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Decision support systems for teambuilding

Natalia Yanova *

Department of Psychometrics and Educational Qualimetry, Altai State University, pr.Lenina 61, Barnaul 6560049, Russia

Abstract

The article discusses the problem of soft factor in decision support systems for teambuilding. This paper initializes a match approach to solve the team formation factors with psychological nature. The subject of this article includes theoretical concept, experimental method and software technology for optimization and automation coacher decisions about team organization. Author's approach concerns the new technique of target group formation, taking into account the effectiveness and efficiency of teamwork. The technique implements optimization algorithm based on mathematical analysis of non-additive and complex factors of group interaction. Match models for measuring and prediction to such effects as complimentarily and participation are proposed. As an engineering solution, an expert system for teambuilding simulation is demonstrated. This type of decision support system is called the test expert system and is based on the professional and psychological diagnostics of teamwork.

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Keywords: Mathematical psychology; psychometrics; soft factors; team formation; group performance; competence spaces of skills; match modeling; decision support systems; test expert systems.

1. Introduction

Approaches of probabilistic modeling to solving problems associated with incomplete information or fuzzy computations are the most common, but not the only ones. Among the important actual mathematical problems, the

* Corresponding author. Tel.: +79039109081; fax: +7-3852-36-6327.
E-mail address: yanova.ng@yandex.ru

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following tasks stand out: team selection and team composition, functions and roles distribution, team cohesion, performance level, transformational leadership. Mathematical models of team formation, as a rule, reflect the described properties of the teams: models of autonomous and joint activity, models of formal and informal teams, temporary and permanent teams, functional and creative teams. For example, models of synergistic effect in the theory of corporate games take into account emergence. Reputation models (Jean Tirole's model or Shapiro-Stiglitzmodel) take into account stability, collaboration and unity of purpose. On the contrary, most models, like the well-known Holmstrom's model, do not reflect such features as specialization and complimentarily of roles in the team, individual contribution to the overall result of the activity. Game theory describes a wide repertoire of agent strategies and includes reflexive games, evolutionary games and behavioral games. All of them are aimed at strategies of "decision-making" by agents (team members) in a statics or dynamics. Such models are widely used in economics, management and production.

The interest of this study is assignment problem as classical match problem of team optimization, but in a neoclassical setting (not same for game theory). Universal parameters for modeling remain the same: team composition (multiplicity of agents); total performance (target function), functions and states of agents, team effectiveness. A new formulation of team formation problem is connected with the characteristics of collaboration: specialization (distribution and redistribution of roles), complementarities (interdependence), compatibility (individual and group) and participation. The search for the solution is aimed at calculating the optimal team composition with maximum of total performance and efficiency of teamwork (maximum result at minimum cost). This task is most relevant for sport games and requires a mathematical model for assessing the objective and subjective factors of dynamic interactions.

2. Methods

2.1. Technique of formation

A new method of team formation is based on the distinction between the group and command functionality interaction. It assumes the calculation of the direct and indirect contribution of the group and its members to the task solution. Direct contribution is related to professional assessment (professional group work), whereas indirect contribution is related to psychological assessment (teamwork). New computational options:

Professional assessment of the team (group) or direct contribution to the task implementation

The team is understood as a target group, the total performance of which is maximally oriented towards the goal (a specific organizational\sport task). By topological representation, this is a group of professionals who have the optimal tool set needed to solve the task. In vector space, the group is described as objects (members of a group) defined in the property space (professional knowledge, abilities, skills) in the form of a set of vectors oriented to the target vector. Technologically it is carried out by constructing a target vector (as the optimal direction of the task solution) and a total performance vector (sum vector of group resulting), the angle between which diagnoses the target principle of team selection and allows quantifying the productive and non-productive costs.

Computational options: an integrated assessment of the professional qualifications of the group towards the task solution (*Group Rating*) and an individual professional contribution to the task solution (*Professional Index*).

Table1. Group Team options:

Team options	Optimal variant	Custom variant
Group Rating	0,43	0,4
Group Efficiency, %	6	6
Average Compatibility Threshold	0,53	0,51
Negative Choices, %	14	19

Psychological and team assessment of the group or an indirect contribution to the task implementation

The team is understood as the integrated functional unity of the group members, providing team stability by principle of group complementation, compatibility and cohesion. In this sense, a team from a group distinguishes the optimal correspondence to the target task, not so much due to the professional qualifications of its members (optimal for the task), but rather due to the optimal way of mutual participation in achieving it (e.g., the concept of "teamwork" or "chemistry" in sports teams and concept of "harmony" in project teams).

The "teamwork" of individual participation in a group is determined not so much by the professional contribution as by the ability to bring the group closer to the optimal achievement of the goal. The team contribution to the task solution is provided by compensation for unproductive expenses: in vector space, this is expressed in how much the individual vector is able to deploy the group vector in the direction of the target vector. As a rule, it is the indirect contribution of the group members that can ensure the optimal achievement of the goal. It plays the role of the main latent component of the group process, which converts the group into a team.

Computational options: "team evaluation" of the group is measured by the options of the group team index *(Group Team Index)* and the threshold of group compatibility in the team (*Average Compatibility Threshold*). Individual parameters are the team contribution of each member of the group to the task solution (*Team Index*) and the level of compatibility with the group (*Compatibility Level)*.

Table 2. Individual Team options

Name	Professional Index (%)	Team Index	Compatibility Level	Leadership Order
Player 1	34	0,44	0,75	1
Player 2	15	0,02	0,80	2
Player 3	22	0,24	0,50	3
Player 4	15	-0,05	0,70	4
Player 5	4	0,03	0,40	5
Player 6	5	-0,07	0,62	6
Player 7	4	-0,03	0,31	7

Psychological assessment of the group is represented by a table of the psychological compatibility coefficients of all group members with each other.

Table3. Pair Compatibility Values

Name	Pl 1	Pl 2	Pl 3	Pl 4	Pl 5	Pl 6	Pl 7
Player 1		0,00	0,00	0,01	0,00	0,00	-0,07
Player 2	0,00		0,70	0,15	0,00	0,00	0,55
Player 3	0,35	0,86		0,69	0,52	0,76	0,70
Player 4	0,82	1,00	0,88		1,00	0,98	0,99
Player 5	0,55	0,98	0,95	1,00		1,00	1,00
Player 6	0,42	0,99	1,00	0,55	0,74		1,00
Player 7	-0,28	1,00	1,00	-0,03	0,74	1,00	

Selection and evaluation of the leader in the group: the target leadership coefficient

The technique is implemented in two versions: (1) automatic formation of teams with the subsequent determination of the most effective team leaders; (2) various options for assigning leaders with the subsequent automatic formation of target groups. A variety of algorithms for determining the leader is associated with the possibility of forming various organizational models of target groups (from bureaucratic structures to creative teams).

- The strategy with the appointment of leaders has two options for implementation.
  It is indicated which of the applicants will be the leader without reference to a specific task. In this case, an additional condition is imposed on the formation of optimal groups - a mandatory entry of one of such leaders into the target groups. Naturally, this can affect the selection of the most effective groups to perform the tasks.
- Directive appointment of specific members to be the leaders of the group on specific tasks.
  This option is the least preferable for the formation of the most effective target groups.
  The technique is implemented in a software version and includes the following program modules:
  - Project manager module
  - Team (staff) testing module
  - Data processing module

2.2. Formation algorithm

The algorithm of formation (data processing) includes consecutive procedures.

- Preliminary division into groups according to the tasks, based on the condition of a positive value of the individual rating for each task. At this stage, the same applicants can simultaneously be in several groups.
- Optimization of target groups is carried out consistently, beginning with the smallest in composition group. The optimization process for each group consists of the following steps:

a. A search of all possible variants of the target group is made proceeding from the psychological compatibility according to the formula C_N^k, where N - the number of applicants in the group after the preliminary selection, $k = 2,3,...,N$ - quantitative composition of the target group. If "k" has a fixed value, then the search of options ends when this value is reached. Simultaneously dynamic control of the group rating and efficiency coefficient is carried out: if the obtained version of the group has the values of these parameters not lower than the threshold, then this option is fixed. If the group rating of the received version exceeds the current maximum value, then the group variants obtained at that moment are revised based on the new group rating threshold value.
b. After obtaining all possible variants of the target group, the choice is made of the one that has the maximum value of the group efficiency coefficient.
c. A check is made of the composition of groups that have not yet been optimized, in order to remove from them the applicants who are part of the target group.
   - direct contribution to the solution of the task (professional index);
   - indirect contribution to the implementation of the problem (team index);
   - level of psychological compatibility of each member of the group with each;
   - target leadership coefficient(ratio) in this group.
d. A forecast is made for the progress of the work of the groups obtained, indicating the group parameters:
   - Group Professional Index
   - Group TeamIndex
   - Average Compatibility Threshold (threshold of group compatibility in the team)
e. A list of applicants not included in any of the formed groups is output, indicating those groups in which it is possible to include applicants with a minimum risk of diminishing the efficiency of the groups.

3. Results

3.1. Formalization

Suppose we have an initial contingent of n-people $\{\Omega_1, \Omega_2, \ldots, \Omega_n\}$, who are used to form groups to solve tasks: $\{Y_1, Y_2, \ldots, Y_r\}$. Each task is realized due to q professional qualities {V1, V2, ...,Vq} - operational means of its solution (parameters of qualifications, skills, knowledge, competences, etc.).

The first stage is the assessment of the professional qualities of V_l of each applicant Ω_i from the initial list of the contingent. This operation is carried out by the consecutive ranking of the subjects N by the experts (or one) with respect to the quality V_l for the current task Y_l. Next is the automatic scaling of ranks on the relativistic scale. As a result, each subject is described by a vector of professional qualities $\vec{v}_i = \left(\overline{v}_{i1}, \overline{v}_{i2}, ..., \overline{v}_{iq}\right)$, where $\overline{v}_{il}$ - the average expert evaluation of the l-quality of the l-subject.

At the second stage, experts (or one) assess ratings of applicants in relation to their ability of solving tasks $\{Y_1, Y_2, \ldots, Y_r\}$. Mathematical processing of expert assessments is made according to the formulas of relativistic psychometrics (the vectors for assessing the qualities of the subjects are translated into the corresponding angular coordinates in Minkowski space).

On the basis of expert estimates, the coordinates of the subjects Ω_i are calculated. Using a component analysis with subsequent "varimax"- rotation, professional qualities are combined according to functional similarities in k category groups: $G_1, G_2, \ldots, G_k$ $(k < m)$, in which the final professional assessment of the applicants Ω_i is made. In such a representation, each member of a group is characterized as a system of independent operational tools $\{g_1, g_2, \ldots, g_k\}$. The target vector $\vec{Z}_j$ (the direction of j-task solution, see Fig.1) is determined from the condition:

$$\vec{Z}_j \cdot \vec{\Omega}_i \cdot P_i = R_{ij}\ , \quad \text{where } \vec{\Omega}_i = U_i \cdot (g_1,\ g_2,\ \ldots,\ g_k, g_{Hi}) \tag{1}$$

is a vector describing the professional qualities of the ***i***-applicant, g_H is a rigidity (a measure of professional stability, calculated in the relativistic scale); R_{ij} is a rating of the i applicant, characterizing his or her ability to solve the task $\mathbf{Y_j}$.

Thus, the maximum rating of the suitability to solve the task has an applicant who has the most optimal set of operational means of its solution and possesses the highest stability at the same time.

The technique allows to decompose the vector of each target goal into categories and determine the significance of each category for the solution of each task, and also to determine the correspondence of each applicant for each task $\mathbf{Y_j}$. This allows forming a professional group as a set of functional tools, maximally focused on the desired target goal. This problem is solved from the condition of maximization of the functional quality $\mathbf{Q_j}$:

$$\max Q_j = \max\left\{\vec{Z}_j \cdot \left(\sum_i \vec{\Omega}_i\right)\right\} \text{ for each } Y_j, \ \sum_i \vec{\Omega}_i \text{ is a "professional" assessment of the group.} \tag{2}$$

The figure shows applicants $\mathbf{\Omega_1}$, $\mathbf{\Omega_2}$, $\mathbf{\Omega_3}$, $\mathbf{\Omega_4}$, in the subspace of the category of operational tools ($\mathbf{G_i}$, $\mathbf{G_j}$). $\mathbf{Z_1}$ and $\mathbf{Z_2}$ –are the target vectors of tasks $\boldsymbol{Y_1}$ and $\boldsymbol{Y_2}$, $\boldsymbol{(R_{ij})}$ - contributions of the applicants in tasks solving. Professional vectors of groups $\mathbf{\Omega_{Z1}}$ and $\mathbf{\Omega_{Z2}}$ are the sum of the first, second, third and fourth applicants. R_1 and R_2 - group ratings on the achievement of the target goals $\mathbf{Z_1}$ and $\mathbf{Z_2}$.

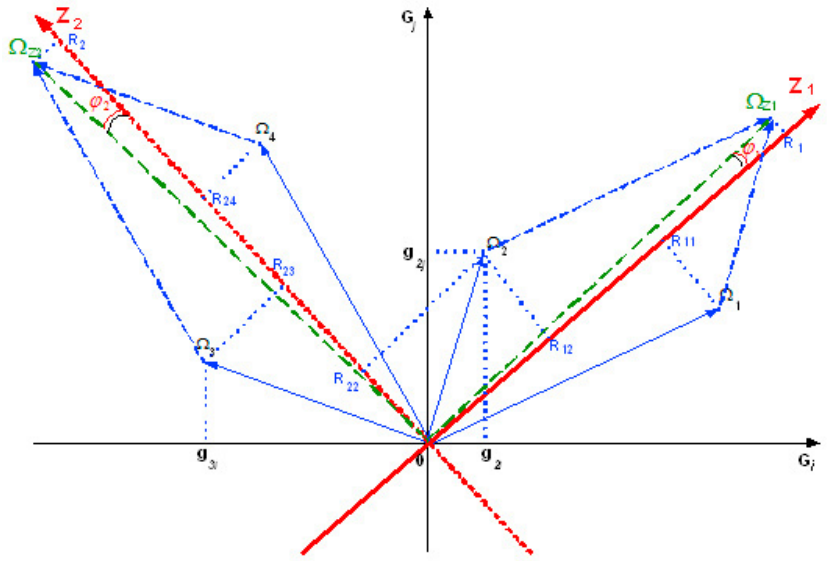

Fig.1 Target vectors

It is obvious that team performance is defined through $R_i = \left|\vec{\Omega}_{zi}\right| \cdot \cos\varphi_i$, where φ_i - is the angle between $\mathbf{Z_1}$ and $\mathbf{\Omega_{Zi}}$. As $\vec{\Omega}_{zi}^2 = \vec{\Omega}_{zi}^2 \cdot \cos^2\varphi_i + \vec{\Omega}_{zi}^2 \cdot \sin^2\varphi_i$, then $\vec{\Omega}_{zi}^2$ - characterizes the total expenses of solving the task, $\vec{\Omega}_{zi}^2 \cdot \cos^2\varphi_i$ - productive and $\vec{\Omega}_{zi}^2 \cdot \sin^2\varphi_i$ - unproductive expenses. Efficiency coefficient of the group is $\cos^2\varphi_i$. The threshold value of the latter is set by the expert.

If several target groups (for specific tasks) are formed from this contingent, the optimal strategy will be:

1. preliminary selection of group options for each task with maximum values (not lower than the specified threshold - "optimization parameter" T) of the group rating;
2. subsequent selection of the variant with maximum efficiency for the task.

The optimization parameter is set by the expert as a value expressed as a percentage of the maximum group rating. However, a professionally oriented group can become a team if there is a psychological compatibility of its members and an effective leader.

At the third stage, the psychological compatibility of applicants in the group is assessed. To assess pairwise compatibility, either an interactive test or a questionnaire is used. Formation of the group occurs on the basis of a given taxonomic parameter with the minimum value of mutual compatibility of the group members.
The degree of psychological compatibility of all group members with each applicant $\boldsymbol{\Omega_i}$. $\{x_1, x_2, \ldots, x_n\}$, is consistently assessed. Here $x_i = 0$, since the applicant's compatibility with himself is not investigated. In this variant, it is sufficient for each applicant to rank the contingent according to the condition: "with whom I would like to work in one group in the first place, second, etc.'' The reverse pole is the condition: "with who would I least like to work together" (in fact, each applicant makes the most optimal groups for himself).

3.2. Implementation

Expert (manager) should set the following parameters for the formation of groups:

a. Create a list of targets (projects)
- Make a list of qualification and professional requirements for solving tasks (the list is compiled separately for each task)
- Create a complete list of possible applicants toa group (groups)
- Set the parameter of the group optimization strategy (in percent). A high percentage determines the high efficiency of the groups in the dynamics of their development (recommended if the groups are planned for a long term in the same formulations), and a low percentage means the rapid fulfillment of current tasks without taking into account the costs of their implementation (labor, financial, material, human).
- Indicate how leaders are defined:
    - Appointment of leaders (with automatic selection of projects and groups for them)
    - Assigning leaders to specific tasks (with automatic selection of groups)

b. Automatic (optimal) selection of leaders and groups

c. Manager (or a group of experts) assesses the qualifications and suitability of applicants to implement the projects. Technologically, it is implemented in the form of testing within a separate software interface.

d. Applicants evaluate each other for psychological compatibility in group activities (rank applicants in the list according to the degree of their desirability in the working group).In the case of recruiting; they are tested for a paired psychological compatibility. Technologically, this is also implemented within a separate software interface.

e. After automatic merging (pooling) of data from experts and applicants, it is transferred to the accounting software module. It forms and optimizes the composition of the group by professional parameters and psychological compatibility.

f. The results are generated automatically by the software module and include the following measured parameters:
    - integral assessment of professional correspondence of the group to the task (Group Rating)
    - integral assessment of the group efficiency (Group Efficiency)
    - individual professional contribution (Professional Index)
    - individual (Team Index) and group (Group Team Index) contribution to the task
    - threshold of group compatibility in the team (Average Compatibility Threshold)
    - player compatibility level with the group (Compatibility Level)
    - table of compatibility coefficients of players with each other
    - target leadership coefficients (Leadership Order) and list of substitute players

The system allows monitoring of the group's progress, as well as comparison of the effectiveness of team composition, including the evaluation of the modeled version (Optimal Variant) and the version of the coach (Custom Variant). This model is a useful tool for the team coaches.

4. Conclusions

The technique allows the user in the shortest time to create optimal composition of target groups for the solution of specific tasks, to predict their total performance, to monitor progress in the quality of teamwork, to calculate the individual contributions to the teamwork and to determine the effectiveness of individual and group expenses to achieve the goal.

The developed technology satisfies the following principles: (1) creation of professional groups that are optimally designed to solve the corresponding task; (2) optimal choice of effective team and work leaders for the tasks; (3) optimal selection of team roles and work positions for group members; (4) optimal psychological compatibility of group members; (5) quantitative optimization of target groups on teamwork effectiveness criteria; (6) monitoring the progress of the current teamwork of the group.

The 'Staff Expert System' has been tested and adapted on the example of the formation and evaluation teamwork of project teams, formation and provision of sports teams, studying teamwork in extreme conditions (rescuers, fire brigades, train crews), as well as planning of organizational design in commercial and government structures.

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