AN EXPERIMENT BASED ON THE "TEAM COMPENSATION POLICY" BUSINESS GAME

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The paper discusses experimental design and data analysis for the TEAM COMPENSATION POLICY business game. Some results of statistical analysis and graphs of the participant strategies are presented.

1. INTRODUCTION

The TEAM COMPENSATION POLICY business game was developed as a teaching and research tool. The game pursued the following experimental goals: 1) selection of the most efficient team compensation policy; 2) investigation of player strategies. This paper describes the experimental design and the results of statistical analysis of the observations. Frequency histograms of the individual strategies in different rounds of the game and the round-average strategies are presented. The main focus is on experiment design. As far as we know, until recently experimental design theory has not been applied to business games in the USSR. The reason for this is apparently that business games are fundamentally different from the controlled scientific experiments for which this theory was originally developed.

The theory of experimental design was applied in order to substantiate the conclusions drawn from the business game. This means that repeating the business game with other players under the direction of other supervisors should produce the same results. Business-game experimental design has three objectives: first, to produce with minimum cost data that are sufficient for drawing valid conclusions; second, to obtain data that are suitable for statistical analysis; and third, to interpret the experiment, because an unstructured experiment is not amenable to any interpretation.

2. THE EXPERIMENTAL DESIGN PROBLEM

The TEAM COMPENSATION POLICY game models the organization of socialist competition in a team. Each player is a team member. If the team exceeds the plan, it receives a bonus $B = B_1 + B_2$, where B_1 is the bonus for exceeding the plan and B_2 is the bonus for participating in socialist competition. The move of player i (the strategy chosen by player i) in each round consists of reporting to the supervisor (the foreman) the volume of work x_i performed in excess of the plan, after which the player is awarded the bonus b_i, $i = 1, 2, \ldots, N$, where N is the total number of players. The objective function of player i has the form $\varphi_i = b_i - z_i$, where $z_i = cx_i$ is the cost associated with performing the excess work, c is the cost coefficient, the bonus of player i consists of two parts $b_i = b_{i1} + b_{i2}$, where $b_{i1} = \left(x_i \Big/ \sum_{j=1}^{N} x_j\right) B_1$ is the bonus for exceeding the plan and b_{i2} is the bonus for participating in socialist competition.

The bonus for participating in socialist competition may be paid out in four different ways: 1) equally to all players, except those who came last with the lowest scores: $b_{i2} = B_2/(N - n_1)$, where n_1 is the number of players in the last place; 2) to all players in proportion to the labor participation ratio (LPR), again with the exception of the lowest scoring players: $b_{i2} = \left(x_i \Big/ \sum_{i \notin Q} x_j\right) B_2$, where $x_i \Big/ \sum_{j \notin Q} x_j$ is the LPR and Q is the set of players in the

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last place; 3) only to the highest scoring players, $b_{i2} = B_2/n_2$, where n_2 is the number of players in the first place; 4) no socialist competition, so that $B_2 = 0$ and $B_1 = B$. The foreman's problem is to select a compensation (incentive) technique which results in the largest volume of work in excess of the plan for a given bonus fund.

Several rounds are played by each group of players. Each round is run in three stages.

In the first stage, the players report to the foreman the volume of work done in excess of plan.

In the second stage, the foreman determines on the basis of these reports the LPR and the bonus for each player. If the team participates in socialist competition, the foreman determines the score of each participant and allocates the bonus accordingly to the competing players. Then the players tally up their transaction revenue and the associated costs.

In the third stage, the foreman announces the bonuses and the players compute the value of their objective functions.

This is the end of one round. In the next round, all three stages are repeated.

The experimental goals are: 1) to investigate the change in the average volume of work in excess of plan as a function of the compensation policy; 2) to determine the dependence of player strategy on the number of the round; 3) to determine the statistical distribution of player stategies and the average strategies in each round.

3. EXPERIMENTAL DESIGN AND DATA ANALYSIS

The observed quantity in the experiment (the response y) is the average volume of work in excess of plan in each round. The response depends on the compensation policy, the number of the round, and the group of players. These factors were denoted by x_1, x_2, x_3, respectively. The factor x_1 has four levels, denoted Σ_1, Σ_2, Σ_3, Σ_4. The mathematical model of the experiment is

$$y=f(x_1, x_2, x_3)+\varepsilon,$$

where ε is a random error. The experimental design is Latin square. The specific design of the business game is shown in Table 1. Each group of players participates in 48 rounds - up to 12 rounds for each compensation policy. The players are students enrolled in professional training courses, and the number of rounds corresponded to teaching objectives.

In order to determine if different factor levels indeed produce different responses, the hypothesis that all the observations for each level are drawn from the same population is tested statistically. The test is based on the statistic

$$F_{x_i}=\frac{ss_{x_i}/n_{x_i}}{ss_\varepsilon/n_\varepsilon}.$$

If the sum-of-square ratio exceeds the critical value under the F-distribution with the corresponding number of degrees of freedom, this means that the samples are drawn from different populations. Here ss_{x_i} is the sum of squares of the deviations of the level means of the factor x_i from the grand mean, i = 1, 2, 3 (specifically, ss_{x_1} is the sum of squares of the deviations

TABLE 1

Cycle No.	Group No. 1	2	3	4
1	Σ_1	Σ_4	Σ_3	Σ_2
2	Σ_3	Σ_1	Σ_2	Σ_4
3	Σ_4	Σ_2	Σ_1	Σ_3
4	Σ_2	Σ_3	Σ_4	Σ_1

TABLE 2

	ss	n	ss/n
x_1	380,2	3	126,7
x_2	192,6	47	4,1
x_3	52,8	3	17,6
ε	530,3	138	4,1
Σ	1155,9	191	6,1

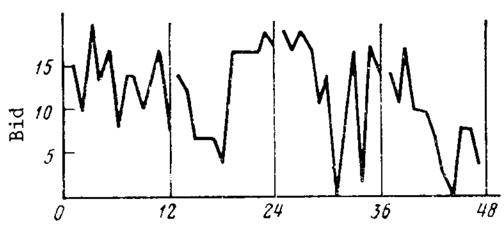

Fig. 1

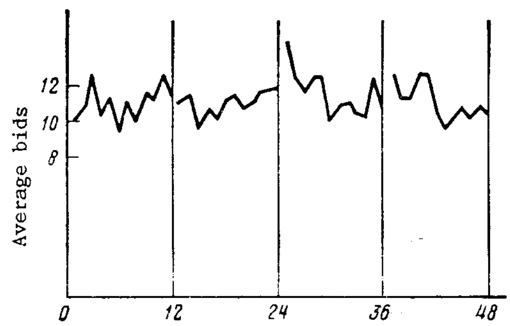

Fig. 2

of the means over the four compensation policies from the grand mean, ss_{x_2} is sum of squares of the deviations of the round averages, and ss_{x_3} is the sum of squares of the deviations of the group averages); ss_ε is the sum of squares of the random error; n_x is the number of degrees of freedom of the factor x_i (the number of degrees of freedom is equal to the number of levels minus 1); n_ε is the number of degrees of freedom of the random error. The sum of squares ss_ε and the degrees of freedom n_ε are calculated from the basic equation of the analysis of variance corresponding to the mathematical model of the experiment:

$$ss_\Sigma = ss_{x_1} + ss_{x_2} + ss_{x_3} + ss_\varepsilon, \quad n_\Sigma = n_{x_1} + n_{x_2} + n_{x_3} + n_\varepsilon,$$

where ss_Σ is the sum of squares of the deviations of the responses in all rounds from the grand mean; n_Σ is the total number of degrees of freedom, equal to the number of rounds minus 1.

The maximum volume of work in excess of plan was taken equal to 20 conventional units in the experiment. The average responses for the four compensation policies were the following: $\bar{y}_{\Sigma_1} = 9.82$; $\bar{y}_{\Sigma_2} = 11.47$; $\bar{y}_{\Sigma_3} = 13.46$; $\bar{y}_{\Sigma_4} = 10.43$. The sums of squares and the degrees of freedom are presented in Table 2. The F-ratios were the following:

$$F_{x_1} = \frac{126.72}{4.1} \gg F_{3,138}, \quad F_{x_2} = \frac{4.1}{4.1} = 1 < F_{47,138} = 1.48, \quad F_{x_3} = \frac{17.6}{4.1} > F_{3,138} = 3.06.$$

Thus, the levels are statistically different for the factors x_1 and x_3.

Duncan's multiple rank test was used in order to compare the levels of the factor x_1 among themselves. The levels Σ_1 and Σ_4 were not statistically different. Thus, it makes no sense to organize a competition in which the bonus is distributed equally and everybody is rewarded, except the last place: the volume of work in excess of plan with this compensation policy is not greater than without any competition. The level Σ_3 is statistically different from all other levels and has the highest value of the test statistic. Thus, the policy that rewards

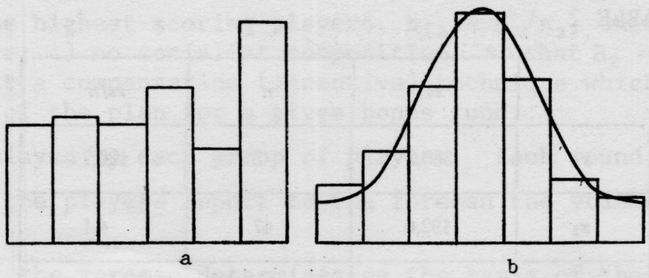

Fig. 3

only the first place produces the maximum volume of work in excess of the plan and is the most effective compensation technique for a given bonus fund.

4. ANALYSIS OF PLAYER STRATEGIES

The initial hypothesis prior to the experiment was that the player strategy should depend on the number of the round. Inspecting the experimental data, we note that the volume of work in excess of plan somewhat decreased in the middle of each series of 12 rounds. Figure 1 plots the variation of the strategies of one of the players during eight rounds, and Fig. 2 plots the variation of the round-average strategies for one of the groups over 48 rounds. Statistical analysis shows, however, that this variation of strategies is statistically insignificant: the F-ratio for the factor x_2 is less than the critical value. Thus, the question of dependence of player strategies on the number of the round in the series remains open.

The second hypothesis that was tested experimentally claimed that an observable variable with a normal or nearly normal distribution can be chosen in the business game [2]. Figure 3 presents two histograms: a are the deviations of the player strategies from the average strategy over the compensation policy and b are the deviations of the average strategy in each round from the average over the compensation policy. These histograms were obtained by summing the histograms for each compensation policy, after standardizing the means. We see that the histogram in Fig. 3b fits the superimposed truncated normal distribution, whereas the histogram in Fig. 3a does not lead to a definite decision. The distribution is truncated, because the volume of work in excess of plan may range from 0 to 20 conventional units. Thus, the round-average strategy (the average volume of work in excess of plan in each round) is an observable with a nearly normal distribuiton.

The fact that the hypothesis was confirmed leads to a number of conclusions. First, the business-game experiment is statistically reproducible. This means that experiments with other groups of players and other supervisors will produce essentially the same results. Second, since the observed variable is nearly normal, application of statistical methods, and in particular analysis of variance, to the business game is fully justified. Third, choosing the round-average strategy as the experimental response reduces the subjective effects. Indeed, the individual strategies are highly sensitive to subjective preferences. These preferences include, for instance, the reluctance to announce the number 13. This preference is so strong that it accounts for the minimum around the number 13 in the histograms corresponding to all bonus policies and for the minimum in the right-hand part of the total histogram. This example of a subjective effect in business games has been often cited as a reason for doubting the applicability of experimental design theory to business games. The subjective effect is unnoticeable in average bids, which are therefore viewed as a "good" observable variable and make it possible to apply the methods of experimental design theory to the analysis of business games.

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