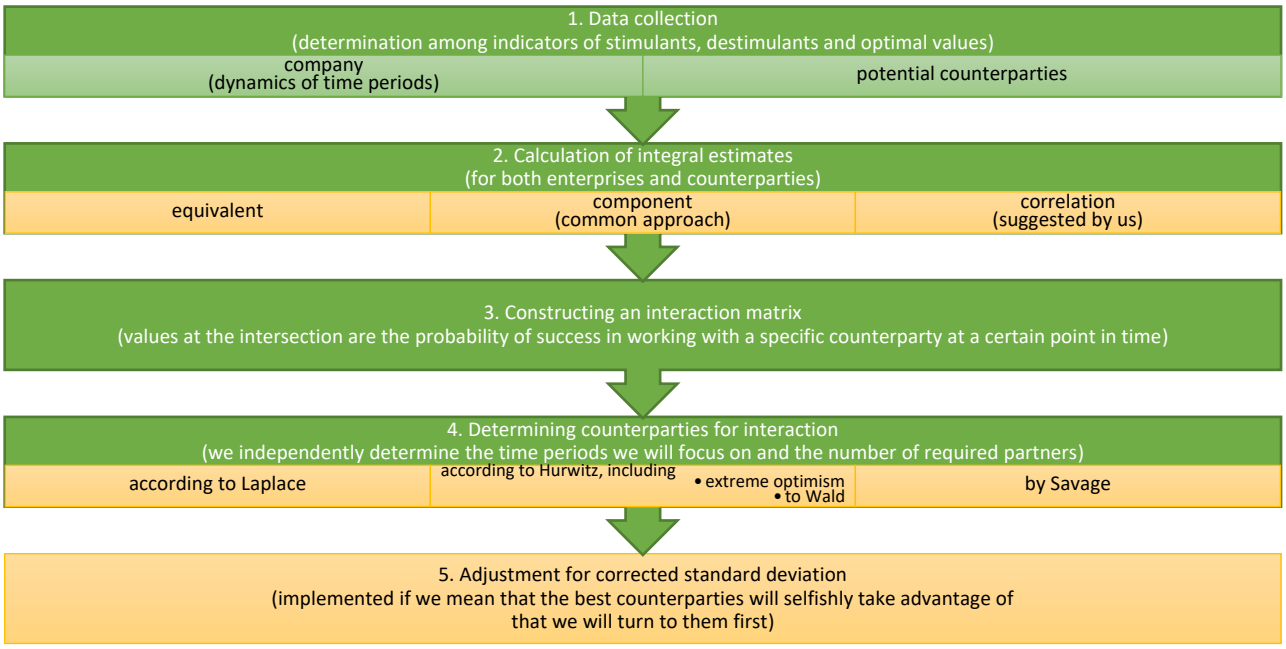

Figure 2. Procedural scheme for selecting counterparties for interaction. —Mandatory procedures. —Selective procedures depending on the characteristics of the situation under consideration.

5. Discussion and Addition of Results

5.1. Extending the Game Component Using Heuristics

The presence of uncertainty allows us to develop the task of finding the best counterparty through the use of multicriteria analysis tools. One of its methods is a detailed analysis of network interactions or hierarchies [61,62].

For a specific task, there is a pre-compiled list of possible contractors, i.e., G. Moreover, each of them is characterized by a set of qualitative and quantitative indicators, i.e., g. The decision maker on the part of the machine-building enterprise must select one counterparty that best meets the requirements and determine whether cooperation is planned with him or whether the relationship will take the exclusive form of issuing and executing orders. The presence of cooperation implies mutual benefit for both the machine-building enterprise and the counterparty. If there is no benefit for at least one of the parties, such cooperation becomes impossible.

The process of making decisions about the interaction for the parties occurs independently of each other; therefore, first, there is a non-cooperative game with two participants, each of whom has two possible strategies (to cooperate or not). Then, the procedure described below can be applied in one direction or the other.

For the criteria g under consideration, a matrix of pairwise comparisons, i.e., A, is constructed. The element a_i^j describes the relative priority of the indicator i over j. At the same time $a_i^j = \frac{1}{a_j^i}$ and $a_i^i = 1$. The grades can be given in accordance with the scale proposed by T.L. Saati. For the resulting matrix, find its maximum eigenvalue λ and its corresponding eigenvector $\vec{u}$ such that $\lambda\vec{u} = A\vec{u}$. Having normalized $\vec{u}$ with respect to the sum of all its values, we obtain a vector of weights of counterparty indicators, i.e., $\vec{w}$.

Next, within the framework of each indicator by which we evaluate potential partners, we build matrices of the pairwise comparisons of the counterparties, i.e., B_G. For each of them, we find the maximum eigenvalue λ, its eigenvector, normalize it, and obtain the corresponding distribution of the counterparties.

Having collected a matrix from all distributions, where the rows are the counterparties and the columns are the indicators by which the ranking was carried out, one can multiply it with the vector of indicator weights, i.e., $\vec{w}$. This will result in the final distribution of all the counterparties, taking into account all the possible indicators by which we assessed them.

This is not the only option for designing a computational procedure. The main point here is that without having statistical information on the objects of interest to us, we can still determine their priority for ourselves. The method is a heuristic that allows us to quickly solve complex applied problems. Within this framework, a heuristic approach such as TOPSIS may also be of interest [63].

5.2. Game Interaction Algorithm

When identifying the appropriate counterparties for an interaction based on integral estimates, a kind of bidding potentially begins with them. They can be visually represented in the form of a graph. If it satisfies the condition of complete information, i.e., since all participants in the interaction know about the consequences of each other's decisions, it is possible to find an unambiguous solution to such a game.

It should be noted that such a decision graph should not be very large; otherwise, the interpretation of the game becomes implausible and far from a real-life situation. An illustrative standard option for interactions with a specific counterparty is presented below (Figure 3).

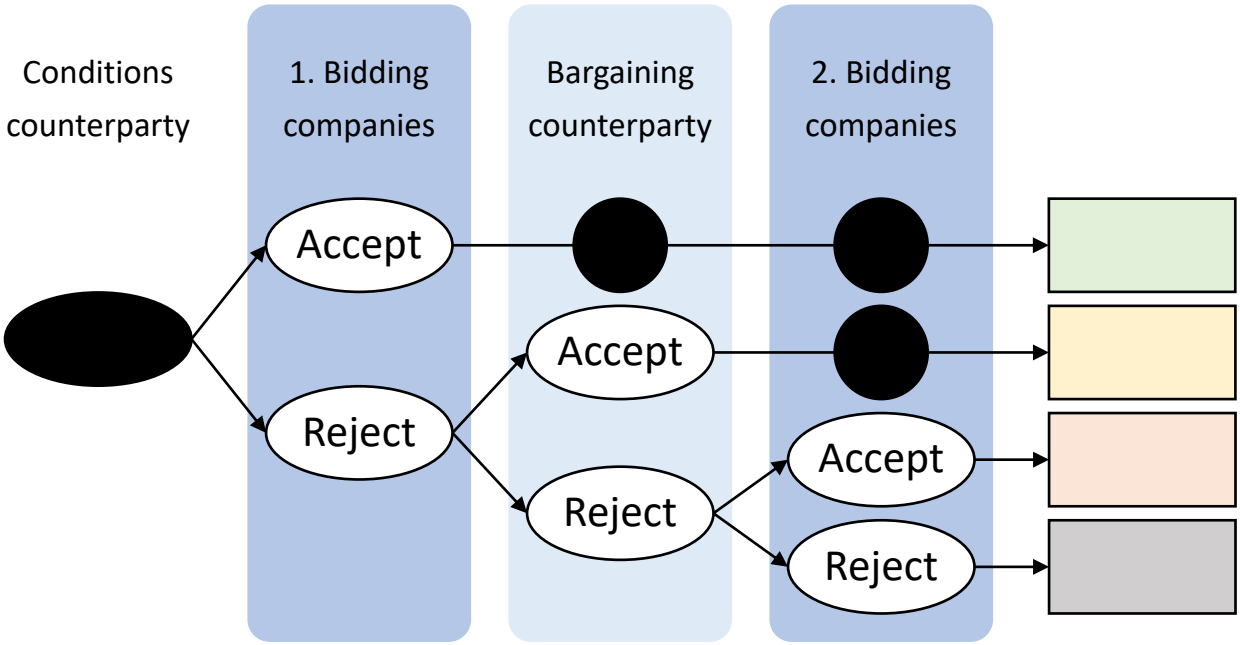

Figure 3. Trading with a standard counterparty.

The constructed graph can also be successfully represented in the form of a matrix (Table 6). Its cells are filled in accordance with the shaded rectangular areas in the figure.

Table 6. Trading matrix with counterparty.

Company \ Counterparty	Accept	Reject
Accept→accept		
Accept→reject		
Reject→accept		
Reject→reject		

The final situation corresponding to those indicated in Figure 3 is highlighted in color.

When considering an example of a positional game with a counterparty, taking as a basis the participants in the interaction in the example in which testing was carried out, the revised Hurwitz criterion is 0.52. In accordance with it, trading should be carried out sequentially with g_6, g_2, and g_8. The potential graph (Figure 4) and matrices (Tables 7 and 8) of the company's bidding with the first candidate for the interaction and the counterparty with the company are presented below. The resulting theoretical calculations and conclusions on this basis are to some extent akin to the game "Hawks and Doves" [64].

If we consider the implemented bidding procedure, we can outline the following ideas:

1. In accordance with the order, the counterparty puts forward certain basic conditions, the assessment of which can be indicated by a unit—1.
2. The subject can accept these conditions, and then, the winnings will be equal to 1, but can also try to push for a more advantageous position in the form of an increase in the discount, according to which the potential winnings can increase to 1.2 units.
3. The counterparty may agree to this condition or make a partial concession, for example, increasing our winnings to 1.1 units, which is ultimately still better than the base position.
4. If the final conditions of the subject are not satisfied, then, he proceeds to negotiations with the next counterparty, i.e., g_2.

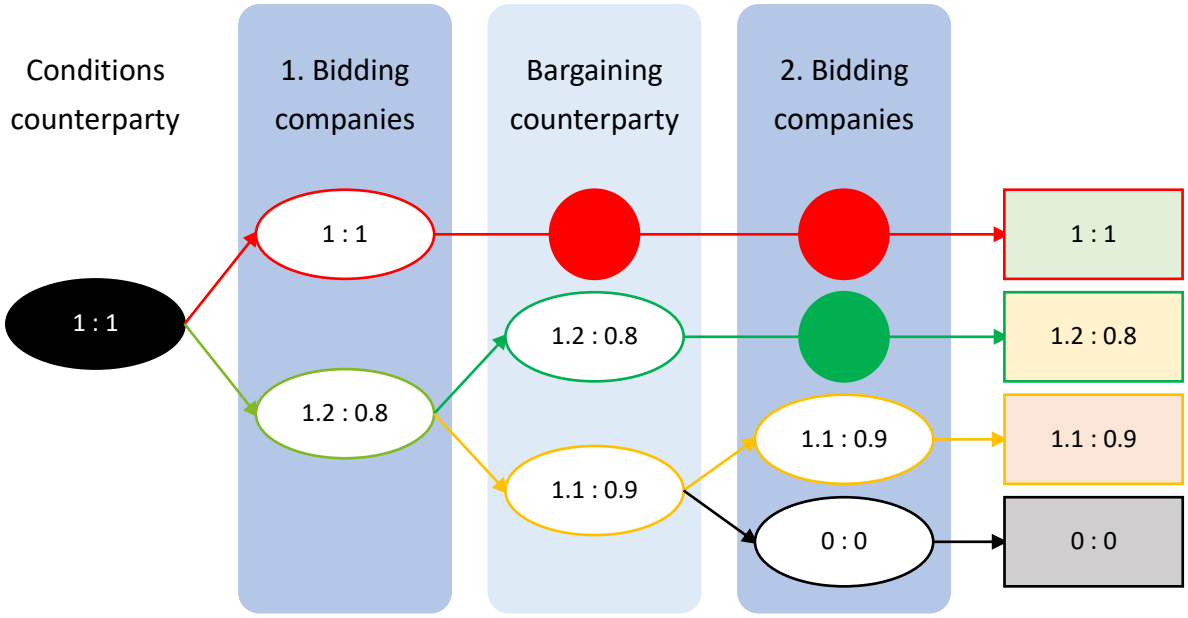

Figure 4. Trading with a standard counterparty. → The path according to which the company's maximum gain and the counterparty's gain can be obtained in pure strategies; → the path by which a company's gains in pure strategies can be achieved; → the path that is common for the maximum gain of the company and its own in pure strategies; → the path according to which the maximum winnings of the counterparty can be obtained; and → the path according to which partner relationships will be undermined.

Table 7. Trading matrix with a standard counterparty.

		Counterparty			
		Accept	**Reject**	**Min**	**Max min**
Company	Accept → accept	1	1	1	
	Accept → reject	1	1	1	
	Reject → accept	1.2	1.1	1.1	1.1
	Reject → reject	1.2	0	0	
	Max	1.2	1.1		
	Min max		1.1		

The final situation and path corresponding to those shown in Figure 4 are highlighted in color.

Table 8. Trading matrix of a standard counterparty with a company.

		Company					
		Accept → Accept	**Accept → Reject**	**Reject → Accept**	**Reject → Reject**	**Min**	**Max min**
Counter party	Accept	1	1	0.8	0.8	0.8	0.8
	Reject	1	1	0.9	0	0	
	Max	1	1	0.9	0.8		
	Min max				0.8		

The final situation and path corresponding to those shown in Figure 4 are highlighted in color.

The configuration of the auction may be modified depending on any specific conditions, but in general, it can be noted that one should not agree with a standard seller on his primary conditions. If successful, the subject will receive a more favorable agreement; in case of partial success, it will still be slightly better than what was agreed upon at the beginning (this can be to some extent evidenced by the intersection of the paths of maximum gain for the company and its own in pure strategies (Figure 4)).

In accordance with the implementation of pure strategies by the company, generally, the counterparty also does not have to agree to the primary conditions put forward by the enterprise. Based on this, at the very beginning of trading, one should slightly overestimate the amount of the planned winnings since it will potentially be underestimated anyway.

If we consider these trades from the position of the counterparty, under no circumstances will his actions in pure strategies consist of losing his client (Table 8) and, therefore, he will have to accept the conditions of the subject. In principle, this can be illustrated by a simpler graph (Figure 5) and bidding matrices (Tables 9 and 10), where the company dictates its terms.

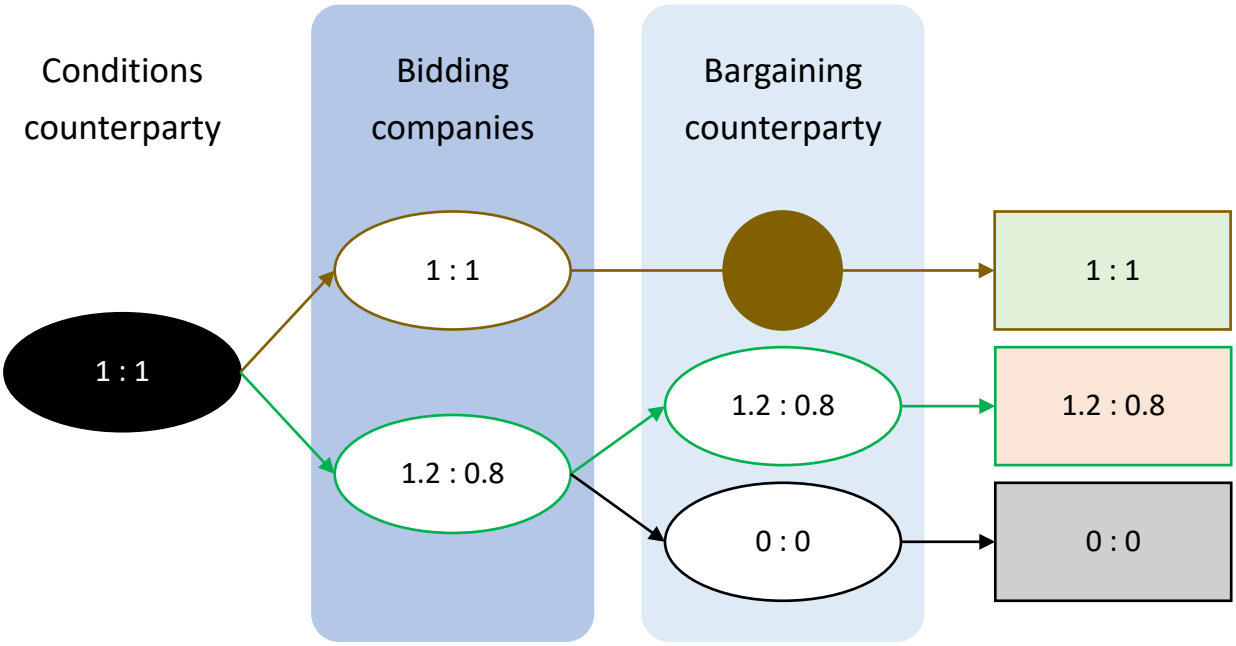

Figure 5. Trading with a weak counterparty. → The path according to which the maximum winnings of the company and the winnings of the counterparty can be obtained in pure strategies; → the path according to which the company's winnings in pure strategies and the maximum winnings of the counterparty can be obtained; and → the path according to which partner relationships will be undermined.

Table 9. Matrix of trading with a weak counterparty.

		Counterparty			
		Accept	**Reject**	**Min**	**Max min**
Company	Accept	1	1	1	1
	Reject	1.2	0	0	
	Max	1.2	1		
	Min max		1		

The final situation and path corresponding to those shown in Figure 5 are highlighted in color.

Table 10. Weak counterparty bidding matrix.

		Company			
		Accept	**Reject**	**Min**	**Max min**
Counter party	Accept	1	0.8	0.8	0.8
	Reject	1	0	0	
	Max	1	0.8		
	Min max		0.8		

The final situation and path corresponding to those shown in Figure 5 are highlighted in color.

It is also possible that the counterparty is completely independent and, in accordance with this, issues an ultimatum that the subject will have to accept in order to interact with him. A similar unambiguous illustration is presented below (Figure 6):

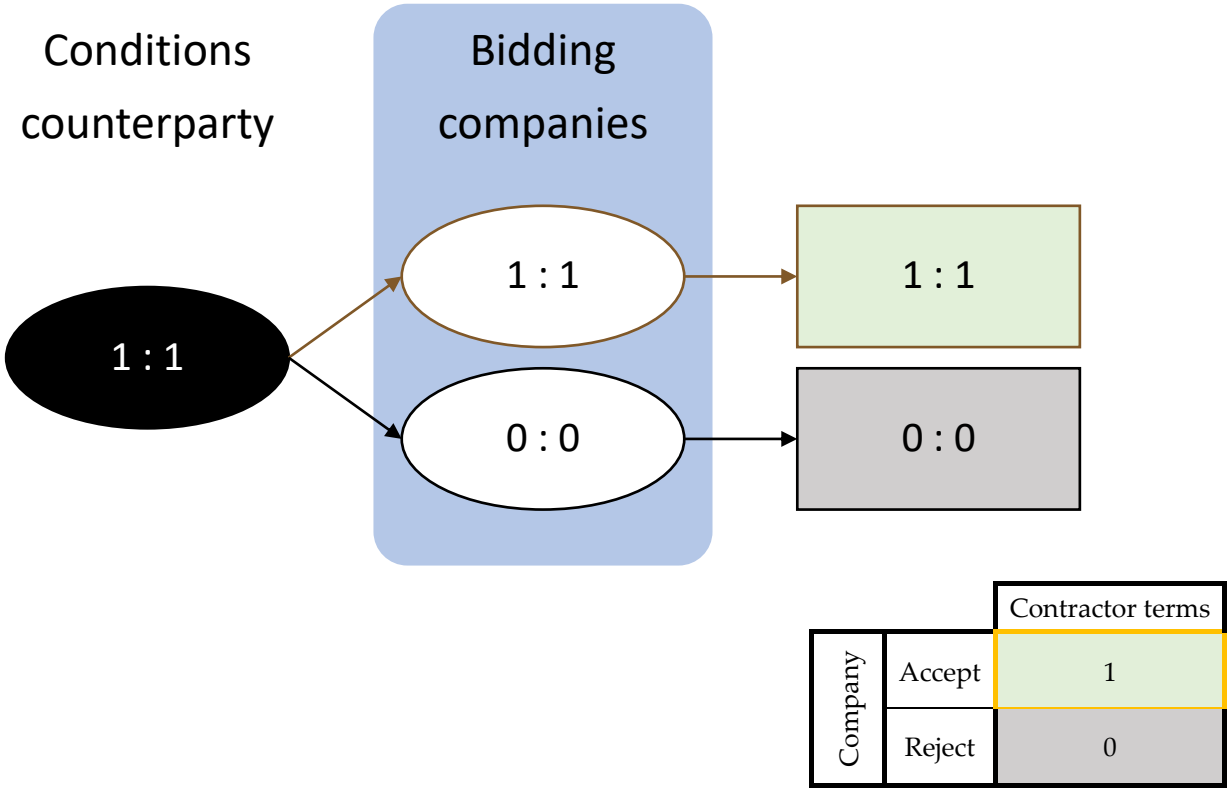

Figure 6. Trading with a weak counterparty. → The path according to which there is only one solution to obtain a win. → The path according to which partner relationships will be undermined.

From all the three situations analyzed, one very interesting point can be seen: if the counterparty does not want to lose the client under any circumstances, he will definitely accept the conditions. In this case, his decision in pure strategies will coincide with the best outcome for the company. When a company implements a solution in pure strategies, some compromise will be worked out. In this case, the company will not receive the maximum possible gain but will maintain stable ties with its business partner.

The trading ideas discussed above can, to some extent, be formalized as follows:

$$\begin{cases} I \in I_g \pm s, \text{ bargaining} \\ I \notin I_g \pm s \begin{cases} I > I_g, \text{ dictate your own conditions} \\ I < I_g, \text{ compliance with the terms and conditions of the counterparty} \end{cases} \end{cases}, \quad (26)$$

where I is the integral assessment of the enterprise;

I_g is the revised integral assessment of the counterparty; and

s is the corrected standard deviation in the aggregate of recalculated integral estimates of the counterparties.

According to our data and the agreed upon methodology, the implementation of the "game" with the counterparties is as follows (Table 11). It is noteworthy that the estimates are taken according to the revised Hurwitz criterion, according to which all participants in the interaction are traded according to a scheme describing a standard counterparty (Figure 4). Thus, at first, we try to improve the terms of the contract, and then, we agree to new, potentially more favorable, terms from the trading partner.

Table 11. Implementation of trades with selected counterparties for interaction.

$s \approx 1.50$	$I_{g_6} \approx 2.32$	$I_{g_2} \approx 2.71$	$I_{g_8} \approx 2.07$
$I \approx 3.11$	$I \in [0.82,\ 3.83]$ bargaining	$I \in [1.21,\ 4.21]$ bargaining	$I \in [0.57,\ 3.57]$ bargaining

The calculations presented above, as well as the calculation of integral estimates, were carried out in the *Excel 2108* spreadsheet editor. It is worth noting here that the software for implementing game-theoretic models is quite specific and narrow-profile. Some of its variants can be found on the Game Theory Society website [65], and the main features of the software can be found in the article on the computer application *Game Theory Explorer* [66].

6. Conclusions and Practical Implications

The increasingly frequent black swans have led to constant changes in supply chains, thus destabilizing them. In this regard, the importance of solving the problem of optimizing interactions with counterparties in the face of uncertainty has increased in the mechanical engineering complex. The comprehensive game algorithm developed by us takes into account the diversity of counterparties' behavior strategies on the market. This will enable the rationalization of a sustainable strategic planning system, which, in the era of digitalization, should become more flexible and responsive.

In this research, particular emphasis is placed on mathematical formalism and the development of an algorithm that integrates the principles of game theory and multicriteria analysis. This study presents an integrated approach to optimizing the interaction of economic entities with counterparties, aimed at increasing the stability and efficiency of business relationships. The basis of the game-theoretic approach made it possible to construct payment matrices for interpreting interaction strategies and, in practice, to consider various scenarios, including the conditions of competition and cooperation.

The research methodology is supplemented by the calculation of integral estimates based on a set of financial and economic indicators. This approach made it possible to use a real example to evaluate the impact of various interaction strategies on the overall efficiency of an economic entity. The testing of the developed models made it possible to obtain data that can be used to optimize the strategic planning of a machine-building enterprise from the perspective of managing its interaction with contractors. It can be concluded that the developed gaming algorithm is an effective tool for improving the operational analysis of enterprises, primarily in industry, helping to increase operational efficiency and optimize strategic interactions.

Our model refers to the currently developing hybrid approach, in which we use a specific mathematical toolkit to solve local problems and then combine the obtained solutions into a single general chain of management actions. In our case, using the multicriteria approach, we collect various indicators on the objects under study, characterizing them from different aspects. Next, using methods of mathematical statistics, we model aggregate indices, which describe complex economic systems in a more visual and simple form. After that, by means of the game theory, we try to predict the behavior of agents in their

interaction. The conducted research can be a basis for further studies of the theory of cooperation of humanitarian and public entities.

The main limitation of the proposed tools is that they are not appropriate for situations where there are few counterparties to interact with, and in fact, we do not have to choose the most suitable one among them for our purposes but build relationships based on the damage that will be received in the event of refusal to cooperate with them. Even if such cooperation is unpleasant for us for some reason, in accordance with economic feasibility, we will still have to maintain partnerships with these entities.

Here, we should note the situation where the necessary information on the considered counterparties may not be fully obtained. In this case, it will be necessary to make some kind of generalization or to model the worst-case scenarios. Having prepared for those, one will definitely be ready for more favorable outcomes. In general, when collecting data, it is worthwhile to follow the principle of "the more, the better".

The main managerial idea of the conducted research is that sustainable and mutually beneficial partnership relations can be built between approximately equal economic subjects. Otherwise, malicious infringement of one's rights and interests is possible.

A potential development of this research could be the use of attractors as integral assessments, which, in essence, should hypothetically more accurately describe a complex dynamic object, representing any company or enterprise. As part of the development of a game-theoretic approach when distributing contracts between identified counterparties, it is possible to implement the concepts of the nucleolus and Shapley vector. Also, according to our algorithm, a full-fledged computer program can be developed as a final summary of all the work conducted.

Author Contributions: Conceptualization, A.Z. and E.M.; Methodology, A.Z.; Software, D.A.; Validation, U.L.; Data curation, N.D. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: Data are contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Dataset for assessing the enterprise under study.

	y_1^1 %	y_1^2 %	y_1^3 %	y_1^4 %	y_1^5 %	y_1^6 %	y_2^1 days	y_2^2 days	y_2^3 days	y_2^4 days	y_2^5 days	y_2^6 days	y_2^7 rub./ rub.	y_3^1 mln. rub.	y_3^2 mln. rub.	y_3^3 mln. rub.	y_3^4 %	y_3^5 %	y_3^6 %	y_3^7 %
2012	54.6	37.7	11.7	47.9	34.7	92.7	129.8	67.1	27.5	8.7	41.3	87.4	6.1	5280.9	86,881.7	6249.2	12.2	17.1	28.8	154.8
2013	57.6	22.8	10.5	63.1	52.2	93.0	126.7	71.2	21.0	7.9	59.2	70.8	6.9	8712.4	105,948.7	10,977.7	9.0	23.7	50.6	95.9
2014	47.5	26.6	21.4	39.9	54.7	90.7	121.1	64.1	15.6	9.6	59.0	56.5	6.8	2491.2	110,591.8	2418.0	2.3	6.8	12.9	51.4
2015	41.3	32.3	41.5	16.3	49.4	92.7	152.7	67.5	19.8	21.1	68.1	73.4	4.6	−1686.2	84,676.8	−1657.3	−1.7	−4.8	−8.9	50.6
2016	36.5	40.8	39.5	8.0	54.0	96.6	138.6	54.0	19.5	21.9	61.5	67.1	4.6	−2613.6	94,587.2	−3058.2	−2.9	−7.3	−16.7	36.4
2017	53.5	22.7	25.7	42.5	56.5	97.3	116.7	53.6	15.6	16.4	61.0	52.1	6.3	3123.1	123,601.2	3846.3	2.9	7.9	21.0	−49.7
2018	51.7	25.2	25.8	32.4	60.7	97.0	118.7	62.4	15.0	16.1	64.1	49.2	6.9	3603.5	137,286.4	4642.7	2.8	8.1	24.1	−70.9
2019	47.0	26.3	25.1	32.0	68.9	97.5	118.9	58.6	15.1	15.0	68.9	41.7	6.3	−171.7	143,529.9	−318.6	−0.1	−0.4	−1.8	1.7
2020	41.6	31.4	26.8	0.8	74.3	97.3	157.5	69.6	20.1	18.1	91.6	44.6	4.6	−1385.1	117,358.1	−1636.0	−1.1	−2.7	−10.7	7.8
2021	41.6	23.8	19.6	28.6	76.1	97.9	136.5	56.8	15.5	13.0	89.2	33.7	5.6	1396.6	155,085.9	2010.0	1.0	2.4	13.1	−6.5

—Stimulant indicator (the more, the better), —disincentive indicator (the less, the better), and —fixed indicator (there is a specific optimal value).

Table A2. Weighting coefficients and integral assessments of the enterprise.

		y_1^1 %	y_1^2 %	y_1^3 %	y_1^4 %	y_1^5 %	y_1^6 %	y_2^1 days	y_2^2 days	y_2^3 days	y_2^4 days	y_2^5 days	y_2^6 days	y_2^7 rub./ rub.	y_3^1 mln. rub.	y_3^2 mln. rub.	y_3^3 mln. rub.	y_3^4 %	y_3^5 %	y_3^6 %	y_3^7 %
Weights	equivalent	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		0.3									0.35							0.35			
	by component	0.079	0.008	0.065	0.083	0.032	0.028	0.028	0.016	0.015	0.072	0.043	0.022	0.055	0.087	0.003	0.084	0.085	0.090	0.082	0.024
		0.294									0.250							0.456			
	by correlation	0.037	0.067	0.042	0.035	0.052	0.066	0.061	0.095	0.062	0.040	0.053	0.052	0.043	0.034	0.064	0.035	0.035	0.033	0.035	0.057
		0.300									0.407							0.293			
2012		4.3925		3.5632		6.9339		4.4908			5.0282		7.7306		4.2252		3.1750			6.5150	
		4.9917										6.1022						4.4695			
2013		2.8233		5.6255		8.3347		2.7552			7.1099		9.4255		2.7158		4.8305			7.7306	
		5.7331										6.8848						5.0476			
2014		5.0452		7.1356		4.2728		6.2440			7.5260		4.2296		4.4226		6.7928			4.3001	
		5.5065										5.6461						5.3513			
2015		4.7245		2.5645		1.4215		5.5612			1.9385		1.1412		4.2288		2.6886			1.5903	
		2.8125										2.6405						2.8279			
2016		3.9048		4.1306		0.8800		3.9942			2.5956		0.2622		3.7319		5.0007			1.2340	
		2.9252										1.9432						3.5155			
2017		3.4019		7.3320		4.3994		4.2317			6.3130		4.6559		2.9243		7.8160			4.2423	
		5.1266										4.9454						5.3018			
2018		3.9204		7.1486		4.7481		5.1444			6.7095		4.8851		3.2997		7.0617			4.6501	
		5.3399										5.4174						5.2270			
2019		4.1955		7.5740		3.1390		5.9417			6.8668		2.1836		3.3977		7.6999			3.6625	
		5.0082										4.4597						5.2263			
2020		3.5698		3.9764		1.9728		4.8822			3.6569		1.2906		2.9878		3.7462			2.3537	
		3.1532										2.9385						3.1104			
2021		3.9775		7.5960		4.3099		6.0508			6.9490		3.4637		3.0781		7.7645			4.7645	
		5.3603										5.0959						5.4801			

Table A3. Dataset for assessing the counterparties.

	x_1 rub.	x_2 %	x_3 thds. rub.	x_4 Days	x_5 Days	x_6 Units	x_7 Units	x_8 Units	x_9 km	x_{10} Days
g_1	1.0640	14.62	955.02	1.5	1.4	0.2800	0.87	88.51	28.27	56
g_2	0.9420	7.10	1038.11	2.5	1.1	0.1200	0.59	87.58	22.74	0
g_3	0.9990	13.34	1124.72	2.2	0.6	0.1700	0.70	93.01	18.43	14
g_4	0.9690	7.00	945.47	1.3	1.6	0.9700	0.52	88.24	30.61	42
g_5	0.9780	6.46	958.81	2.7	1.3	0.4400	0.54	93.88	16.12	28
g_6	0.9980	10.20	1175.37	2.6	1.3	0.3400	0.88	84.76	31.20	7
g_7	1.0480	9.02	1181.85	1.1	0.7	0.9000	0.55	81.42	26.46	28
g_8	1.0910	6.07	1182.51	1.3	1.6	0.2400	0.69	88.80	27.83	63
g_9	0.9820	13.69	1140.62	2.8	1.9	0.2900	0.67	89.54	17.24	63
g_{10}	1.0510	7.04	965.73	1.9	1.2	0.1200	0.90	91.00	23.95	35

—Stimulant indicator (the more, the better) and —disincentive indicator (the less, the better).

Table A4. Weighting coefficients and integral assessments of counterparties.

		x_1 rub.	x_2 %	x_3 thds. rub.	x_4 Days	x_5 Days	x_6 Units	x_7 Units	x_8 Units	x_9 km	x_{10} Days
Weights	equivalent	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	by component	0.1369	0.0076	0.0183	0.2692	0.0004	0.1176	0.0002	0.1787	0.2272	0.0438
	by correlation	0.0849	0.1377	0.1352	0.0745	0.1178	0.0887	0.1003	0.0856	0.0827	0.0927
	g_1	6.0517				4.6316			6.4135		
	g_2	3.7611				4.1260			3.7664		
	g_3	5.5962				5.6629			5.6950		
	g_4	5.2938				6.2241			5.1314		
	g_5	5.1416				6.0715			5.0514		
	g_6	3.3019				2.0497			3.3789		
	g_7	4.3148				5.1059			4.1206		
	g_8	3.5174				4.5476			3.1215		
	g_9	4.9716				5.0434			4.9105		
	g_{10}	5.1695				4.6832			5.2228		

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