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DECISION SUPPORT SYSTEMS FOR MULTI-ACTOR NEGOTIATIONS WITHIN ENTERPRISES AND RESEARCH ORGANIZATIONS

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ABSTRACT

The paper is concerned with problems of determining growth strategies of enterprises and research organizations functioning under conditions of economic reform. Three types of enterprise management structures are analyzed. The choice of growth strategy is to be made by all the actors involved in the decision making process. Due to the fact that the objectives of these actors are not the same, this process is, in general, very lengthy and arduous. Some formalized procedures of expert judgement and collective decision making that can facilitate the negotiations on the development of an enterprise or research organization are discussed. To make the choice of an enterprise growth strategy easier, a computerized model describing financial aspects of the functioning of an enterprise under conditions of economic reform was constructed. Using it, various scenarios of the enterprise growth can be simulated and verified. Computer systems were also worked out for the purpose of selecting scenarios to be examined and the choice of the best one(s). The paper presents in brief results of the application of the approach discussed as well as experience gained.

Keywords: Decision support, expert judgement, collective decision making, auction procedures, growth strategy, management structure

1. ENTERPRISE MANAGEMENT STRUCTURE AND RELATED PROBLEMS

The choice of a growth strategy of an enterprise functioning under conditions of economic reform is a crucial problem due to the socio-economic consequences resulting from implementation of a chosen strategy. The manner in which this choice is made is strictly connected with the management structure of an enterprise. In Poland, many problems related to various structures of enterprise management have recently been under discussion. Three types of this structure are being taken into account: strictly centralized, strictly decentralized and multi-interactive.

1.1. Strictly centralized (pyramid) structure

For enterprises (or research organizations) the most common management structure is such as shown in Fig.1. This hierarchical (pyramid) structure is typical for the centrally planned economy. The most decisive influence on the functioning of such enterprises comes from governmental agencies (e.g. the Central Planning Board) or branch ministries. Top managers (i.e. director-in-chief and deputy-directors) and representatives of political organizations and trade unions constitute the upper level of enterprise. Heads of divisions and/or departments form the medium level. Heads of production units, teams, laboratiories etc., compose the bottom level of this structure.

From the experience gained during the last 40 years it follows that this management structure is not very effective because: (i) The information flow is improper and delayed. Moreover, false reporting of the obtained results very often takes place; (ii) The top level does not really understand problems to be solved at lower levels; (iii) The objectives of a higher level are not adjusted

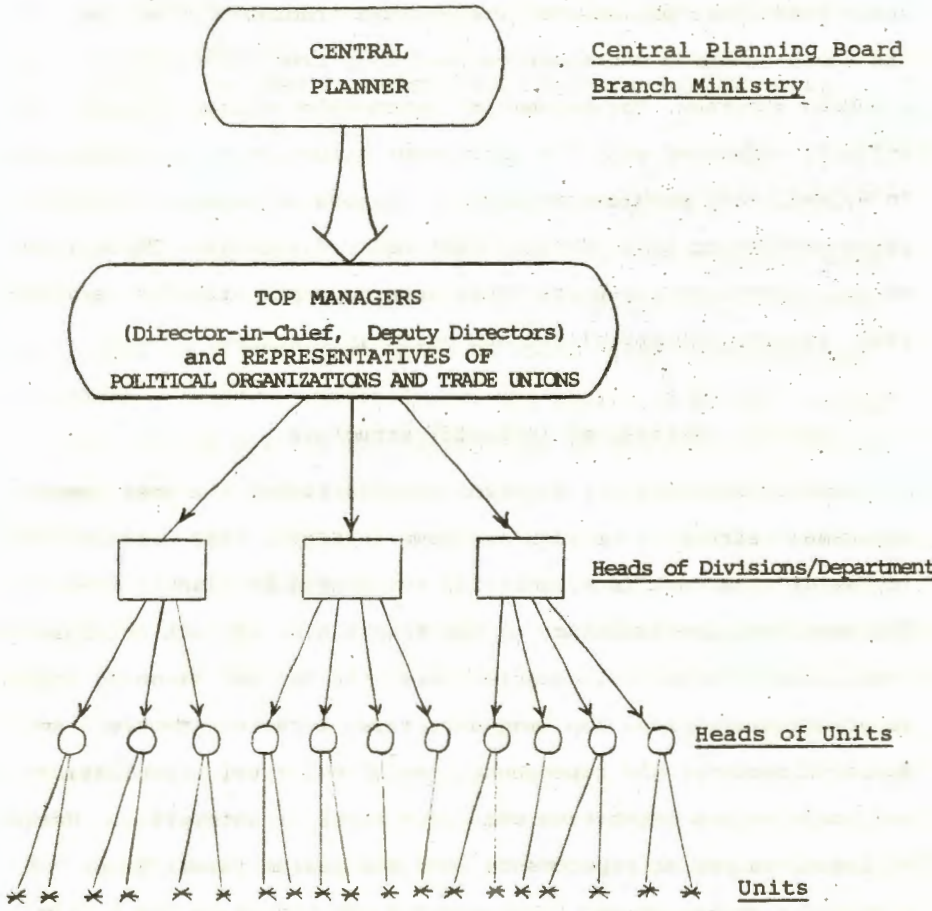

Fig.1. The strictly centralized (pyramid) structure of enterprise management.

to those of a lower one and there are no effective methods for solving these between-level conflicts; (iv) Decision making is made difficult due to bureaucratic procedures; (v) The role of workers is neglected; (vi) The enterprise activity is mostly plan and production volume oriented.

Moreover, the economic effectiveness of enterprises having the hierarchic structure is not satisfactory.

1.2. Strictly decentralized (autonomous) structure

As the result of economic reform some attempts have recently been made at establishing a new type of management structure, strictly opposite to the hierarchical one (Fig.2). Such an approach to management problems is based on the concepts of partnership, active participation, industrial democracy etc. It relies on the assumption that in a modern enterprise the main role is to be played by the self-management. In enterprises of this type the growth strategy (short-term as well as long-term) is to be determined by the self-management and managers are only to implement this strategy [Madżar (1987), Vanek (1970)]. Such a management structure is characteristic for the Yugoslav-type socialist economy and, to some extent, for Algeria's economy [Martyniak (1988), Meister (1981)]. Various concepts of self-management enterprises are also being discussed in the Soviet Union, France (the works of A. Meister (1981), P. Rosenvallon (1981), J.Bounine and F. Dalle (1981)) and in many other East - and West - European countries [Madżar (1987), Vanek (1970)]. The economy based on self-management enterprises is called in literature the Labour Market Economy; also a new category of the so-called Participatory Economy is now being introduced [Vanek (1970)].

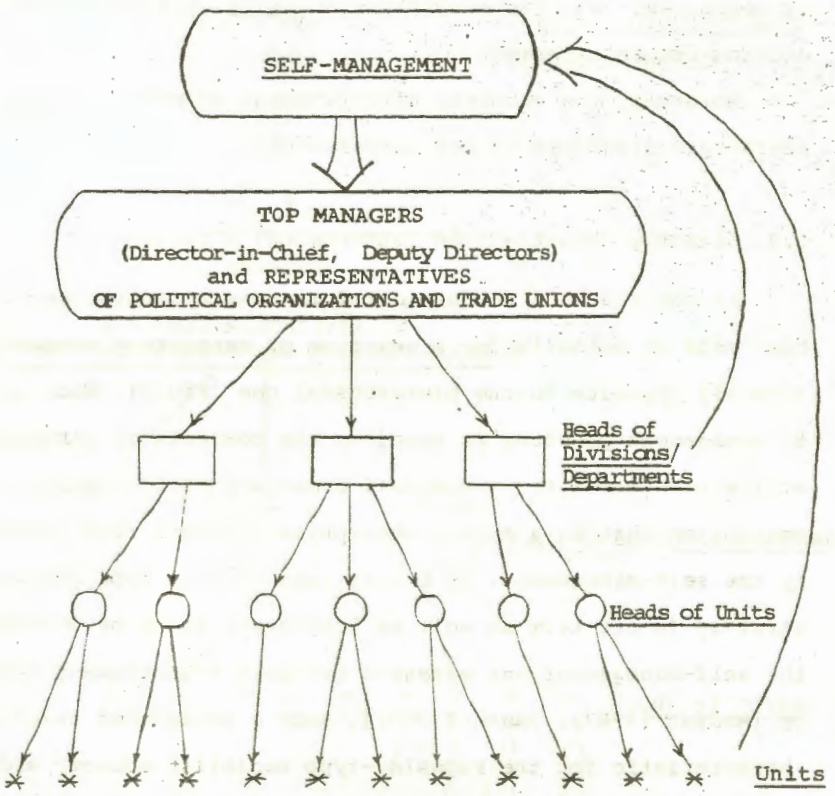

Fig.2. The strictly decentralized (autonomous) structure of enterprise management.

However, the experience gained from the analysis of the performance of Yugoslav enterprises points out that the management structure under discussion is also not very effective. Such a situation is due to the fact that the self-management idea is based on too many, not very realistic, assumptions. The most crucial ones are as follows: there is no conflict between (i) the individual and social choice; (ii) the long-term objectives and the current ones.

It is observed that in enterprises of the self-management type the major part of the profit is used for wages increases and bonuses; the enterprise operation is mostly determined by short-term forecasts. In general, long-term objectives, because of a long period of money return, are underestimated. As a result, the level of innovation is relatively low and R&D problems are neglected.

1.3. Multi-interactive (societal) structure

The analysis of enterprises acting in the centrally planned and market economies makes it possible to assume that for the Polish industry a reasonable management structure can be such as shown in Fig.3; it can be called the societal management structure. This approach is justified only under the assumption that an enterprise is functioning in conditions of real economic reform involving: (i) changes in the ownership structure; (ii) proper role of prices; (iii) decentralization of planning; (iv) credit policy based on commercial principles etc.

A proposed management structure consists of two main levels having different time horizons. The upper level constitutes the Board of Negotiators which is the counterpart of the Board of

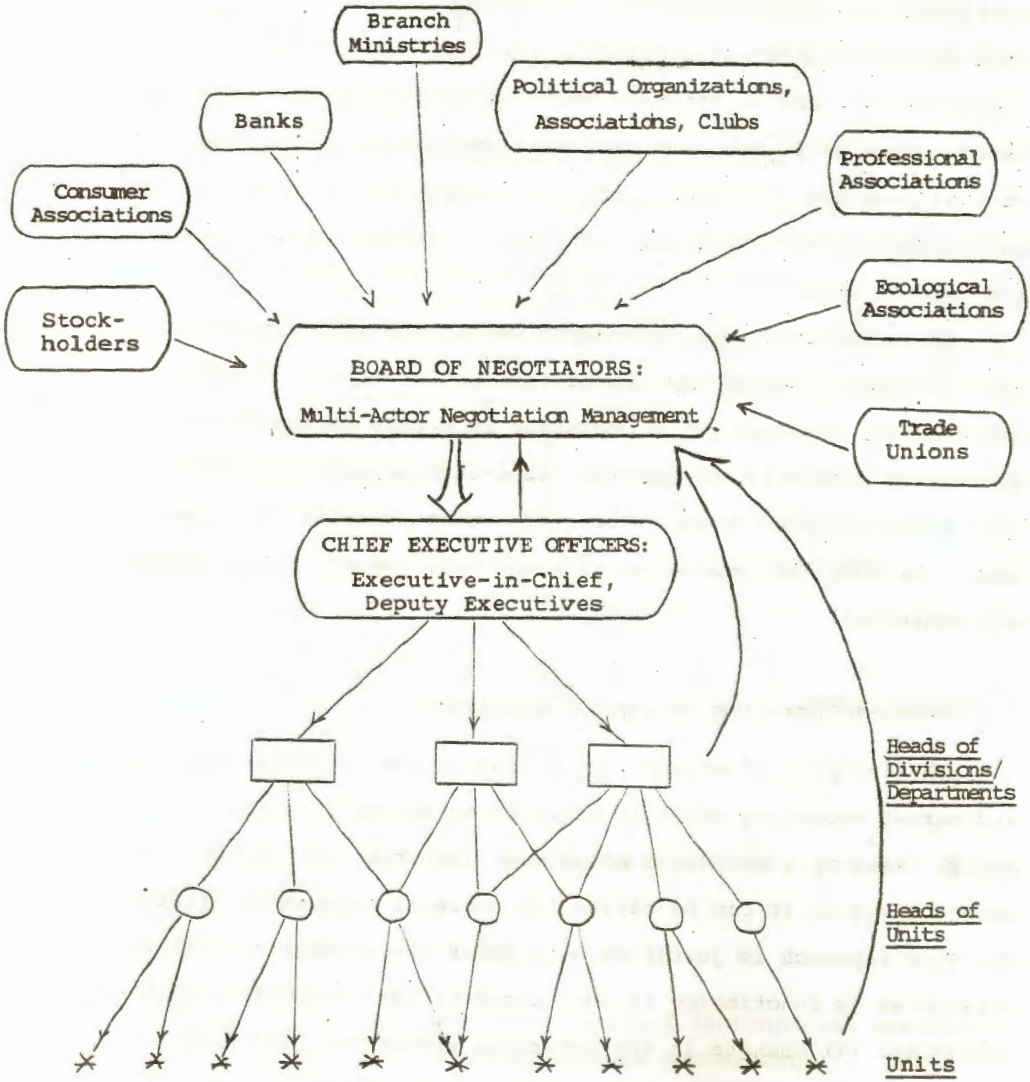

Fig.3. The multi-interactive (societal) structure of enterprise management.

Directors, typical for the Western type market economy. This Board should comprise all the actors having influence on the functioning of an enterprise; i.e. acting within the enterprise: (i) chief executive officers (i.e. executive-in-chief and deputy executives); (ii) stockholders (being employed in the enterprise); (iii) representatives of workers; (iv) political organizations (parties); (v) trade unions as well as from its environment: (i) branch ministries (representing the Treasury); (ii) banks; (iii) stockholders (not employed in the enterprise); (iv) professional associations (societies); (v) political associations (societies, clubs); (vi) ecological associations; (vii) consumer associations. Strategic decisions of the Board, related to the long-or medium - term objectives, should result from the negotiation process, as formalized as possible. The voting power of all the members of Board should be precisely defined.

The lower level is constituted by the Chief Executive Officers (i.e. Executive-in-Chief and Deputy Executives). The Executives are to follow the growth strategy determined by the Board of Negotiators, however they are in charge of all the problems connected with implementation of this strategy in a given time horizon, i.e. with the current functioning of an enterprise as well as the short--term objectives. They are nominated and they can be fired by the decision of the Board only. From the above it follows that the role of Chief Executive Officers is not the same as that of Top Managers in the strictly centralized structure.

Recently, special attention is being paid to the problem of introducing the category of stockholders to the Polish economy. Many alternative solutions to this problem are now under discussion at the Parliament (e.g. within the Socio-Economic Council), governmental agencies (e.g. within the Consulting Economic Board),

professional associations (e.g. within the Polish Economic Society, Chief Technical Organization, Polish Operations Research and Systems Analysis Society), trade unions as well as in the Polish press [Kierczyński (1988), Korwin-Mikke (1988), Krawczyk (1988), Martyniak (1988), Żyżyński (1988)]. The emission of bonds, recently approved by the Parliament, can be an additional tool in this case. Also, some decisions related to this problem have already been made in the Soviet Union.

It should be pointed out that the branch ministries (i.e. Ministry of Industry, Ministry of Finance representing the Treasury etc.) are considered as stockholders only. Their role in enterprise management is therefore less important than in the case of strictly centralized structure, characteristic for the centrally planned economy (see Subsection 1.1, Fig.1). The voting power of these ministries would depend upon the volume of their stock.

In general, it can be assumed that the voting power of particular actors depends upon: (i) the volume of stock they own, and/or; (ii) the importance of the societal power they represent.

A given part of total weights (fixed in the course of negotiations) is allocated to non-economic, societal representation in the Board of Negotiators; e.g. ecological associations, consumer associations etc. If some negotiators belong to both groups (i) and (ii), their negotiation power adds up. Moreover, the problem of establishing different or equal weights for the stock of particular negotiators is an open question now. One approach to this problem is given in [Korwin-Mikke (1988), Krawczyk (1988), Martyniak (1988), Żyżyński (1988)].

The effective operation of the Board of Negotiators is not possible without computerized models (data bases, expert systems, simulation models, computer graphics etc) that allow various

scenarios of enterprise development as well as different aspects of the functioning of enterprise to be examined. This follows from the fact that all of the members of the Board should have at their disposal the entire necessary and reliable information on enterprise activity and outcomes - at least to the same extent as the Chief Executive Officer . It is hoped that the use of these models would make all kinds of false reporting and cheating (manipulation) more difficult, since this often takes place at different levels of the strictly centralized management structure.

It is expected that the multi-actor negotiation structure of management would be more effective than the strictly centralized and strictly decentralized ones. Moreover, it is supposed that it has all the positive features of the latter; e.g. easiness of strategic planning (typical for the centralized structure) and industrial democracy, active participation and partnership features (typical for the decentralized structure). At the same time, one can also expect that this structure is free of the drawbacks specific for centrally planned and autonomous economies.

2. PROBLEM STATEMENT

From the previous Section it follows that the choice of enterprise growth strategy is to be made (according to the management structure) under more or less active participation of all the actors involved in the decision making process at a considered level of hierarchy. A characteristic feature of this process is that the final decision is usually made as a result of tedious negotiations. This is the case for every type of management structure analyzed. For the strictly centralized structure one can expect that the generation of a development policy is connected with negotiations

among the top managers (i.e. director-in-chief and deputy directors) and representatives of political organizations and trade unions. A similar situation occurs for the self-management enterprise; in this case the number of negotiators is even greater. The multi-interactive structure of enterprise management assumed to be the most suitable for the Polish economy, involves the greatest number of actors taking part in the decision making process (see Fig.3). In general, they have different or sometimes even opposing objectives. Possible differences in the actors' opinions on the enterprise development are mostly related to: (i) the profit gained in a specified time horizon; (ii) the production level; (iii) employment; (iv) wages; (v) investments; (vi) the cost of raw materials and energy; (vii) R&D expenditures; (viii) advertising expenditures.

Such a situation leads to different proposals on the enterprise growth strategy; the negotiation process is thus very lengthy and arduous and, in general, it is difficult to obtain a compromise solution. It is obvious that in this case computer-aided decision support procedures are necessary to reach consensus on this matter. Using them, this goal can be achieved much faster than in the case of traditional negotiation techniques; e.g. "difficult talks" etc. Moreover, the application of computerized procedures of collective decision making as well as expert judgement techniques yields better results than those based on the managers/experts' individual experience and intuition. Due to the application of computerized models of enterprise functioning a greater number of approaches and alternative solutions can be analyzed and evaluated.

It should be pointed out that to construct the enterprise growth strategy one has to know not only the current state of an enterprise and its environment (i.e. all the mechanisms and regu-

lations), but also possible changes of this state in the future. For this reason the choice of enterprise growth strategy is, in general, accomplished in two stages: (i) At the first one, a set of possible scenarios, constituting the basis for construction of alternative growth strategies, is determined (at this stage all possible trade-offs can be made); (ii) At the second one, all of the actors involved make the choice of the best strategy (or strategies) from the selected set.

The process of constructing a set of alternative growth strategies of which the best one (or ones) is to be chosen can be significantly simplified by means of expert judgement procedures. Having such a set, the best alternative(s) can be chosen using collective decision making procedures that facilitate the negotiation process. Some of them, called "the auction procedures", are formed as non-cooperative, non-zero-sum games of Nash type.

In order to make the choice of an enterprise growth strategy easier, a computerized model describing financial aspects of the functioning of an enterprise under conditions of economic reform was constructed at the Systems Research Institute [Straszak et al (1987)]. Using this model, various scenarios of enterprise growth can be simulated and verified. A computer package EXPERT, also worked out at the Systems Research Institute, implemented on an IBM PC [Księżopolska (1987)] can be used to construct the set of the most substantial alternative growth strategies. To examine possibilities of the proposed approach this model was applied for determining a research institute growth strategy. To determine such a strategy one has to solve the problem of assigning research workers to particular projects.

For this purpose a computer-aided negotiation system was worked out [Jakubowski, Kulikowski, Wagner (1984)].

The successive sections present the theoretical background, results of the application of the considered approach as well as the experience gained.

3. PROCEDURES FOR COLLECTIVE DECISION MAKING

In this section a brief description of procedures for collective decision making is presented. It should be pointed out that the analysed procedures can be applied ad hoc for solving the essential problems related to multi-actor negotiation management (see Subsection 1.3).

In general, collective decision making problems are defined as follows. There is a collective, whose members (referred to as individuals, participants or bidders) intend to realize a joint venture (called throughout the public good) and conditions of it are to be established on the basis of collective agreement. In other words, a collective is said to have reached agreement when the outcome of the decision process takes into account - to the masimum possible extent - the preferences of all its members. It is assumed that the participants have to contribute the private good (this is to be understood more generally, i.e. it can be measured not only in monetary units) for the production of the public good. Various procedures are used to solve this problem.

A general taxonomy of methods for collective decision making is presented in Fig.4. In the paper only those are considered that make it possible to reveal the preference of each participant for the public good and give him a possibility to change his decisions on the basis of information on the behaviour of others. As we have

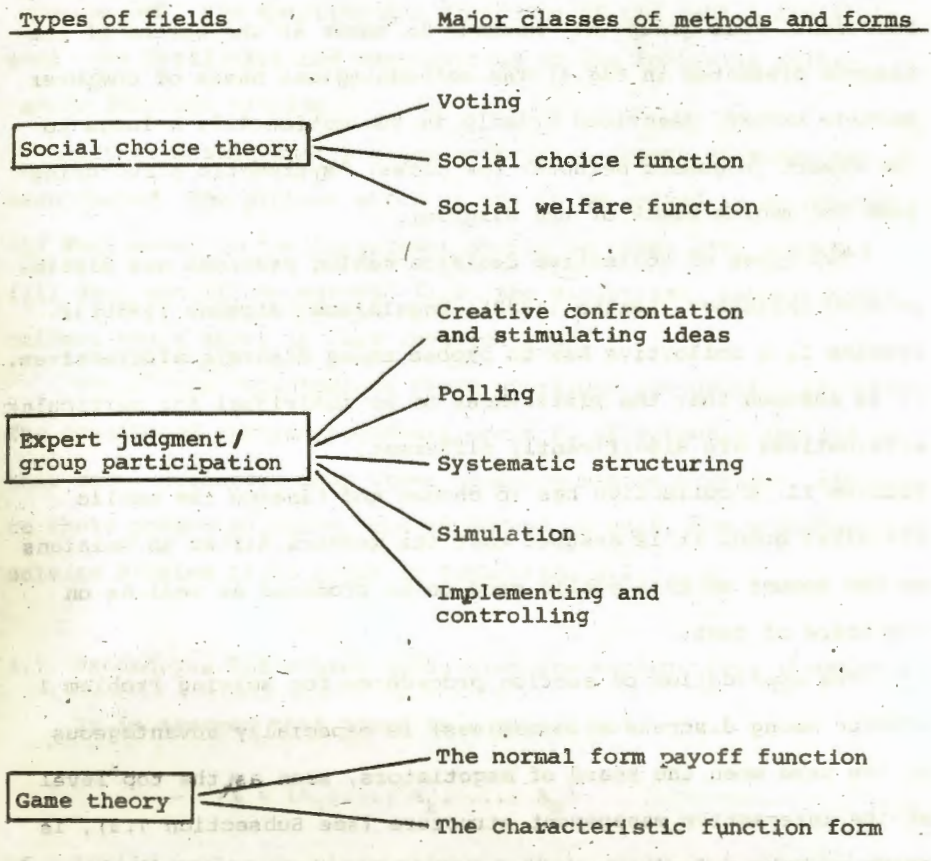

Fig.4. A taxonomy of methods for collective decision making [Hwang, Lin (1987)].

already mentioned, the game theory is the basis of these auction procedures; more precisely the games with normal forms of pay-off functions. This group of methods is shown at the bottom of the diagram presented in Fig.4. The methodological basis of computer package EXPERT, described briefly in Subsection 4.2, belongs to the expert judgement methods; the class: "systematic structuring" (see the medium block of the diagram).

Two types of collective decision making problems are distinguished [Afanasev, Lezina (1982), Engelbrecht-Wiggans (1980)]:
Problem I. A collective has to choose among discrete alternatives. It is assumed that the preferences of an individual for particular alternatives are significantly different.
Problem II. A collective has to choose and finance the public divisible good. It is assumed that its members differ in opinions on the amount of this public good to be produced as well as on the share of cost.

The application of auction procedures for solving Problem I (choice among discrete alternatives) is especially advantageous in the case when the Board of Negotiators, seen as the top level of the interactive management structure (see Subsection 1.3), is going to make a decision on the choice of growth strategy from a given set. For strategies resulting from different objectives, such as: (i) maximization of the enterprise profit; (ii) maximization of the production level; (iii) maximization of wages, or (iv) minimization of the production costs, the negotiations on the choice of one of them can be effectively facilitated if the mentioned auction procedure of collective decision making is used. Also, the final ordering of the considered alternatives, being "the average" outcome of particular actors' preferences, can be obtained as a result of negotiations carried out with the help of this procedure.

On the other hand, the auction procedure for solving Problem II (choice of the quantity and financing of the public divisible good can facilitate the negotiations on the following multi--actor decision problem:

Let us assume that a given enterprise growth strategy has been chosen. The problem which is now to be solved is as follows: (i) What level of the investment should be taken into account; (ii) What should the actors' (i.e. the ministries, banks, stockholders etc.) share in this investment be.

The actors' opinions on these questions are usually different. The considered auction procedure could be effectively applied in this case. Moreover, many other decision making problems, similar to those presented above, can be solved as well. The procedure for solving Problem II is given in Subsection 3.2.

3.1. Procedures for choice among discrete alternatives (Problem I)

It is assumed that there is a finite set

$$\mathcal{A} = \{A_1, \ldots, A_k, \ldots, A_W\}$$

of mutually exclusive alternatives A_k $(k=1,\ldots,W)$ and a collective of N actors has to choose among them.

From the theoretical standpoint such a problem can be considered as that of ordering a set of elements. It should be noted that the problem formulated is similar to that solved by well known, traditional auctions of objects. Due to this similarity some procedures used in the collective decision making for the choice among discrete alternatives are patterned after these auctions. The alternatives can be auctioned simultaneously or sequentially.

Simultaneous auctions:

Let us denote

b_k^i - the quantity the i-th participant (U_i) is willing "to pay" for the k-th alternative (i.e. the U_i's bid);

$b_k^i \geq 0$; $i=1,\ldots,N$; $k=1,\ldots,W$.

ω_i - the i-th participant's endowment of the private good.

It is assumed that

$$\sum_{k=1}^{W} b_k^i \leq \omega_i, \text{ for } \forall\, i=1,\ldots,N.$$

A "winning" alternative (or alternatives) A_* is one for which the algebraic sum of the participants bids is maximal; i.e.

$$\sum_{i=1}^{N} b_k^i \Rightarrow \text{MAX}.$$

If due to the imposed constraints more than one alternative can be chosen, then an auxiliary procedure should be available to determine the best option among those having the same sum of bids.

Sequential auctions:

Two types of sequential auctions can be applied depending on the fact whether the auctioneer (or bidders themselves) call successively higher or lower "prices" for a given alternative. The first case corresponds to the so-called English (ascending) auction, the second one - to the so-called Dutch (descending) auction.

The English auction proceeds as follows:

- For each alternative A_k ($k=1,\ldots,W$) the auctioneer calls successively higher "prices" until only one willing bidder remains.

- The participant U_i^* making the highest bid for a given alternative A_k "pays" the amount he has bid; i.e. this amount b_k^* is subtracted from his endowment ω_i^*.
- When all the alternatives are "sold", they are ordered with respect to "the price" paid (i.e. b_k^*, k=1,...,W).
- If the resulting order is not accepted by all the participants, then the process of bidding is repeated etc.

The Dutch auction proceeds as follows:

- For a given alternative A_k (k=1,...,W) the auctioneer initially calls for a very high "price", then he lowers it until some bidder stops the auction and "claims" this alternative for that price.
- The endowment of a winning bidder is reduced by his bid b_k^*.
- When all the alternatives are "sold", they are ordered with respect to "the price" paid (i.e. b_k^*; k=1,...,W).
- If the resulting order is not accepted by all the participants, then the process of bidding is repeated.

If the auctioneer knows the quantities ω_i (i=1,...,N) of private good owned by the participants, then the highest (initial) bid can be established as equal to $(\omega_i)_{max}$.

It should be emphasized that - in both cases of sequential auctions presented above - the order in which alternatives are auctioned as well as determining of the highest (or lowest) bid affects the final choice.

3.2. Procedures for choice of the quantity and financing the public divisible good (Problem II).

Consider a collective composed of N members, who are going to contribute to the production of the public good. The amount of this good as well as the participant's U_i (i=1,...,N) share of the total cost is to be determined.

The following notation is used

X - the quantity of the public good (this quantity is not known a priori);

X_i - the quantity of the public good proposed by the i-th participant;

ω_i - the endowment of the private good of the i-th participant;

B_i - the bid of the i-th participant; i.e. his share of the total cost

$y_i=(\omega_i-B_i)$ - the quantity of the private good retained by the i-th participant after submission of the bid B_i, $0\leq y_i\leq\omega_i$;

$V_i(y_i,X)$ - the payoff function of the i-th participant yielding V_i units if the i-th participant retains y_i units of the private good and the collective chooses to produce X units of the public good; it is assumed that this function is increasing and quasiconcave in the variables y_i and X.

Usually, it is assumed that

$V_i(\omega_i,0) < V_i(y_i,X)$ for every $y_i\in(0,\omega_i)$; $X>0$.

This condition is equivalent to the assumption that each of the collective members is interested in the production of the public good; i.e. for every non-zero bid B_i (hence $y_i=\omega_i-B_i<\omega_i$), the value of the participant's payoff function is greater then in the case

when $B_i=0$ (hence $y_i=\omega_i$). In other words, the participants have nothing to gain by desisting from the production of the public good.

To solve the problem under consideration the following multi-stage procedure is used:

It is assumed that at each stage t (t=1,2,...) the participants submit their proposals (B_i,X_i). On the basis of the information received, the auctioneer computes: (i) the "average" quantity of the public good, i.e. $\overline{X} = \frac{1}{N}\sum_{i=1}^{N} X_i$; (ii) the total cost share allocated to the i-th participant, i.e.

$$\beta_i = (q - \sigma_i/\overline{X}_i)\overline{X};$$

where

q - the unit cost of the public good (it is assumed that $q = \text{const}$),

σ_i - the sum of bids of all participants excluding the i-th one, i.e.

$$\sigma_i = \sum_{i\neq j=1}^{N} B_j,$$

$\overline{X}_i$ - the partial average quantity of the public good resulting from the proposals of all participants excluding the i-th one, i.e.

$$\overline{X}_i = \frac{1}{N-1}\sum_{i\neq j=1}^{N} X_j.$$

In general, the quantity β_i is different from the bid B_i proposed by the i-th participant; i.e. $\beta_i \neq B_i$.

It is assumed that the collective reaches agreement if each of its members accepts the share of total cost allocated to him and the collective's proposed quantity of the public good as his personal proposal; i.e. if the following equalities hold:

$$B_i = \sigma_i, \quad X_i = \overline{X}; \quad \text{for } \forall_i = 1,\ldots,N.$$

when $B_i=0$ (hence $y_i=\omega_i$). In other words, the participants have nothing to gain by desisting from the production of the public good.

To solve the problem under consideration the following multistage procedure is used:

It is assumed that at each stage t (t=1,2,...) the participants submit their proposals (B_i, X_i). On the basis of the information received, the auctioner computes:

(i) the "average" quantity of the public good, i.e.

$$\bar{X} = \frac{1}{N} \sum_{i=1}^{N} X_i;$$

(ii) the total cost share allocated to the i-th participant, i.e.

$$\beta_i = (q - \sigma_i/\bar{X}_i)\bar{X};$$

where

q - the unit cos of the public good (it is assumed that q = Const),

σ_i - the sum of bids of all participants excluding the i-th one, i.e.

$$\sigma_i = \sum_{i\neq j=1}^{N} B_j,$$

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It is assumed that the collective reaches agreement if each of its members accepts the share of total cost allocated to him and the collective's proposed quantity of the public good as his

personal proposal; i.e. if the following equalities hold:

$$B_i = \sigma_i,\ X_i = \bar{X};\ \text{for } \forall_i = 1,\ldots,N.$$

If the participants fail to reach agreement on the quantity of the public good to be produced and/or to the cost share allocated to them, then the next step of the procedure must be undertaken. The participants submit new two-tuples (B_i, X_i) and the auctioneer computes the quantities defined by steps (i)-(ii). Using them, the participants evaluate their payoff functions and so on.

3.3. Realization of collective decision making procedures

The information received by participants at the end of each iteration has a profound effect on the process of collective decision making. Two extreme situations should be distinguished. The information comprises the complete data concerning all the participants or aggregated information on some chosen performance indices is available only. It should be emphasized that the auctioneer can control this information in order to achieve his own goals or influence the final results of the decision making process. Similar problems occur in expert judgement. It seems reasonable to make use of experience gained in this field, e.g. that resulting from implementation of different versions of the Delphi procedure, for the purpose of constructing efficient and reliable auction procedures.

For the process of collective decision making to be efficient, it is necessary to determine precisely the stopping rule. It is evident that if after the t-th iteration no one wants to change his bid, then the results obtained can be considered as agreed upon and the procedure is stopped. However, a collective

can fail to reach unanimity on a final choice. Therefore the maximal admissible number of iterations should be fixed in advance. The introduction of such a constraint affects the dynamics of interactions between the auctioneer and participants. This conclusion is confirmed by experience gained from practical applications of the procedures mentioned [Sawaragi, Inoue (1986)].

The auction procedures for collective decision making are discussed in more detail in [Afanasev, Lezina (1982), Engelbrecht--Wiggans (1980), Groves, Ledyard (1977), Jakubowski, Kulikowski, Wagner (1984), Kulikowski, Jakubowski, Wagner (1986), Smith (1980)].

4. CHOICE OF AN ENTERPRISE GROWTH STRATEGY

Three main components of enterprise growth strategy can be distinguished: (i) financial strategy; (ii) employee's income strategy; (iii) research & development strategy.

As was already mentioned, in order to facilitate the construction of these strategies, computerized models describing some chosen aspects of the enterprise functioning have been worked out.

4.1. Financial model of an enterprise (FME)

A computerized model describing financial aspects of the functioning of an enterprise under different tax regulations was constructed [Straszak et al (1987)]. In this model the decision variables are as follows: production level, employment, wages, investments, advertising expenditures, cost of raw materials and energy connected with the chosen technology, R&D expenditures. The enterprise environment is described by the inflation rate and market characterization. The profit gained in a specified time horizon is considered as one of the objectives. Other objectives can be as follows: (i) maximization of the production level;

(ii) maximization of wages; or (iii) minimization of production costs.

To simulate the behaviour of an enterprise one has to specify the values of all the variables involved, i.e. those describing the enterprise itself and its environment. Hence using this model, it is possible to simulate and verify various scenarios of enterprise growth. Such scenarios can be constructed by specialists having intimate knowledge of a given enterprise. All the aspects of the functionning of an enterprise have to be taken into account when establishing these scenarios; hence the number of them can be quite large.

It should be readily apparent that the number of strategies to be decided upon by all the actors taking part in the decision process has to be small enough. Hence the most substantial scenarios, i.e. those constituting the basis for construction of alternative growth strategies, should be chosen. For this purpose the computer package EXPERT can be applied [Księżopolska (1987)].

4.2. Computer package EXPERT

The computer package EXPERT comprises the following expert judgement procedures: (i) those making it possible to determine a winner in the sense of Condorcet, Copeland, Borda, Pareto and Banks; (ii) Kemeny's median; (iii) the geometric approach (proposed by Kuzmin et al.) [Księżopolska (1987)].

They can be used to order a set of alternatives. The number of alternatives can be as high as 30, the number of experts up to 20-50 (depending upon the procedure used). Orderings of alternatives given by experts should have the form of linear or partial order (depending upon the procedure used). In the case of the Kemeny's median it can be assumed that some alternatives cannot

be compared. The package EXPERT is written in PASCAL and is implemented on an IBM PC type computer.

4.3. Computer-aided negotiation system for allocation of research funds (CANS)

In order to verify the model discussed in Section 4.1, it was applied to determining the growth strategy of a research institute. To determine such a strategy completely one has to solve the problem of assigning research workers to particular projects in such a way that some desired financial requirements are satisfied. For the purpose of solving this problem an auction-type procedure was proposed [Jakubowski, Kulikowski, Wagner (1984)].

A program which is the implementation of this procedure was written in FORTRAN IV S for a MERA-400 minicomputer. Some experiments were carried out to investigate the effectiveness of this computer-aided negotiation system. Five heads of Departments of the Institute took part in a game aimed at determining the contribution of their research teams in the realization of 6 projects related to systems analysis. These projects were chosen using the EXPERT package. Proposals of the research projects were supplied by all the senior research workers of the Institute. Results of experiments carried out show that with the aid of this system, some equilibrium point can be reached in 5 or 6 runs.

5. CONCLUDING REMARKS

In the paper the following procedures and models intended to support negotiations on the choice of enterprise growth strategy have been briefly discussed: (i) Auction procedures for choice among discrete alternatives [Afanasev, Lezina (1982),

Kulikowski, Jakubowski, Wagner (1986)]; (ii) Auction procedures for choice of the quantity and financing the public divisible good [Kulikowski, Jakubowski, Wagner (1986), Smith (1980)]; (iii) Computer-aided negotiation system for allocation of research funds (CANS) [Jakubowski, Kulikowski, Wagner (1986)]; (iv) Expert judgement procedures, e.g. computer package EXPERT [Księżopolska (1987)]; and the financial model of an enterprise (FME) [Straszak et al (1987)].

The above-mentioned tools can be applied to construct a decision support system to be used to facilitate arduous multi--actor negotiations on the enterprise growth strategy. They can be of special help in the case of a multi-interactive structure of enterprise management, which seems to be the most effective under the conditions of real economic reform supposed to be introduced in Poland [Straszak (1981)].

At the Systems Research Institute, some of the mentioned tools, i.e. CANS, EXPERT, FME, were computerized and experience was gained in the course of the laboratory and field experiments. The detailed analysis of these procedures as well as the experimental results can be found in the literature cited.

The auction procedures for collective decision making have not been computerized by the authors yet and no experience related to their application has been gained. The following conclusions concerns them.

It should be emphasized that the theory of auctions for choice among discrete alternatives. (Problem I, see Subsection 3.1) is still poorly developed. This is due to the discrete character of the problem to be solved. The analysis (performed from the point of view of game theory) of the iterative process of interactions among the considered actors is very difficult [Afanasev, Lezina (1982), Engelbrecht-Wiggans (1980)]. Further

investigation in this area is needed.

Auction procedures for the choice of the quantity and financing the public divisible good (Problem II, see Subsection 3.2) need further studies too.

In the presented procedures we have assumed that the main interest of the center managing and coordinating the multistage process of interactions among the participants $U_i (i=1,\ldots,N)$ is to reach such a collective agreement, which to the maximum possible extent, satisfies all U_i. Hence "the rationality" of the final collective's decision can be measured in terms of the sum of utilities achieved by the participants at the equilibrium point.

However, it can be shown that in many cases the above assumption does not hold. Very often the global goal to be achieved by the coordination center is not in agreement with the local goals of the participants U_i. The system consisting of N auction participants aiming at maximization of their goal functions and the coordination center having its own goal function, can be considered as an (N+1) - person non-zero-sum game of the Stackelberg type. In the theory of auction procedures for collective decision making the mentioned problem has not yet been considered in more detail. Some aspects of this problem have been solved by Germejer and Watel (1974). Many problems similar to those considered are also discussed by Burkov (1977) within his theory of active systems.

It should be emphasized however that the formulation of (N+1) - person auction procedures is a difficult problem. In general, the analytical form of the coordination center goal function is not known. This results from the fact that very often

the preferences of the coordination center for particular collective solutions can be given as orderings only; i.e. the center states that a given solution is "better" or "worse" than others. K. Shimizu (1984) has obtained interesting results concerninig the hierarchical system of collective decision making under the condition that the preferences of coordination center are given in the ranking scale.

Results of application of both types of auction procedures are influenced by so-called "free-rider" or "sophisticated voting" behaviour of participants. Such behaviour relies on the false reporting of the participant's preferences, aimed at misleading other members of the collective. A. Gibbard (1977) proved that even in the case of applying such simple procedure as voting to ordering of elements, manipulation is possible. In order to prevent this behaviour specific mechanisms are applied. Some of them have been utilized in the so-called Groves-Ledyard procedures (1977).

Evaluation of the participant's utility is also a difficult problem. In experiments carried out by V. Smith (1980), in order to determine the practical usefulness of collective decision making procedures, the participant's utility functions were modelled as Cobb-Douglas ones. However, his approach has some disadvantages due to the multiplicative form of this function. To avoid them, one can use functions having the additive - multiplicative form, e.g. the CES type functions [Kulikowski, Jakubowski, Wagner (1986)].

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