MATHEMATICAL MODELS OF PROJECT MANAGEMENT FOR THE SUPPLIER

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Annotation

In this article the complex of the interconnected mathematical models intended for project activities management at all stages with participation of interested party - General Supplier, is considered. The use of such models aims at increasing efficiency of the activity, ensures that relevant competences and the desired objectives achievement under various conditions of modalities for the project implementation are put into effect.

KEY WORDS: stakeholder, mathematical models of project management, competence of project management.

INTRODUCTION

In [1], the attempt is made to structure the features of the main interested parties (stakeholders) and construct mathematical models of project management taking them into account. The examples of such models are provided for the investor, customer, project team, main contractor, suppliers and regulators.

Ibid we noted that the choice of methods and project controls is largely determined by the management of which project stakeholder is considered in this case, and under which conditions. Various interested parties in the project differ by their expectations, roles, degree of responsibility and actions. This is due to their various purposes in the project, criteria of success and an assessment of the degree of goal achievement, different values and strategy for the achievement of the objectives. These distinctions can influence significantly project goals and objectives setting, methods used, tools and techniques of problem solving management, focused on their specific requirements. But also in modeling activity of a certain interested party there can be various options of goal settings, connected with various conditions of project implementation. Besides, problem implementation methods of optimized decision making also possess essential diversity.

This article suggests mathematical models intended for management of project execution at all stages with participation of one interested party – General Supplier. For
each suggested variant specific conditions to which this model is adequate are considered. At the same time solving techniques which also can be multi-versioning are suggested and analyzed. The use of such models aims at increasing efficiency of General Supplier’s activity, ensures that relevant competences and the desired objectives achievement under various conditions of modalities for the project implementation are put into effect.

1. KEY DEFINITIONS

1.1 Key definitions of interested parties are contained in [3] and are given in [1]. Here we will refer in detail to the concept of General Supplier.

General Supplier is a company managing the process of providing for supply and purchase on contracts with various suppliers.

General Supplier realizes the coordinated, ordered and systematic process of supply management of all necessary materials and equipment for project implementation, allowing to provide project implementation due-by-date with the predetermined quality, thus, possibly, to reduce a total cost of purchased materials, goods and services while maintaining or improving quality, services and technologies.

General Supplier's management system is intended for meeting the following tasks:

- The analysis of needs in materials and equipment necessary all project works.
- A choice of optimum supply sources (Evaluating of suppliers' qualification, tenders and auctions).
- Contraction and control over carrying out established contracts(treaties) with suppliers.
- An arrangement of the centralized project supply and accounting of the general costs for supply.
- The implementation of tactical and strategic analysis of the relations with suppliers.

The activities of the General supplier the following opportunities could be realized:

- the reduction of purchasing costs by consolidation of requirements of various project activities, the reduction of one time buy, the price optimization as a result of tenders and auctions;
- the reduction of buying cycle due to automatization of routine tasks of interaction with suppliers;
- the supply optimization and the improvement of the quality of project supply.

1.2 The structure and the content of project management competences for interested parties are subdivided into two groups — basic and special [3]:

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basic competences define general requirements of all interested parties for the structure, the content and the level of ability, knowledge, skills and personal features and characteristics;

special competences define specific requirements of a certain interested party for the project for the structure, the content and the level of abilities, knowledge, skills and personal qualities taking into account its (party's) role, interests and carried-out functions.

Below here are examples of specific characteristics and parameters of projects management in the behalf of General Supplier.

**The expectations** - Earnings from supply (in the case when General Supplier role is performed by Customer, other expectations – cost reduction and/or reliability improvement, the appropriate models are given in [2]).

**The project vision** - The process of contractual providing for supply.

**The purpose in the project** - Providing for necessary supply, in the right place, on necessary time, at a price advantageous to General Supplier.

**The criteria** - Risks and losses minimization, profit maximization.

**The restrictions** - The specifications, the terms, the prices and the supply place.

**The strategy** - The supply and purchase process optimization with observance of interests of the client and the supplier.

**The main risks**–Delay in supply, high prime cost and possible penalties.

**The main project management tools** - The supply plan, purchase and supply contracts, monitoring and control.

1.2 The interrelation of project management mathematical models of General Supplier with other interested parties.

The scheme of interrelation is presented in Figure 1:
Figure 1. The scheme of interrelations of General Supplier's management mathematical models with other interested parties of the project.

2. SUPPLY MANAGEMENT PROCESS

Supply is one of the key elements in project management. Reducing costs connected with purchase of materials and services allows to increase project profitability. At the same time, the reduction in the quality of purchase items is not allowed, so it is necessary to make a choice of qualified suppliers to form steady and mutually profitable partnership relations with them. The management of these processes allows reduced risks of purchases. Thus, the general supplier's management system should be organized as the effective optimization tool of purchasing activities in execution the project.

The engagement of the General supplier at the initial stage of project development can lead to reduction of expenses up to 18%. According to researches, the integration of the project development processes and the attraction of third-party resources lead to reduction of stock resources by over 30%, and the timeliness of supply increases to 73% [4].

In some areas, the general supplier has a choice, whether it is worth buying certain production or it will be enough to rent it for the project time. These are such "goods", as the equipment, machines, information services, etc. which many projects can rent. As a rule, the rent is cheaper for the project than purchase, but after completing a mission, all rented items of material support will not remain with the project Customer. Therefore the option of a rent always has two sides, respectively connected with the budget economy of the project and with the return of a rented object the part of the cost of which has already been paid in the form of a rent. It is useful to consider a compromise derivative in the form of finance lease. It often happens that plant leasing turns out to be
the optimal decision in comparison with the option of a rent or purchase option. The choice of optimal option lies in the area of the project budget, with account of long-term strategic advantages to the project Customer, possibility of full project support, taxing, intellectual property, etc.

It is necessary to keep in mind the existence of a direct, single option supply where there is no choice problem. Further, the aspects of suppliers’ selection and choice are highlighted to allow us better understand the mathematical model of the General supplier of managing the project.

The supplier selection process consists of the following stages:

1. **Collecting and ranging of business requirements to the supplier.**

Business requirements can be specific to different projects, but generally it is promptness of supply, an optimum cost/quality ratio, supplier responsibility (support of the delivered goods, a well-timed replacement of faulty goods and so forth).

2. **Analyzing the following characteristics of potential suppliers:**

   - Production capabilities
   - Processing capabilities
   - Intellectual property rights
   - Management maturity, including project management
   - Financial status / stability
   - Form and size of organisation
   - Property right
   - Reference list with recommendations

3. **Creation of "a long list" of potential suppliers**

   The search for all potential suppliers who satisfy the risen requirements (use of the Internet, advertising magazines, recommendations of other companies, etc.) is performed.

4. **Creation of "the short list" of suppliers**

   A number of approaches to forming "the short list" of suppliers is suggested.

   - selection of suppliers by the degree of supply package influence on the integrated quality indicator of production (model 3.1);
   - qualitative expert selection of possible suppliers with the usage of Spearman and Kendall correlation criteria (model 3.2);
- qualitative expert selection of possible suppliers with the usage of pair-wise comparison principles (model 3.3).

The proposed models can be used either individually, or in their combination with each other.

5. Estimating the suppliers according to "the short list"

At this stage, it is necessary to compare their capabilities with the requirements to the supplier and the priorities of these requirements. This comparison is in the forming of the numerical estimate, how well an applicant corresponds to each qualitative requirement. The obtained estimates will be used at the next stage at the construction of mathematical models of the supply plan formation.

6. Supplier selection and choice

The last phase of contracting life cycle is judgment (conclusion). At this stage the analysis of all the entered replies to the request of application, supplier selection and the conclusion of the contract take place.

There are various methods of supplier selection and contract award. The procedure performed for this purpose sometimes is not formalized, and for this purpose the selection committee which analyzes and distributes answers on the basis of one of the techniques is created. The most common of them is the Positional system which is in expert evaluation of suppliers according to the promoted criteria and collected characteristics.

Scoring model or positional system represents a rather good tool to estimate replies to the request of application. This model is rather objective and guarantees that while analyzing the replies all members of selection committee use identical criteria.

The positional scoring model is now often used in purchasing process and selection of estimation methods and comparison of various criteria and final decision. It is quite effective in case of a small nomenclature of the supplied products and a small number of suppliers. In the case where the number of suppliers is significant and there is a big nomenclature of the supplied products, different variants of acquisition and employment of equipment, this "manual" approach is very complicated and doesn't encourage obtaining the optimal decision. And modern projects are characterized just by the big information capacity.

This article suggests mathematical models of general supplier management related to the selection of the most effective suppliers and formation of the optimal supply plan (models 3.4-3.6). In case of non-competitive supply the process is described by Gant simple linear analog or by the activity network as the subproject in the main project. The subproject final time is the supply calculating date according to the complex schedule as a landmark or a time limit. Counting forward the subproject duration, we define the
date when it is necessary to begin the supply process that the supply can be in time, in the right place and in the necessary volume.

Using the suggested models it will be possible to solve the problems of general supplier (discussed earlier) for projects of any degree of complexity, thus there is an opportunity to automate these processes.

3. MATHEMATICAL MODELS OF PROJECT MANAGEMENT FOR GENERAL SUPPLIER

3.1. The mathematical model describing the nature of the influence of the supply volume of each supplier on product quality.

Let us assume that the supplied product is characterised by parameter $Y$ which is an indicator of its quality. If the production of different suppliers differs on quality, then, the quality parameter might change depending on the supply volume of this or that supplier $X_i$. This model is to reveal the nature of dependence of quality parameter from the supply volume of each supplier.

The given data represent monthly ranks of the supply volumes of each supplier $x_{it}$ and indicator quality value $y_i$ ($i=1, \ldots, n$; $t=1, \ldots T$).

The construction of a regression linear (additive) model of the supply volume influence on the quality parameter. The following type of dependence is being sought:

$$Y = a_0 + a_1 X_1 + \ldots + a_n X_n,$$  

(1)

Where $a_i$ - are the regression coefficients showing the influence extent of the supply volume of the supplier $i$ on quality parameter. If the supply volume changes for some supplier per unit (the unit of measurement of submit data), the quality value indicator changes by the value of the corresponding regression coefficient.

In the process of the model construction the optimal set of suppliers is defined. Reviewing the reasonableness of entrance the suppliers in the model is conducted by design method of $r_{ij}$ correlation for each couple of disposal variables $X_i, X_j$ in the equation (1). Correlation of variables shows how much they connect with each other. If the connection is rather big ($|r_{ij}| \geq 0.8$), usage of one of the variables is inexpedient and superfluous. Therefore, it can be excluded from the model without big loss in explaining properties. The supplier to whom there are more claims on production quality, supply time and so forth is excluded. Besides, it is necessary to exclude the suppliers whose influence on quality indicator $Y$ has weak extent. This decision is made by the responsible person individually for each supplier, by the analysis of the received regression coefficients. As a result, we have a certain set of suppliers, whose influence on studied parameter $Y$ is most significant, and the redundancy of variables will be eliminated.
Let's implement the following search algorithm of the optimal model specification. Let's include or exclude independent variables from the model at every step of regression. Firstly we use one variable, secondly we add one more and look at the results. If the importance of coefficients is deteriorated, we seek the other combination from the two variables. As a result, we receive the optimal model specification.

The experience of using this model shows that most commonly the nature of influence of supply volume on a quality parameter is negative. This fact dictates the following tactics of the supplier selection: we would either have to refuse major suppliers who have major modulo negative regression coefficient (it also allows financial losses because of the difference in prices of large and small wholesale), or organize the tightened quality control of such large supply (that is also related with expenses). We compare the expenses connected with refusal of major suppliers, to costs associated with monitoring their activity, and choose the lesser of two evils.

The construction of a nonlinear (multiplicative) model of the supply volume influence the quality parameter. The following type of dependence is being sought:

\[ Y = a_0 x_1^{a_1} x_2^{a_2} \cdots x_n^{a_n}. \]  

(2)

Here the received exponents of \( a_i \) are elasticity coefficients, they show by what percentage the analyzed indicator \( Y \) changes when factor \( I \) is changed by one percent. It is easy to assume the converse [8], especially if the elasticity coefficients are constants, i.e. are independent from the supply volume, then the dependence between quality indicator and the supply volume is expressed by equation (2). Thus, we receive the rule for a choice between (1) and (2). Analyzing statistical data on the supply volume and calculating elasticity coefficients at low and high values of volume, we make a conclusion about their variability concerning these values. In case the variability is next to nothing, we choose model (2), otherwise (1). Step-by-step operation with model (2) is similar to work with model (1) by convention of an optimal set of suppliers.

3.2. Expert selection of possible suppliers with the usage of Spearman and Kendall correlation criteria

Let us assume that experts are invited to range \( n \) of potential suppliers, assigning it sequence numbers (ranks) 1, 2, 3... \( n \) depending on individual representation. And ranging can be made both according to the separate criteria suggested in model 3.3, and according to their totality. The degree of consistency of ranging results of two experts can be estimated by means of coefficient of rank correlation \( R \) suggested by Spearman. If \( \{x_i\} \) and \( \{y_i\} \) denote ranks, identified by two experts, then the correlation coefficient \( R \) will be defined by the following formula:

\[ R = 1 - \frac{6 \sum d_i^2}{n^3 - n}, \]

(3)
where \( n \) is a number of compared suppliers, \( d_i = x_i - y_i \) is the difference of suppliers ranks of two experts.

Obviously, the maximum of the degree of experts consistency is +1 (it is reached when ranks of both experts coincide), and the minimum is −1 (fit the case when experts opinions are opposite).

In theory, the number of ranged suppliers can be unordered, but the process of ranging of more than 20 suppliers is difficult. Supposedly, that is why the table of critical values of Spearman's correlation coefficient is designed only for 30 ranged signs [8]. If the number of compared variables is greater it is necessary to use the table for Pearson's correlation coefficient [9]. The finding of critical values is performed at \( k = n \).

Using Spearman's correlation coefficient, consider the following example. The experts ranged 11 suppliers per totality of criteria.

<table>
<thead>
<tr>
<th>No of supplier</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expert 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>5</td>
<td>6</td>
<td>1</td>
<td>4</td>
<td>11</td>
<td>9</td>
<td>2</td>
<td>8</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Expert 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>7</td>
<td>8</td>
<td>3</td>
<td>4</td>
<td>6</td>
<td>11</td>
<td>1</td>
<td>10</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>( d_i )</td>
<td>1</td>
<td>-2</td>
<td>-2</td>
<td>-2</td>
<td>0</td>
<td>5</td>
<td>-2</td>
<td>1</td>
<td>-2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>( d_i^2 )</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>0</td>
<td>25</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Now substitute the findings into a formula (3) and settle the account. As a result:

\[
R = 1 - \frac{6 \times 52}{11(11 \times 11 - 1)} = 0.76.
\]

To find a significance level, refer to [8] in which critical values for coefficients of rank correlation are given.

It must be emphasized that in [8] all variables of correlation coefficients are given in absolute magnitude. Therefore, the sign of correlation coefficient is considered only in its interpretation.

Finding of the significance values in this table is performed on \( n \) number, i.e. on number of suppliers. In our case, \( n = 11 \). For this number find \( r_{kp} \) :

- 0,52 for \( P \leq 0,05 \);
- 0,74 for \( P \leq 0,01 \).
The received correlation coefficient coincides with critical value for a significance level of 1%. Therefore, it can be said without prejudice that the experts' opinions are very well correlated.

**The case of equal (tied) ranks**

It is a frequent situation for an expert when they can't draw the fine line between two objects of estimation. In such case it is preferable to put in "connected ranks" when for those objects of estimation among which the expert can't choose, one and the same number (probably fractional) is attributed. For example, the expert can't draw the fine line in order of importance between the third and fourth supplier. Then one and the same fractional rank 3.5 is attributed to both of them. Involving equal ranks (each expert can have some groups of them) the calculation formula of Spearman's correlation coefficient will be a bit different. In this case, new members taking account of equal ranks are added in the calculation formula of correlation coefficient. They are called the corrections on equal ranks and are added in numerator of a calculating formula.

\[ D_j = (k_j^3 - k_j)/12, \]

Where \( k_j \) is a number of equal ranks in a group \( j \).

The calculation formula of Spearman's correlation coefficient with the corrections:

\[ R = 1 - \frac{6 \sum d_i^2 + \sum D_j}{n^3 - n}, \quad (4) \]

**Example.**

<table>
<thead>
<tr>
<th>№ of supplier</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expert 1</td>
<td>6</td>
<td>7</td>
<td>4</td>
<td>5</td>
<td>9</td>
<td>12</td>
<td>2.5</td>
<td>2.5</td>
<td>10</td>
<td>8</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>Expert 2</td>
<td>5</td>
<td>8</td>
<td>7</td>
<td>11</td>
<td>3</td>
<td>6</td>
<td>11</td>
<td>11</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>( d_i )</td>
<td>1</td>
<td>-1</td>
<td>-3</td>
<td>-6</td>
<td>6</td>
<td>6</td>
<td>-8.5</td>
<td>-8.5</td>
<td>9</td>
<td>5</td>
<td>8</td>
<td>-8</td>
</tr>
<tr>
<td>( d_i^2 )</td>
<td>1</td>
<td>1</td>
<td>9</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>77.25</td>
<td>77.25</td>
<td>81</td>
<td>25</td>
<td>64</td>
<td>64</td>
</tr>
</tbody>
</table>

In this case one group of the first expert has two equal ranks (2.5), therefore, the allowance is \( D_1 = \frac{2^3 - 2}{12} = 0.5 \).
The second expert has two groups with three equal ranks (3 and 11), therefore, the allowance: \( D_2 + D_3 = \frac{(3^2-3)+(3^2-3)}{12} = 4. \)

Calculate rank coefficient taking into account additives according to the formula (4). As a result:

\[
R = 1 - \frac{6 \times 471.5 + 0.5 + 4}{12 \times 143} = -0.651.
\]

Counting without an additive:

\[
R = 1 - \frac{6 \times 471.5}{12 \times 143} = -0.648.
\]

The difference is not large. By [8] find critical values of correlation coefficients at \( n = 12 \):

- 0.50 for \( P \leq 0.05 \),
- 0.70 for \( P \leq 0.01 \).

In this case the result says that expert estimates of suppliers are correlated with an operational margin of less than 5%, but more than 1%. But expert opinions of these suppliers are diametrically opposite! The higher one expert estimates the supplier, the lower estimate he (the supplier) gets from the second expert. Such anti-compatibility can't be fortuitous, it is evidenced either of incompetence of one of the experts, or of the criminal premeditation of their actions.

Used in some evaluation systems Kendall's correlation coefficient \( \tau \) is calculated according to a formula:

\[
\tau = \frac{S^+ - S^-}{\sqrt{0.5n(n-1)}} \tag{5}
\]

To calculate \( S^+ \) and \( S^- \), ranks of all various couples of suppliers according to one expert and another are compared. Add 1 to \( S^+ \) if there is a particular equal rank order, and 1 to \( S^- \) if it's inverted sequence. Total of couples = \( S^+ + S^- \), where \( S^+ \) is a number of positive, and \( S^- \) of negative units, attributed to the couples by comparison of their ranks according to both experts.

From formula (5) we see that the coefficient \( \tau \) represents a difference of deals of the suppliers couples with matching order according to both experts (with reference to a number of all couples) and deals of the suppliers couples with non-matching order. For example, Kendall's coefficient value 0.60 means that 80% of couples have a matching order, and 20% - non-matching (80% + 20% = 100%; 0.80 – 0.20 = 0.60). Thus it is possible to interpret \( \tau \) as a difference of probabilities of coincidence and non-coincidence of orders according to both experts for chosen at random couple of suppliers. In the general case, the calculation of \( \tau \) even for \( n = 10 \) is lengthy. Besides, practical calculations show that Kendall's coefficient \( \tau \) gives more conservative estimate
of correlation, than Spearman's coefficient \( R \) (the number value \( \tau \) is always less than \( R \)), i.e. Spearman's coefficient \( R \) reacts more strongly on non-concurrence of rankings than \( \tau \), therefore we suggest using Spearman's coefficient for determining the degree of experts coherence.

Practically, alongside with rank correlation coefficients, characterizing opinion consistency of each couple of experts, the concordance coefficient, defining opinion consistency of the group of experts is of the utmost interest.

Let's explain the meaning of this term as exemplified in table 1 with the ranks brought into it by \( m \) experts for the supplier evaluation. In the bottom line of the table ranks of all experts for each supplier \( p \) are summarized. Let's rearrange the columns in the order of increasing these sums. The central tendency of these sums is designated by \( A_p \).

\[
A_p = \frac{1}{m} \sum_{i=1}^{m} a_{ip}
\]  

Table 1

<table>
<thead>
<tr>
<th>Experts</th>
<th>Ranks for suppliers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( A_1 )</td>
</tr>
<tr>
<td>The 1st</td>
<td>( a_{11} )</td>
</tr>
<tr>
<td>The 2nd</td>
<td>( a_{21} )</td>
</tr>
<tr>
<td>( \ldots )</td>
<td>( \ldots )</td>
</tr>
<tr>
<td>( m )</td>
<td>( a_{m1} )</td>
</tr>
<tr>
<td>Sums</td>
<td>( \sum_{i=1}^{m} a_{i1} )</td>
</tr>
</tbody>
</table>

If all observations were identical, we would receive the following sums column-wise: \( m, 2m, \ldots, nm \). Genuinely, in the first column there would be a supplier to whom all experts appropriated rank 1, in the second - the supplier with a rank 2, etc.

It is possible to calculate the sum of squared deviations:

\[
S = \sum_{p=1}^{n} \left( \sum_{i=1}^{m} a_{ip} - A_p \right)^2
\]

This value characterizes the coincidence rate of opinions of all experts. At full consensuses the value of \( S \) will be equal to zero or to a very small variable. Therefore, for determining the degree of coherence of opinions of the expert group it is offered to identify the concordance coefficient as follows:
\[ W = \frac{12 \cdot S}{m^2(n^2 - n)}. \]  

(8)

The varying of \( W \) from 1 to 0 indicates an increase in the degree of coherence in the opinions of the experts.

The works with the expert group of the supplier evaluation decision is performed in several steps. At the first stage Spearman's coupled correlation coefficients are defined and analyzed, the work on identification an exception the incompetent and corrupted experts from the group is performed. Then according to formula (8) the concordance coefficient is calculated, organizational work with experts (their informing, elimination and the following recalculations) continues until we receive \( W \leq 0.15 \) value that means high degree of coherence of expert opinions. Then \( A_p \), calculated according to formula (6), will be priorities of the suppliers.

### 3.3. Expert selection of possible suppliers with the usage of the principles of pair-wise comparison (The Saati method of hierarchy)

The selection criteria for the supplier are the following:

- promptness of supply,
- cost/quality ratio (taking transportation expenses into account),
- supplier responsibility (support of the delivered goods, a well-timed replacement of faulted goods and so forth),
- production and processing capabilities,
- financial status (creditability, stability).

Supplier selection with the usage of convolution methods of criteria and (or) complex criteria are considered in [6,7]. Here we suggest the Saati method of hierarchy analysis.

In the beginning the matrix of pair-wise comparison of criteria is constructed and the vector of priorities of criteria is formed. Each project is unique, comparative evaluations of criteria are also unique. In tab. 2 there is an example of pair-wise comparisons of criteria for some project (“The Gorky” hypermarket construction project in Chelyabinsk is taken for the analysis).
Table 2. The matrix A of pair-wise comparison of criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>promptness of supply</th>
<th>cost/quality ratio</th>
<th>supplier responsibility</th>
<th>production and processing capabilities</th>
<th>financial status</th>
</tr>
</thead>
<tbody>
<tr>
<td>promptness of supply</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>cost/quality ratio</td>
<td>1/3</td>
<td>1</td>
<td>1/3</td>
<td>1/3</td>
<td>5</td>
</tr>
<tr>
<td>supplier responsibility</td>
<td>1/5</td>
<td>3</td>
<td>1</td>
<td>1/5</td>
<td>3</td>
</tr>
<tr>
<td>production and processing</td>
<td>1/3</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>capabilities</td>
<td>financial status</td>
<td>1/5</td>
<td>1/3</td>
<td>1/3</td>
<td>1</td>
</tr>
</tbody>
</table>

For a vector of priorities of criteria to be formed, at first normalize matrix A, by dividing all its elements by the sum of elements of each corresponding column.

\[
N_A = \begin{pmatrix} 0.48 & 0.290.43 & 0.62 & 0.29 \\ 0.16 & 0.100.03 & 0.07 & 0.29 \\ 0.10 & 0.290.08 & 0.04 & 0.18 \\ 0.16 & 0.290.43 & 0.20 & 0.18 \\ 0.10 & 0.030.03 & 0.07 & 0.06 \end{pmatrix}
\]

The components of vector \( W^E \) are calculated as arithmetic middling of row elements of the normalized matrix.

\[
W^E = (0.422, 0.13, 0.1380.252, 0.058)
\]

On this project, the criterion "promptness of supply" (0.422) is a top priority, then comes "production and processing capabilities" (0.252), then - "supplier responsibility", "cost/quality ratio", and the last - "financial status of supplier".

Then for each criterion the matrix of pair-wise comparison of suppliers is constructed and corresponding vectors of priorities are formed. The received vectors of priorities of suppliers according to each criterion are scalarly multiplied by a vector of priorities of criteria and, thus, the resultant vector of priorities of suppliers \( \{A_p\} \) is obtained.

3.4. Single-product static problem of a choice of the supplier selection

Let us consider a set of suppliers (of full n) who can supply a certain type of a product at specified time. Let us assume that

- \( X_p \) - the volume of supply of production performed by \( p \) supplier in specified time interval, is limited by \( V^{im}_p \) enterprise-supplier opportunities;

- \( V \) - consumer need for production in specified time interval;

- \( V_{min} \) - minimum requirement volume of production providing continuity of consumer operations in specified time interval;
$V_{max}$ - maximum volume of supply of production guaranteeing the avoidance of transportation idles by which production is delivered to the consumer, for the specified time interval;

$Z_p$ - purchasing price of production volume unit delivered by $p$ supplier;

$D_{tr}^p$ - transportation cost of production volume unit delivered by $p$ supplier;

$P_p$ - product quality index delivered by $p$ supplier, is defined as a probability of getting production conforming to all quality requirements, (is set according to the statistic data of incoming quality inspection of delivered production);

The terms of supply and forms of payment, on the assumption of limitation of the consumer finances, are defined by corresponding shares of possible purchases in bulk of supply:

a) $Q_1$ - purchase share on a deferred-payment basis;

b) $Q_2$ - purchase share on a payment after delivery basis;

c) $Q_3$ - purchase share on a prepayment basis.

The efficiency criteria according to which we will estimate decision of the supplier selection.

For the criterion formation, corresponding to cost estimate of purchases, we shalldefine the combined expenses on the volume purchases in specified time interval including all the suppliers:

$$SC = \sum_{p=1}^{n} (Z_p + D_{tr}^p)X_p$$

and the total volume of supply

$$SV = \sum_{p=1}^{n} X_p.$$  

Then the minimum price of the production volume unit at large volume of $SV$ is expected:

$$C_{min} = \min_p (Z_p + D_{tr}^p).$$

Let’s form the first subtest efficiency criterion in a form of the ratio of the variable $C_{min}$ corresponding to minimum price, offered by suppliers (taking transportation costs into account), to the average price of purchases $C_{av}=SC/SV$:

$$K_1 = \frac{C_{min}}{C_{av}}.$$
$K_1$ criterion characterizes a share made by minimum possible price of purchase in average purchase price. This indicator has the maximum value ($K_1 = 1$) if all purchases are performed only from the supplier, whose product price is the lowest. In all other cases $K_1 < 1$ that correspond to less favorable price conditions of purchases. Thus, on the basis of cost cutting of purchases, $K_1$ criterion should be maximized.

As the second criterion we choose this one which allows to estimate terms of supply and a form of payment. Certainly, it is more favorable for the consumer to make purchases on a deferred-payment basis, it is less favorable to make purchases on a payment after delivery basis, and it is even less favorable to buy on a prepayment basis. It is possible to estimate the profitability of the purchases made by various described options of forms of payment, by means of corresponding efficiency coefficients: $E_{dp}$ (on a deferred-payment basis), $E_{pad}$ (on a payment after delivery basis), $E_{pp}$ (on a prepayment basis).

In this case create the following complex criterion:

$$K_2 = \frac{(E_{dp}SV_{dp} + E_{pad}SV_{pad} + E_{pp}SV_{pp})}{SV}, \quad (14)$$

where: $SV_{dp}$ – the total volumes of purchases for the specified time interval by the suppliers allowing a delay of payment;

$SV_{pad}$ – the total volumes of purchases for the specified time interval by the suppliers on a payment after delivery basis;

$SV_{pp}$ – the total volumes of purchases for the specified time interval by the suppliers, demanding a prepayment.

$K_2$ criterion characterizes (taking efficiency coefficients into account) a share of the purchases made on these or those conditions in the total volume of purchases, and has the maximum value $K_2 = E_{dp}$ if all the purchases are performed by the suppliers allowing a delay of payment. Let us assume, for example, the purchases of each production unit volume, made with a payment delay, have an indicator of efficiency $E_{dp}=1$, purchases of production unit volume on a payment after delivery basis have an indicator of efficiency $E_{pad}=0.5$, and the least favorable purchases (on a prepayment basis) let have an indicator of efficiency $E_{pp}=0.2$. Then maximum value of complex criterion $K_2=1$. In all other cases $K_2 < 1$ that corresponds to less favorable supply conditions. Specific values of the efficiency coefficients of purchases according to the condition of forms of payment can be received by expert estimates or by means of reflection of limited budgetary possibilities of business-to-consumer.

Thus, the effective decision based of this criterion reduces to maximizing $K_2$.

As the third subtest criterion we shall consider an indicator characterizing the quality of the supply production. As the production quality is represented through the probability
rates, define the mathematical expectation of volumes of qualitative production supply in a bulk of supply:

\[ MV = \sum_{p=1}^{n} P_{p}X_{p}. \]

In this case the quality criterion has the following form:

\[ K_3 = \frac{MV}{SV}. \] (15)

\( K_3 \) criterion has the maximum value corresponding to the quality indicator of the supplier of the most qualitative production, if all purchases are performed just by him. In all other cases \( K_3 \) has smaller values that corresponds to less qualitative production, therefore, maximizing \( K_3 \) is required.

As the fourth subtest criterion we shall take a deviation of total volume of supply from its necessary quantity:

\[ K_4 = |SV - V|. \] (16)

The deviation of the settled volume of a product from its necessary quantity can cause the additional expenses connected both with storage of surplus, and with idles of performers because of the product shortage. Therefore, according to this criterion minimization is required.

The multi-criteria problem-solving procedures are described in sufficient detail [10]. In [2] we used some of them, particularly, a method of consecutive concessions. It can also be used here, but alongside with it, it is advisable in this case to implement a convolution of the received criteria, using summability method with a task of weighing coefficients. While stating the weighing coefficients it is expedient to use the expert evaluation method, thus defining their values both directly, and by means of pair-wise comparisons, forming a vector of priorities (9). At the same time it should be noted that the variability of the numerical values of coefficients doesn't change a task crucially, it only changes the priorities of the consumer while purchasing that allows him to make the decision on the assumption of the particular circumstances developing at the moment. Then the total efficiency criterion in the form of convolution of subtest complex criteria of \( K_1, K_2, K_3, K_4 \) we present in this way:

\[ W = g_1K_1 + g_2K_2 + g_3K_3 - g_4K_4, \] (17)

where: \( g_1, g_2, g_3, g_4 \) - are weighing coefficient.

\( g_i > 0. \)

Let's construct the mathematical model of a task.

The set of constraints consists of two subsystems; the first is based on the consumer needs and possibilities of suppliers:
The second subsystem is based on the limited budgetary possibilities of the consumer that is expressed by relevant requirements to the supply conditions:

\[
V_{\text{min}} \leq SV \leq V_{\text{max}},
\]

\[
0 \leq X_p \leq V_{\text{lim}}^p, \quad (18)
\]

The second subsystem is based on the limited budgetary possibilities of the consumer that is expressed by relevant requirements to the supply conditions:

\[
SV_{dp}/SV \geq Q_1, \quad (20)
\]

\[
SV_{pad}/SV \leq Q_2, \quad (21)
\]

\[
SV_{pp}/SV \leq Q_3. \quad (22)
\]

The subsystem (20)-(22) reflects the requirements that the share of production purchases on a deferred-payment basis in bulk of purchases should be no less than \(Q_1\), and shares of purchases on a payment after delivery basis and on a prepayment basis shouldn't exceed \(Q_2\) and \(Q_3\) respectively.

Thus, it is required to determine the volumes of purchases \(X_p\) corresponding to sets of constraints (18)-(22) and maximizing the total efficiency criterion (17).

Example. The basic data are taken from [7]. The project need for metal makes 4200 tons per month. With that, according to the conditions of the normal implementation of the project, the minimum required supply of metal should make no less than two carriages (120 tons) per day.

At the same time, not to bear the costs of the compelled idles of carriages payments; the maximum daily supply shouldn't exceed five carriages (300 tons).

The list of suppliers and their characteristics are presented in table 3.

<table>
<thead>
<tr>
<th>N in order</th>
<th>Supplier</th>
<th>Cost inc. VAT for 1t, RUR000’s</th>
<th>Railway rate, for 1v, RUR000’s</th>
<th>Supply volume limitation, t. per month</th>
<th>Terms of supply</th>
<th>Quality indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Satka, Chelyabinsk Region.</td>
<td>2,800</td>
<td>200</td>
<td>300</td>
<td>Up on delivery</td>
<td>0.86</td>
</tr>
<tr>
<td>2</td>
<td>Chelyabinskmet. concern</td>
<td>2,770</td>
<td>220</td>
<td>Unrestricted</td>
<td>Prepayment</td>
<td>0.87</td>
</tr>
<tr>
<td>3</td>
<td>Lipetsk,&quot;SvobodnySokol&quot;</td>
<td>2,976</td>
<td>124</td>
<td>Unrestricted</td>
<td>Up on delivery</td>
<td>0.89</td>
</tr>
<tr>
<td>4</td>
<td>Novotroitsk met. concern, Orenburg Region.</td>
<td>2,880</td>
<td>237</td>
<td>1200</td>
<td>Delay in payment</td>
<td>0.8</td>
</tr>
<tr>
<td>5</td>
<td>NizhnyTagil met. concern</td>
<td>3,120</td>
<td>249</td>
<td>Unrestricted</td>
<td>Up on delivery</td>
<td>0.9</td>
</tr>
<tr>
<td>6</td>
<td>Ekaterinburg met. concern</td>
<td>3,250</td>
<td>199</td>
<td>Unrestricted</td>
<td>Delay in payment</td>
<td>0.92</td>
</tr>
<tr>
<td>7</td>
<td>Magnitogorsk met. concern</td>
<td>3,780</td>
<td>234</td>
<td>360</td>
<td>Delay in payment</td>
<td>0.97</td>
</tr>
</tbody>
</table>
The quality indicator given in table 3, represents the variable of probability of receiving production conforming to all quality requirements (is settled from statistic data of incoming quality inspection of the supplied production).

On the assumption of a constant deficiency of financing existing now, we shall set the following efficiency coefficients of production purchases:

- the purchases made on a deferred-payment basis: $E_{dp} = 1$;
- the purchases made on a payment after delivery basis: $E_{pad} = 0.5$;
- the purchases made on a prepayment basis: $E_{pp} = 0.2$.

Let’s set shares of possible purchases in the total volume of supply:

$$Q_1 = 0.5;$$
$$Q_2 = 0.35;$$
$$Q_3 = 0.15.$$

Let’s define the weighting coefficients of subtest efficiency criteria:

$$g_1 = 0.7; g_2 = 0.2; g_3 = 0.1; g_4 = 0.3.$$

Let’s construct the mathematical model of a task of the supply optimization.

The set of constraints has the following form:

According to the average number of working-days per month $21.8 \times 120 = 2616$, $V_{\text{min}} = 21.8 \times 300 = 6540$, where from

$$2616 \leq SV \leq 6540,$$

$$SV = \sum_{p=1}^{n} X_{p},$$

$$X_1 \leq 300,$$
$$X_4 \leq 1200,$$
$$X_7 \leq 360, \quad (23)$$
$$X_8 \leq 300.$$

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$$2616 \leq SV \leq 6540,$$

$$SV = \sum_{p=1}^{n} X_{p},$$

$$X_1 \leq 300,$$
$$X_4 \leq 1200,$$
$$X_7 \leq 360, \quad (23)$$
$$X_8 \leq 300.$$
\[
(X_4 + X_6 + X_7 + X_9)/SV \geq 0.5,
\]
\[
(X_1 + X_3 + X_5 + X_{10})/SV \leq 0.35,
\]
\[
(X_2 + X_8)/SV \leq 0.15,
\]
\[0 \leq X_p.
\]
Therefore, it is required to define \(X_p\) values corresponding to set of constraints (23) and maximizing the total efficiency criterion:

\[W = 0.7 K_1 + 0.2 K_2 + 0.1 K_3 - 0.3 K_4 \to \text{max}.
\]

Let us find

\[c_{\text{min}} = \min_p (Z_p + D_p^{mp}) =
\]
\[= \min \left(2.8 + \frac{200}{60}, 2.77 + \frac{220}{60}, 2.976 + \frac{124}{60}, 2.88 + \frac{237}{60}, 3.12 + \frac{249}{60}, 3.25 + \frac{199}{60}, 3.78 + \frac{234}{60}, 2.7 + \frac{253}{60}ight) =
\]
\[= \min (6.13, 6.44, 5.04, 6.83, 7.27, 6.57, 7.68, 6.92, 5.23, 5.28) = 5.04.
\]

\[K_1 = 5.04 \times SV(6.13X_1 + 6.44X_2 + 5.04X_3 + 6.83X_4 + 7.27X_5 + 6.57X_6 + 7.68X_7 + 6.92X_8 + 5.23X_9 + 5.28X_{10}).
\]
\[K_2 = (1 \times (X_4 + X_6 + X_7 + X_9) + 0.5 \times (X_1 + X_3 + X_5 + X_{10}) + 0.2 \times (X_2 + X_8))/SV.
\]
\[K_3 = (0.86X_1 + 0.87X_2 + 0.89X_3 + 0.8X_4 + 0.9X_5 + 0.92X_6 + 0.97X_7 + 0.87X_8 + 0.93X_9 + 0.96X_{10})/SV.
\]
\[K_4 = |SV - 4200|.
\]

The solution of the problem with the usage of Microsoft Excel ("Decision Search" program) gives the following result:

\[X_1 = 56, X_2 = 0, X_3 = 69, X_4 = 56, X_5 = 0, X_6 = 116, X_7 = 0, X_8 = 0, X_9 = 3561, X_{10} = 236,
\]
\[W = 0.948.
\]

Choosing other weighting coefficients of criteria convolution, the result of the solution will change. So, for example, if \(g_1 = 0.8, g_2 = g_3 = 0.1, g_4 = 0.3\), we will receive the following optimum volumes of purchases:

\[X_1 = 121, X_2 = 2, X_3 = 168, X_4 = 2, X_5 = 0, X_6 = 98, X_7 = 0, X_8 = 0, X_9 = 3589, X_{10} = 220.
\]

If the exact observance of supply to the set volumes is not necessary (to clean \(K_4\) criterion), the result is \(X_9 = 3584\) (the others equal to 0), i.e. supplies have to come from the supplier on a deferred-payment basis with the lowest price.
In practice, often, it is required to deliver production by full carriages (the railways requirement). Let us introduce the additional constraint: all variables must be a multiple of 60.

The result: $X_1=60$, $X_3=180$, $X_4=60$, $X_6=120$, $X_9=3540$, $X_{10}=240$, the values of subtest criteria $K_1=0.95$, $K_2=0.94$, $K_3=0.93$, $K_4=0$, $W=0.947$. As optimum values of subtest criteria $K_1=K_2=K_3=1$, $K_4=0$, we receive the decision close to the ideal.

3.5. Multi-commodity dynamic mathematical model of General supplier activity

The transportation problem of definition of the supply optimal plan of several products is considered. It is given:

- planned volumes of supply according to the whole nomenclature of material resources $R$ in the period of $T$;
- financing limits in the period of $T$ by groups of resources (one group can consist of one resource).

Possibilities of product acquisition by the sub-supplier $p$:
- volumes of possible purchases carriage paid in the period of $T$;
- purchase prices;
- the cost of delivery of a resource unit $R$;
- probability for the delay for $t$ days,
- penalties for failure of deliveries for $t$ days.

It is necessary to perform management optimization by the process of deliveries and purchases with observance of the supply plan and minimization of expenses and penalties. Thus, it is necessary to find $X_R^T$ — volumes and terms of supply of all material resources, $X_{Rp}^T$ — volumes and terms of purchases by subsuppliers $p$ with delivery in the period of $T$, meeting the following conditions:

$$X_R^T = \sum_p X_{Rp}^T;$$

(24)

$$X_{Rp}^T \leq W_p^R;$$

(25)

$$\sum_p \sum_{R \in GR} X_{Rp}^T (Z_p^R + D_p^R) \leq L_{GR}^R. \quad (26)$$

Providing for planned value of supply:
\[ \forall s \sum_{t=1}^{S+\delta R} X_{t}^{R} \geq \sum_{t=1}^{S} PP_{t}^{R}, \]  

(27)

Where \( \delta_{R} \) — maximum term of fails to deliver of \( R \) resource.

The objective function — total costs for purchase and transportation of resources:

\[
\sum_{T_{p}} \sum_{t=1}^{T_{p}} \sum_{v=1}^{T_{p}} X_{t}^{R} \left( Z_{p}^{R} + D_{p}^{R} + \sum_{t=1}^{S} PZ_{p}^{R}(t) \times SS_{p}^{R}(t) \right) \rightarrow \min .
\]  

(28)

\( T_{dup} \) — the target time period.

Resulting from the solution \( X_{t}^{R} \) are necessary for the conclusion of purchase contracts with observance of the client and the supplier interests.

3.6. Mathematical model of multi-commodity dynamic problem of the supply optimization taking into account priorities of the suppliers

In this model some ideas of models 3.4 and 3.5. are integrated.

It is given:

- \( V_{Rmin}^{t}, V_{Rmax}^{t} \) - minimum and maximum required supply volumes of \( R \)-product in \( t \)-period;

- \( \delta_{e}, \delta_{l} \) — acceptable deviation from demanded terms of supply (earlier, later);

- \( C_{Rp}^{t} \) - the cost of a unit of a delivered \( R \)-product from the supplier \( p \) in \( t \)-period;

- \( A_{p} \) — priorities of suppliers (is calculated according to formula (6) or according to the method stated in 3.3);

- \( B_{Rpmin}^{t}, B_{Rpmax}^{t} \) — minimum and maximum possible supply volumes of \( R \)-product from the supplier \( p \) in \( t \)-period;

- \( S_{R}^{tt} \) — the losses connected with individual variation of demanded terms of supply of \( R \)-product in \( t \)-period;

- \( S_{R}^{tv} \) — the losses connected with individual variation of demanded volumes of supply of \( R \)-product in \( t \)-period;

- \( V_{R} \) - the general need of the project for \( R \)-product.

It is necessary to find \( X_{t}^{R} \) — volumes of supply of \( R \)-product from the supplier \( p \) in \( t \)-period meeting the following conditions:

\[
B_{Rpmin}^{t} \leq X_{t}^{R} \leq B_{Rpmax}^{t},
\]  

(29)
\[ \sum_{v_p} X_{tp}^R \in \Omega V_t^R, \quad (30) \]

where \( \Omega V_t^R \) - set allowable by volume and time of supply (at the necessary volume of supply of R-product in \( t \)-period \( V_t^R \), there can be acceptable deviations of volume from \( V_{Rmin}^t \) to \( V_{Rmax}^t \) and of time \( t - \delta_e \leq t \leq t + \delta_l \)).

\[ \sum_{v_p} X_{tp}^R = V_R. \quad (31) \]

Optimization criteria:

\[ F_1 = \sum_{vlt, p, R} A_p \cdot C_{R_p}^t \cdot X_{tp}^R \rightarrow \min, \quad (32) \]

\[ F_2 = \sum_{vlt, R} \left( \sum_{v_p} X_{tp}^R - V_t^R \right) \cdot S_{R}^{t^v} + |t - \tau| \cdot S_{R}^{tv} \rightarrow \min. \quad (33) \]

CONCLUSIONS

The suggested models realize the problems of mathematical programming with linear and nonlinear restrictions and the objective functions. Now there is a wide range of software for the solution of similar tasks, it is enough to point out a Solver package (Finding solutions) belonging to EXCEL. For the construction of a regression model and a numerical estimate of regression coefficients in 3.1 it is possible to use "Regression" function of the Data Analysis package, forming part of EXCEL, or modules of STATISTICA "Multi-regression" and "Nonlinear Estimation" package.

The presented mathematical models with the usage of the developed multi-criteria estimation of suppliers are the effective solution tool of the supplier selection problem, allowing to reveal not only the most favorable suppliers, but at the same time to determine the optimal volumes of the production purchases by each of competing supplier on the basis of computer realization under changing conditions of the market. The problem statements for General supplier considered in this article can serve as methodological basis of the development of software application packages (of automated system) for the solution of described above problems of interaction with the supplier during the project management at all stages of its implementation.
REFERENCES

7. Bazhin II, Barinova N.M., Sysoev, V. Anti-corruption mechanisms for selecting a vendor to manage resource provision//"The head of budget organization," 2011, N 8
9. Pearson's Correlation Coefficient r (Critical Values) http://psystat.at.ua/Articles/Table_Pearson.PDF
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