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INCENTIVES IN ORGANIZATIONS: UNCERTAINTY AND EFFICIENCY

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Abstract: Game-theoretical models of incentive mechanisms in organizations are considered. General formulation of incentive problem is introduced and classification of special cases is explored. It is stated below that in most of the incentive models under interval, stochastic and fuzzy uncertainty jump or compensating incentive functions are optimal. The study of the uncertainty role leads to the conclusion that with the growth of uncertainty the guaranteed efficiency of management decreases.

Keywords: management systems, active elements, game theory, uncertainty, efficiency enhancement.

1. INTRODUCTION

Incentive problem, which consists in inducing the elements of organization (active system - AS) to undertake certain actions, is explored in psychology, economy, sociology and management theory. The complexity of incentive problems is stipulated by the activity of the managed objects - agents, i.e. by their ability for purposeful behavior, independent choice of states and actions, information misrepresentation, etc. This paper is devoted to the consideration of game theoretical models of incentive mechanisms in AS under uncertainty. Essential attention is paid to the influence of uncertainty on the efficiency of management.

The exposition below has the following structure. At first the structure of agent's activity is considered from psychological point of view. This approach allows to define incentives as a complex purposeful influence of the management body (principal) on the components of agent's activity. Then the general formulation of incentive problem and the classification of its special cases are given. Consideration of basic incentive problems under interval, stochastic and fuzzy uncertainty shows the optimality of jump (C-type) or compensative (K-type) incentive functions in most of AS under uncertainty. Then the criterion for the comparison of uncertainties is introduced, which gives a powerful instrument for the study of uncertainty's role in incentive models. Application of this criterion shows that guaranteed efficiency of management increases with the decrease of uncertainty and tends to the deterministic one. Conclusion contains some inferences and the discussion of future perspectives.

2. PSYCHOLOGICAL BACKGROUND OF INCENTIVE PROBLEMS

Consider an active system which consists of the principal and one agent. Agent's activity is subjected to the management by the principal and the influence of the environment. The structure of this interaction is presented on Fig.1.

The process of internal motivation which is based on the need leads to the forming of the motive and activity's purpose (anticipated result of activity). Being coordinated with external and internal conditions the purpose is transferred in a set of tasks. Tasks of activity are solved by application of certain technology: a set of content, forms, methods and means. Action - the act of activity leads to some result of activity (satisfaction or partial satisfaction of the need), whose comparison with the purpose modifies the components of activity (tasks, technology, etc.).

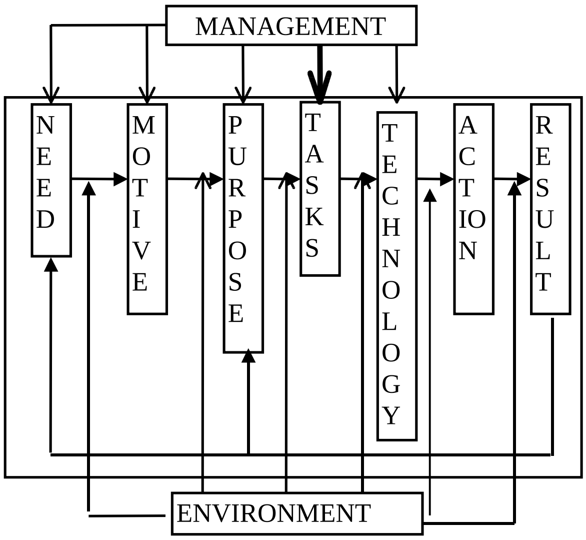

Fig.1. The structure of agent's activity.

Stimulation (incentives) is a complex and purposeful influence on the components of agent's activity and processes of their forming. It is worth noting that environment also influences on this components (the discrepancy between the action and the result of activity is one of the examples).

Most of formal models of management applies narrower definition: stimulation is usually considered as the influence on agent's tasks and processes of their forming with fixed needs, motives, purposes and technologies. This paper follows this tradition.

If an active system operates under uncertainty, then external and internal uncertainty must be separated. The former corresponds to the lack of information about the agent, the latter - about the environment (states of nature, etc.).

3. INCENTIVE PROBLEMS: GAME-THEORETICAL MODELS

Game-theoretical description of the model includes definition of system's structure, principal's and agent's interests (preferences), feasible sets, informational restrictions and the sequence of strategies choice and information transmission. Generally principal may influence on all the components of the model. For the simplicity usually the following assumption is adopted: principal influences only on the preferences of the agent. As the choice of incentive scheme is the strategy of the principal the direct incentive problem is formulated as to find feasible incentive scheme, which induces the agent to choose the action, which is most preferable from principal's point of view. The inverted incentive problem is to find a class of incentive schemes, which induce the agent to undertake certain action. Particular problem is the choice of the planning mechanism: some rule which connects principal's information with the plans (desirable actions of the agents).

The sequence of functioning is the following: the principal chooses the planning procedure, then the agent reveals some information, then they get some information about uncertain factors, then the principal chooses the incentive scheme, then the agent chooses the action, then the result of his activity is observed. This general description embraces most of the game theoretical models, which are explored in the theory of active systems (TAS) - Burkov (1977), Burkov and Enaleev (1994), Burkov and Novikov (1996), informational theory of hierarchical systems (ITHS) - Germejer (1976), theory of contracts (TK) - Hart and Holmstrom (1987), Myerson (1982), implementation theory (IT) - Dasgupta et al (1979), Moore (1992), etc.

As the elements of the active system possess activity, principles of their strategies choice must be defined. According to the hypotheses of the rational behavior, they remove uncertainty (utilizing all the information) and choose the strategies which maximize their goal functions. The efficiency of management (guaranteed efficiency) is defined as maximal (or guaranteed) value of principal's goal function over the set of implementable actions - see Burkov (1977).

4. CLASSIFICATION OF INCENTIVE PROBLEMS

Introduce the following bases of classification: structure of AS (two-level or multilevel AS), time horizon (number of periods: static AS and dynamic AS), order of functioning (standard - described above and nonstandard), number of agents, informational structure (symmetric, asymmetric or mixed), uncertainty form (no uncertainty, interval, stochastic, fuzzy or mixed uncertainty), uncertainty type (internal, external or mixed uncertainty).

Define the class of basic models: incentive problems in static active system with one agent standard order of functioning, one form or type of uncertainty (or deterministic). There are 13 basic models in this class, listed in Table 1. In the "notes" row branches of management science, which explored certain model, are given. Model M6 was perfectly explored in the theory of contracts, while M8 - in the collective choice theory (implementation theory). It is worth noting that models M3 and M9 (internal stochastic uncertainty) were not studied yet due to the complexity of their practical applications.

Table 1. Classification of incentive problems and main results

N	Information	Uncerta-inty form	Uncerta-inty type	Notes
M1	Symmetric	-	-	TAS, TK
M2	Symmetric	Internal	Interval	TAS, ITHS
M3	Symmetric	Internal	Stochastic	-
M4	Symmetric	Internal	Fuzzy	-
M5	Symmetric	External	Interval	TAS, ITHS
M6	Symmetric	External	Stochastic	TAS, TK
M7	Symmetric	External	Fuzzy	-
M8	Asymmetric	Internal	Interval	TAS, IT
M9	Asymmetric	Internal	Stochastic	TAS
M10	Asymmetric	Internal	Fuzzy	-
M11	Asymmetric	External	Interval	TAS, IT
M12	Asymmetric	External	Stochastic	TAS, TK
M13	Asymmetric	External	Fuzzy	-

5. BASIC MODELS AND MAIN RESULTS

Table 2 contains the following information about the basic models (except M3 and M9): number of the model, optimal incentive scheme («and» means that both C-type and K-type incentive functions are optimal while «or» means that in some subcases only one of them is optimal), the ratio between the efficiency K (guaranteed efficiency K^g) and deterministic efficiencies K_0, K_0^g (≥1, ≤1), the tendency of efficiencies $K(U)$, $K^g(U)$ change with the change in uncertainty (↑ - increases with the increase of uncertainty, ↓ - decreases, ↑↓ - depends on particular case).

Table 2. Main results on incentives under uncertainty

N	Optimal incentive function	K/K_0	K^g/K^g_0	$K(U)$	$K^g(U)$
M1	C- and K- type	=1	=1	-	-
M2	C- and K- type	≤1	≤1	↓	↓
M4	C- or K- type	≥1	≤1	↑	↓
M5	K- type	≤1	≤1	↓	↓
M6	C- or K- type	≤1	≤1	↓	↓
M7	C- or K- type	≥1	≤1	↑	↓
M8	C- type	≤1	≤1	↑↓	↑↓
M10	C- type	≤1	≤1	↓	↓
M11	C- type	≤1	≤1	↓	↓
M12	K- type	≤1	≤1	↓	↓
M13	C- type	≤1	≤1	↓	↓

Deterministic models of active systems were explored in: Burkov (1977), Burkov and Enaleev (1994), Burkov and Novikov (1996).

5.1 Incentives under interval uncertainty

Assumptions and proofs of the results on incentive models under interval uncertainty (M2, M5, M8, M11) Burkov et al (1996), Novikov (1997a), Novikov (1997c). It is worth noting that in a wide class of AS correct mechanisms are optimal, i.e. mechanisms which induce the agent to fulfill the plan and to tell the truth have maximal efficiency. But generally in multiagent AS the revelation principle, introduced in Myerson (1982), is not valid (see details in Novikov (1997c)).

5.2 Incentives under stochastic uncertainty

Assumptions and proofs of the results on incentive models under stochastic uncertainty (M6, M9) are given in: Burkov et al (1993), Burkov and Novikov (1995),. Burkov and Novikov (1996), Novikov (1995).

5.3 Incentives under fuzzy uncertainty

Unlike AS under interval and stochastic uncertainty, AS under fuzzy uncertainty turned to be unexplored. Probably the first systematic research of incentive problems in fuzzy active systems (including models with fuzzy preference relations, fuzzy income functions and fuzzy information about the environment) was carried out in Novikov (1997b).

6. UNCERTAINTY AND EFFICIENCY OF MANAGEMENT

Two key questions arise when solving an incentive problem under uncertainty. The first question is what is the correspondence between the efficiency of management in the active system in hand and corresponding deterministic active system. The second question is how does the "degree" of uncertainty influence on the efficiency and guaranteed efficiency of management.

All well-explored incentive problems under uncertainty satisfy the principle of correspondence: when the uncertainty tends to "zero" the efficiency of management tends to the efficiency of management in the corresponding deterministic model. Moreover, it tends from below (except models M4 and M7). Thus the lack of information (the presence of uncertainty) leads to the decrease of efficiency.

To show the influence of uncertainty on the efficiency of management one should introduce the criterion for the comparison of active systems by uncertainty degree. Consider two active systems with the same forms and types of uncertainty. In the case of interval uncertainty some AS is referred to as "more uncertain" then the other if its interval of possible values of uncertain parameter includes corresponding set of the second AS. In the case of stochastic uncertainty one active system is characterized by "less" uncertainty if its probability to find the result in any vicinity of agents action is greater then in the second AS. In fuzzy AS uncertainty is compared by the embedding relation of corresponding fuzzy sets. Binary relation, introduced above on the set of AS, allows to compare different active systems (but not all of them) by the "degree" of uncertainty. For AS with different forms and types of uncertainty a "natural measure" is the efficiency of management, which factorize all active systems on classes with different uncertainties but with the same minimal efficiency of management.

In accordance with the Table 2 for all basic models guaranteed efficiency decreases with the growth of uncertainty. This fact corresponds to common sense: the less is the information about the managed object the lower is the efficiency of control. But one should not rely entirely on the common sense: in the models M4 and M7 efficiency increases with the growth of uncertainty. Qualitatively this effect may be explained by the expansion of the sets of implementable actions, caused by the growth of uncertainty under the hypothesis of agent's benevolence towards the principal

7. CONCLUSION

Thus, the proposed description of agent's activity structure and the classification of incentive mechanisms allow to list all the incentive problems, which are feasible in the framework of the adopted game-theoretical approach. Unfortunately, nowadays there exists rather complete understanding of approaches towards the simplest (basic) incentive problems. The possibility of the uniform description and existence of unified analyses technic indicate that it is high time for the design of a general methodological approach towards the exploration of complex active systems under uncertainty. Therefore, it is worth waiting for the creation of the general incentive theory by joint efforts of mathematicians, psychologists, economists, etc., taking into account that corresponding technic of formal analyses exists.

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