

## RECONCILIATION OF PROFESSIONAL COMPETENCE IN THE ERGATIC CONTROL SYSTEMS

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**Abstract** Matching competencies of experts in the article is considered from the standpoint of implementation of general and specific requirements in terms of the nature of the functional relationships among experts in the control group. In terms of execution of the general requirements to ensure criteria assessments of the effectiveness of the decisions to higher levels in terms of vagueness of the results of evaluations of experts of the underlying level of the hierarchy are determined and proved the necessary conditions for the consistent aggregation of information in hierarchical control systems, based on the requirements of the necessary narrowing of the information field and increasing the clarity of decisions at higher levels of the hierarchy. It is shown that the conditions for compatibility of proven competence are valid for any hierarchical control systems of any physical nature, having at its core the active elements that have the possibility of goal-setting.

**Keywords (11 pt):** competence, competence levels, aggregation, membership function.

### 1. INTRODUCTION

Necessary dynamic changes of control systems by the enterprises for the solution of essential target development problems of production set special demands regarding professional experts' characteristics in a control system and first of all to their executive directors starting on the top management of the organization, and finishing on head centers of divisional or matrix organizational structures. In existing conditions directors should possess creative mentality not only within the professional activity in the narrow sense of the word, but also sufficiently to be guided professionally within the activity of experts to high and subordinate levels in the solution of the current and perspective problems of production management. They should be competent in this sense. Levels of experts' competence and the most optimal organizational structure for management of this production in actual situations are interconnected for it according to the enterprise. Numerous examples of management practice in various spheres of a production activity testify to it. However, the competence problem demands the solution of one more important task and namely: coordination of experts' competences of the team business management which is an indispensable condition of their target coordinability. This means the coordination of competences should be considered as an iterative process of formation the management experts' team with mutual understanding of the purposes, tasks, management mechanisms and priorities of their application at all levels of hierarchy of business management.

Now experts have no clear understanding of the phenomenon of competence coordination. In definitions there is only its lexical and grammatical treatment. For this reason, there are no tools for an assessment of extent of competence coordination in hierarchical control systems. At the same time

there is an understanding of that the phenomenon of coordination should be considered on the one hand as an iterative process of gradual rapprochement of knowledge and opinions of experts, and with another - as an assessment of development to their competence's levels from the point of view of efficiency according to their professional communication.

In practice, high dynamics of necessary rebuilding of enterprise's organizational structure not always allows to realize a fully iterative process of concordance the competences and in these conditions predetermines the sense of co-ordination the competences as the formation of experts' team in realized enterprise's organizational structure, at which experts' competence of the team will be coordinated at the demanded level. It should be noted that problems of competences' coordination have enough general characteristics and are actual not only for human-machine systems, but also for any intellectual hierarchical control systems in various areas of their application, in which central elements of a network are the active and having abilities of formation goals of the tasks' solution, according to the analysis of their situational definition.

## **2. THE GENERAL PRINCIPLES OF COORDINATION OF COMPETENCES OF EXPERTS IN HIERARCHICAL CONTROL SYSTEMS**

Coordination of competences of experts is considered from the point of view of the implementation of the general and particular requirements to nature of functional experts' relationship in a management system (Figure 1). This nature of consecutive aggregation of initial information is considered by experts in synthesis of control systems as an indispensable condition of effective functioning of any control system.

Complexity of its conclusion is defined by an illegibility as initial information (from underlying level of management), and actually procedures of its aggregation at higher level.

## **3. AGGREGATION OF INDICATORS OF ACTIVITY OF EXPERTS IN MANAGEMENT GROUP**

Methodological bases of the solution of consecutive problems of aggregation are based on the principles assuming the definition of the coordination's conditions of aggregation and the relations of preference on a set of results of groups' activity.

Importance of the solution of this task is connected with that the set diagnosed at some level of hierarchy (in the assumption to hierarchical model of functional structure of the group) properties of experts' group interaction is usually sets by some systems of the restrictions which are connected with existence of clear ideas of the interaction's pattern of specialists in the group, the influence of conditions in their work on activities' efficiency, etc., i.e. the factors following from previous practice of similar research. Thus, it is necessary to remember [1,2,3] that estimated parameters of experts' activity give not the most detailed description of their group interaction in a management team.

The choice of "depth" to the analysis of management group members' activity is defined by two requirements. First, the description of group's activity should be rather detailed that the person, the making decision, could judge unequivocally degree of an admissibility of use in this management

systems group. Adoption of the optimum decision, from this point of view, also is based on the definition of coordination's conditions to the relations of parameters' preference according to the group members' activity at different levels of hierarchy to the description of their interaction. Principles of a similar approach to the design tasks of technical systems are known and stated in works [4,5]. However, their use according to the assessment of person's parameters in models of experts 'group of team's activity in business management is not obviously possible without certain assumptions, first of all, to illegibility of initial information and nature of their interaction in the group. In the stated procedure of indicators' aggregation is considered the lack of existing approaches.

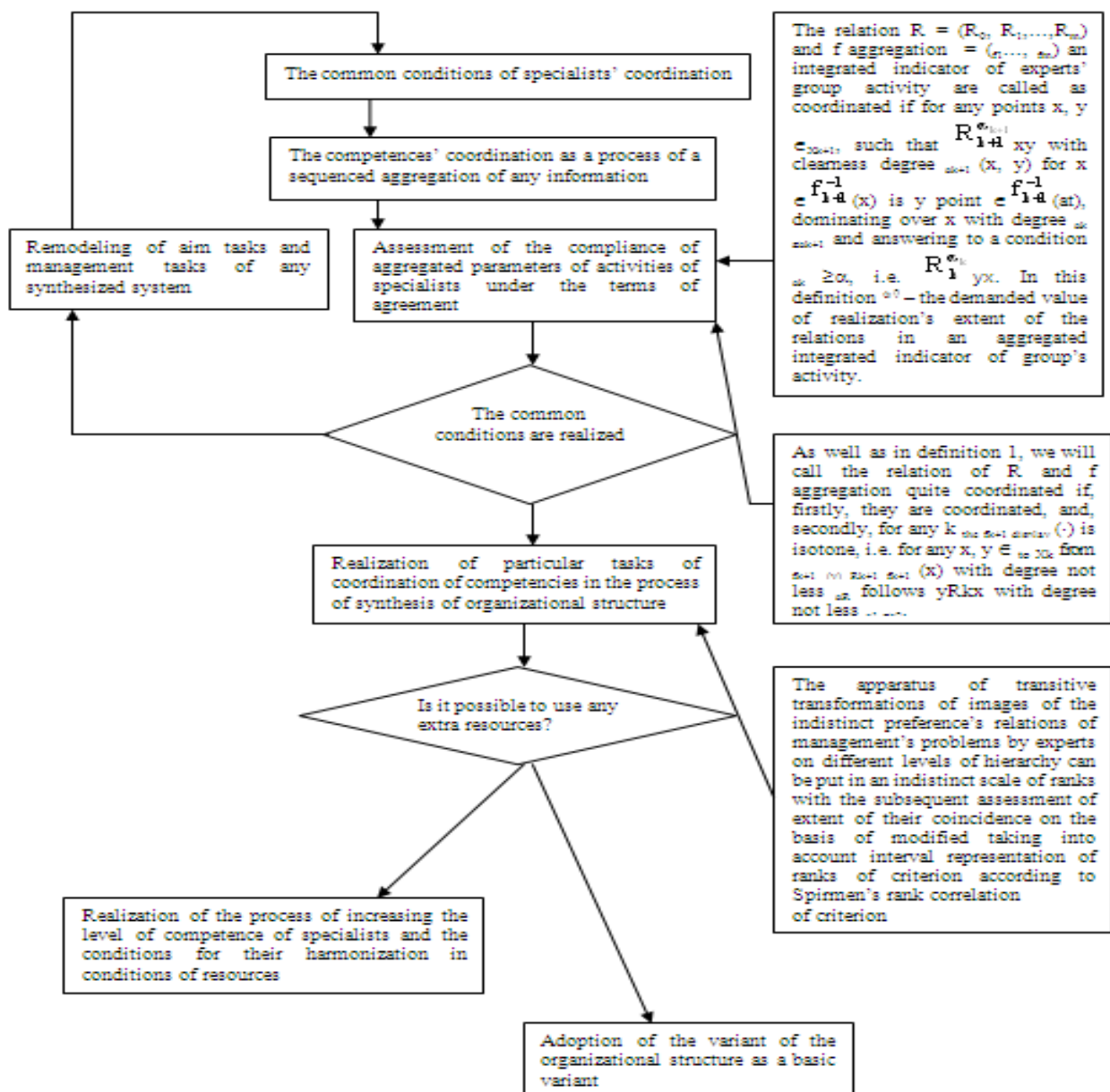


Figure 1. The block diagram of the sequenced value of conditions' coordination to specialists' competence in the synthesis of organizational structure in a management system.

Let's believe that the model of efficiency of group's activity has hierarchical structure, and components making it form space criterion. Let's consider the aggregated indistinct indicators of activity's efficiency on the first level. For this purpose we will use a principle of generalization [5]. Let's designate integrated indicators (PS) of the management experts team's activity on the first level through  $x(1) \in X_1$ , and private indicators corresponding to them through  $x(0) \in X_0$ .

Here  $X_1 = \{x(1) = f_1[x(0)], x(0) \in X_0\}$ ;  $X_0 \in E^{n_0}$ . As  $n_1 < n_0$ , i.e. the vector's dimension of indicators of experts in increasing of the hierarchy's level decreases, then  $x(1)$  gives more completed idea, than  $x(0)$ , to the efficiency of their activity's group. It is clear, that  $f_1, X_1$ , must be definitely coordinated by  $x(0), X_0$ .

Applying the principle of generalization [5] and considering an illegibility of initial information the functions of accessory to an illegible display of PS of the first level  $\mu[x(1)]$  for each of the private indicators, the preference can be presented as follows  $\mu[x(1)] = \sup_{(x_{10}, \dots, x_{n_{10}}) \in X_0} \min \{\mu_{10}(x_{10}), \dots, \mu_{n_{10}}(x_{n_{10}})\}$  where  $\mu^{(x(1))}$  – the function of accessory of a preference's private indicator at the characteristics which, are described by a vector  $\{x_{10}, \dots, x_{n_{10}}\} = x(0)$ ;  $X_1 = \{x(1) = f_1[x(0)] \mid x(0) \in X_0\}$  - an indistinct image  $X_0$ .

The display  $f_1[x(0)]$  defines the structure of transformation of basic data  $x(0)$  about some parameters of operators' activity are entering into a private preference indicator of the first level. The aggregation's process of estimates of efficiency to the experts' activity of a management team can be continued. Therefore we will receive the following chain:

$$\begin{aligned}
 &x(0) \in X_0 \in E^{n_0}, \mu[x(0)] \in E^{N_0}; \\
 &x(1) = f_1[x(0)] \in X_1 \in E^{n_1}, n_1 < n_0, \mu[x(1)] \in E^{N_1}; \\
 &x(k+1) = f_{k+1}[x(k)] \in X_{k+1} \in E^{n_{k+1}}, n_{k+1} < n_k, \mu[x(k+1)] \in E^{N_{k+1}}; \\
 &x(m) = f_m[x(m-1)] \in X_m \in E^{n_m}, n_m < n_{m-1}, \mu[x(m)] \in E^{N_m}. \tag{1}
 \end{aligned}$$

As evident from expressions (1), the increasing number  $m$  of aggregation's steps of an integrated indicator demands the display's specification at each stage of aggregation of SP that is connected, as a rule, with need of the accounting of thinner structure of the model of specialists' activity of management groups, and consequently, with its complication and with growth of mistakes because of an illegibility in basic data. Due to the existence of an illegibility in basic data and results of their convolution, transition from one step of aggregation to another is ambiguous, and realization at least one option of aggregation demands a lot of works of the experts are possessing knowledge of purposes which are carried-out by researches of groups' activity. The essence of practical activities of experts is reduced to that at each level of aggregation of individual characteristics to specialists' activity of management group the preference relations in a set of the received values of private estimates according to results of experts' work of this level are defined by them. According to the contents, the specified relations of preference are indistinct and should not conflict with an initial underlying level of management. Thus, there is a problem of coordination in the preference relations

at aggregation of estimates on a set of private indicators of activity experts' group activity on various levels of a control system.

#### 4. CONDITIONS OF COORDINATION OF EXPERTS' COMPETENCES AT AGGREGATION OF INDICATORS OF THEIR JOINT ACTIVITY

Let's consider set  $X_{k-1}$  and individual indicators of efficiency of experts' activity of the level  $k$  of an enterprise management system:  $F_k[x(k-1)] = \{f_k^1[x(k-1)], \dots, f_k^{nk}[x(k-1)]\}$ . By means of  $F_k$  and  $X_{k-1}$  it is possible to enter the binary relation  $R_{k-1}$  as follows. For any  $x, y \in X_{k-1}$  we believe  $x R_{k-1} y$  in only case then when  $f_k^{-i}(x) \geq f_k^{-i}(y)$ , and will be found  $i_0$ , for which  $f_k^{i_0}(x) > f_k^{i_0}(y)$ .

Believing  $x$  and  $y$  indistinct, the relation  $of_{Rk}$  should be estimated the accessory of function  $\mu(\square \tilde{x} \tilde{y})$  which value defines the dominated degree of an indicator  $of y$  over an indicator  $\tilde{x}, \tilde{y} = F_k[y(k-1)] = f_k(y); \tilde{x} = F_k[x(k-1)] = f_k(x)$ . Thus  $\tilde{x}$  also  $\tilde{y}$  belong to the same subject domain and are measured in the same scales. Obviously, as for images  $of f_k(x)$  and  $of f_k(y)$  the binary relation  $of_{Rk-1}$  should be carried out with the degree which is not below the set size  $^{a0}$ .

Let's designate through  $\mu(\tilde{x}, \tilde{y})$ , the degree of a dominating of an image  $\tilde{y}$  over the image  $\tilde{x}$ . Let's define this function as follows:

$$\mu_B(\tilde{x}, \tilde{y}) = \min \{ \mu_A(X), \mu_V(\tilde{x}\tilde{y}) \}, X = f^{-1}(\tilde{x}) \quad (2)$$

where  $\mu_A(x)$  – the function of accessory of a set of aggregated indicators  $x$  (for example, if  $x \in X_0$ , to  $\mu_A(x) = \min\{\mu[x(0)]\}$ );  $x = f^{-1}(x)$ ;  $\mu_V = (x, \tilde{y})$  - the function of accessory of display  $x$  in  $\tilde{y}$ , an element representing an indistinct image at this fixed display;  $f^{-1}(x)$  - a set of all elements  $x \in X_k$ , the image at display is an element  $\tilde{x} \in X_{k-1}$ .

In case  $\tilde{y} = f_k[x(k-1)]$ , then  $\mu_A(x, \tilde{y}) = 1$ , and at  $\tilde{y} = f_k[x(k-1)] \mu(x, \tilde{y}) = 0$ . Therefore, in the last case the extent of domination of an image  $\tilde{y}$  over the image  $x$  is equal to zero. If for all  $x, y \in X_0 \mu(x, \tilde{y}) = 0$ , then  $\mu_V(\tilde{x}\tilde{y}) = 0, \forall x, y \in X_0$ . Let's similarly receive:

$$\mu_B(\tilde{x}, \tilde{y}) = \sup_{y \in f^{-1}(\tilde{y})} \min (y) \{ \mu_A(x), \mu_\Psi(x, \tilde{y}) \} \quad (3)$$

It is easy to check that in a case, when  $\mu_\Psi$  - an usual display (for example,  $x \rightarrow y$ , i.e.  $\mu(x, y) = 1$  at  $\tilde{y} = \varphi(x)$  and for other pairs  $(x, \tilde{y})$ ,  $\mu_B(\tilde{x}, \tilde{y}) = \sup_{y \in f^{-1}(\tilde{y})} \min (y) \{ \mu_A(x), \mu_\Psi(x, \tilde{y}) \} = \sup_{y \in f^{-1}(\tilde{y})} \mu_A(x)$ . In special cases, when  $x = y$ :  $\mu_B(\tilde{x}) = \sup_{x \in f^{-1}(\tilde{x})} \min \{ \mu_A(x), \mu(x, \tilde{x}) \}; \mu_B(\tilde{y}) = \sup_{y \in f^{-1}(\tilde{y})} \min \{ \mu_A(y), \mu(y, \tilde{y}) \}$  that

corresponds to the definition of an indistinct image underlying the principle of generalization to Zada. Let's consider a set of the aggregated  $X_k$  parameters. On this set according to the purpose of the efficiency's assessment of experts group activity of management's team the head can set the vector criterion  $W_k[x(k)] = \{W_k^1[x(k)], \dots, W_k^{nk}[x(k)]\}$  which is defining the extent of achievement by group of the activity's purpose. The criterion of  $w_k[x(k)]$  can be qualitatively presented in this or that scale, or it grows out of the subjective analysis of values of aggregated parameters on  $k$ -m aggregation



level. In the first case the preference relation for any  $x, y \in X_k$  is defined by a way of comparison of their quantitative values. In the second case the aggregated parameters  $x$  and  $y$  are considered as arguments of some procedure of transformation subjectively, which can be realized by the head, as a result of which application it forms corresponding to aggregated values of parameters subjective  $W_k(x)$  and  $W_k(y)$  the criteria, which numerical values it can not define, and represent only their qualitative or interval relations of preference.

As a rule, the preference relations in this case are expressed indistinctly. Let's say that results of work (for example, productivity of two groups of management) make  $W_k(x) = 4,0$  and  $W_k(y) = 4,5$ . Thus it is known that initial individual parameters of specialists' activity of these groups are various. The preference relations in this case, obviously, cannot be defined unequivocally, and is determined only in determination of interval values of the aggregated parameters.

Let's consider that by means of  $W_k$  at  $X_k$  it is possible to enter the relation  $R_k^{\alpha_k}$  which is carried out with clearness  $\alpha_k$ , as follows: for any  $x, y \in X_k$  is believed  $xy \in R_k^{\alpha_k}$  in only case when  $w_k(x) \geq w_k(y)$ ,  $\forall i$  and there will be  $i_0$ , for each of which  $w_k(x) > w_k(y)$ . Thus clearness of performance of inequalities:  $\alpha = \alpha_k$ .

**Definition 1.** The relation  $R = (R_0, R_1, \dots, R_m)$  and  $f$  aggregation  $= (f_1, \dots, f_m)$  an integrated indicator of experts' group activity is called as coordinated if for any points  $x, y \in X_{k+1}$ , such that  $R_{k+1}^{\alpha_{k+1}} xy$  with clearness degree  $\alpha_{k+1}(x, y)$  for  $x \in f_{k+1}^{-1}(x)$  is  $y$  point  $\in f_{k+1}^{-1}(y)$ , dominating over  $x$  with degree  $\alpha_k \leq \alpha_{k+1}$  and answering to a condition  $\alpha_k \geq \alpha$ , i.e.  $y \in R_k^{\alpha_k} x$ . In this definition  $\alpha^0$  – the demanded value of realization's extent of the relations in an aggregated integrated indicator of group's activity.

The given definition, unlike [4], allows considering an illegibility of initial information in an aggregated indicator of efficiency of experts' group activity of management's team.

Considering expressions (2) and (3) for an assessment of mutual domination's extent of images in an integrated indicator of operators group activity, clearness of realization of the relations of preference for considered indicators can define degree as follows:

$$\alpha_{k+1} = \max_x \max_y \{ \mu^*(x, y), (y, x) \} \quad (4)$$

where  $\mu^*(x, y) = \min \{ 1 - \mu(x, y), \mu_n(x, y) \}$ ;  $\mu^*(y, x) = \min \{ 1 - \mu(y, x), \mu_n(y, x) \}$ ;  $\mu_n(x, y)$  – the function of preference to the aggregated parameter  $\tilde{x}$  over parameter  $\tilde{y}$ .

Clearness degree is measured for each private indicator, which is used at the description of integrated characteristics of researching object at this level of aggregation to its parameters. At studied levels of aggregation, the specified private indicators are considered as parameters of an integrated indicator of aggregation's higher level, and in their description the preference relations  $\mu_n(x, y)$  can be already defined.

The justice of the given statement in definition 1 according to increasing in realization's clearness of the preference's relations in growing process of aggregation's level of SP of researching object is defined that at each subsequent level of aggregation of SP the knowledge of a certain property of an

object should be more concrete (accurate). Actually, in the purpose of aggregation of parameters also consists. If growth of "specification" of the description of an object it is not observed (and it is defined just by degrees of clearness of the preference's relations of a set of SP changes), such convolution of parameters loses meaning and it is necessary to look for other options of their joint expression.

Determination of values of preference's functions  $\mu_n(\tilde{x}, \tilde{y})$ , the aggregated parameters  $\tilde{x}$  also  $\tilde{y}$  makes an object of activity of the researcher (head) both at evaluation stages of results of group's activity, and during planning of the directions of its organizational coordination in the course of acquisition. Violations of conditions of coordination observed in the course of such analysis will testify the necessity of changing in the experts training's plan (preparation), and the accounting of influence of other unrecorded factors, etc.

If variables  $\tilde{x}$  and  $\tilde{y}$  are not comparable among themselves, for example,  $\tilde{x}$  and  $\tilde{y}$  are estimated in various scales,  $\mu_n(\tilde{x}, \tilde{y}) = \mu_n(\tilde{y}, \tilde{x}) = 0$ . Extent of realization of the relation of R in this case is equal  $\alpha_k = 1$ . At  $\mu_n(\tilde{x}, \tilde{y}) = \mu_n(\tilde{y}, \tilde{x}) = 1$  parameter  $\alpha_k$  is defined by the value of domination's extent of parameter  $\tilde{x}$  over parameter  $\tilde{y}$ . In case all parameters are measured accurately and  $\{x\} \cap \{y\} \neq \emptyset$  ( $x = f^{-1}(y)$ ;  $y = f^{-1}(x)$ ), i.e.  $\mu_A(x) = \mu_A(y) = 1$ ;  $\mu(x, \tilde{y}) = \mu(y, \tilde{x}) = 0$ ,  $\alpha_{k+1} = 1$ .

Therefore, the definition of coordination's conditions at aggregation of the preference's relations for these conditions will correspond to similar definition in work [4]. The requirements to value of degree  $\alpha^0$  than coordination of the relations at the aggregation; the area of changes of initial parameters at which the aggregated integrated indicators of model will be coordinated with the preference's relations of initial private indicators is wider. Thus, the indistinct relation of aggregated parameters of model on  $(k+1)$  - m level under the condition of their coordination should include  $R_k$  relation on k-m aggregation level that is emphasized with need of performance of an inequality  $\alpha_k \leq \alpha_{k+1}$ .

**Definition 2.** As well as in definition 1, we will call the relation of R and f aggregation quite coordinated if, firstly, they are coordinated, and, secondly, for any k  $f_{k+1}(\cdot)$  is isotone, i.e. for any  $x, y \in X_k$  from  $R_{k+1}(x)$  with degree not less  $\alpha_R$  follows  $yR_kx$  with degree not less  $\alpha_1 \leq \alpha_2$ . Formally check of full coherence of private (individual) indicators of activity of certain operators will be reduced to inequality check:  $\alpha_k(\tilde{x}, \tilde{y}) > \alpha_{k-1}(x, y)$ ,  $\tilde{x}, \tilde{y} \in X_k$ ;  $x, y \in X_{k-1}$ ,  $\forall x, y$ ;  $x = f^{-1}(\tilde{x})$ ;  $y = f^{-1}(\tilde{y})$ .

Unlike the procedure of checking coherence of aggregation and the preference relations degree of clearness of the preference's relation is calculated for all pairs of values of the aggregated indicator, i.e.  $\alpha_{k+1} = \max \{ \mu^*(x, y), \mu^*(y, x) \}$ . It is obvious that, as well as in the previous case, at accurate measurement of parameters of researching object and the accurate preference's relations  $\alpha_{k+1} = 1$ ,  $\forall x, y \in X_{k+1}$ . Under these conditions, the definition 2 becomes equivalent to the similar definition given in work [4].

Let's discuss the substantial sense of the entered definitions. The statements 1 and 2 are defined by necessary conditions of providing a criteria's basis of efficiency's estimates of accepted decisions at higher level in the conditions of an illegibility of estimates of results of experts' activity of underlying level of hierarchy in a control system. Coherence of the preference's relations at aggregation of

private indicators in an integrated indicator of experts' group activity, in this case, means that the head of higher level has identical ideas of at what ratio of initial estimates of characteristics of the model of group's activity and private indicators of preference of underlying (k-1) – the efficiency of division of k-go of level will be better than level of indicators' aggregation of experts' group activity of management's team. More precisely, it allows carrying out of a problem of formation of group and detailing professional requirements to experts of k level of hierarchy, on the basis of the analysis of model of group's activity on (k+1) - m level to keep results of comparison of any two versions of the analysis, being guided thus by a certain degree of their mutual compliance. Such approach gives the chance to give the full analysis of causes of infringement coordination's conditions of the preference's relations at information aggregation in control systems.

Differently, the requirements of the definitions 1 and 2 define only the general requirements to coordination of aggregation's processes according to the information of overlying and underlying levels of management, in interests of achievement of necessary conditions of target unity of activity of experts at various levels of hierarchy of a control system. They are a basis for the subsequent, deeper, estimates the degree of coherence of experts' competence at the level of their individual relationship in the course of the solution of problems of management.

At this level of the coordination's estimates important becomes not only target the unity of interaction's subjects, but also their internal structure, which is expressed, on the one hand, in dynamics and priorities of solved tasks by the expert of underlying management's level, and on another one - the expected volume and priority initial for decision-making by information of subjects on higher level of hierarchy of a control system. Coordination of competences from this point of view is considered in horizontal and in vertical the planes of experts' interaction.

For definition of conditions to hierarchical coordination of competences, similarly as well as in work of authors of this article [6], it is considered theoretically sets of the indistinct preference's relations of the tasks are connected with a solution of the current situation of production's transformation at underlying and overlying levels of management on the basis of which their ranging is carried out. i.e on a set of ranks for each level-triggered set of tasks accessory functions are defined (ranging parameters  $M(x,y)$ ,  $M(\tilde{x},\tilde{y})$ ). Then the expert competence's coherence of underlying and overlying levels of management will be defined by the degree of statistical compliance of indistinct ranks of tasks' priorities, which are decided by them that answers the internal content of the encyclopedic concept "coordination". For these purposes possibly application of criterion of Spirmen's rank correlation at the level of clear definition of the rank relations corresponding to full coherence by definitions 1 and 2. On a basis of such an analysis the device of transitive transformations of images of the indistinct preference's relations of management's problems by experts on different levels of hierarchy can be put in an indistinct scale of ranks with the subsequent assessment of extent of their coincidence on the basis of modified taking into account interval representation of ranks of criterion according to Spirmen's rank correlation [6].

As follows from the formulas (2) - (4), the increase in level of aggregation is connected with need of a further specification of transformation's images of initial information at various levels of aggregation of an integrated assessment of experts' group activity of management's team. Coordination of competences of team's experts of management is technologically realized in the



course of group's acquisition of the management corresponding to option of organizational structure of management, which is realized in the course of situational production's reorganization. The organizational structure being built in in the course of synthesis process of acquisition of management's teams taking into account coordination of competences influences a choice of its optimum option, providing, on the one hand, maximizing system effectiveness of management, and with another - limiting the nomenclature of options of synthesis. Thus, iterative process of coordination of experts' competences in the course of activity is considered as a strategy of formation of a management's team, and process of its acquisition taking into account coherence of experts' competences - as processes of operative response to a situation and management of enterprise's organizational structure.

Such approach allows realizing adaptive organizational structures in which functional interaction of experts is provided both in horizontal and in vertical planes. Such understanding of coordination of competences allows realizing processes of necessary functional interaction of experts in the conditions of situational production's transformation.

In this sense, the stated technique of conditions' definition to aggregation's coordination of information possesses the defined community in relation to processes of knowledge of the phenomena of the various physical nature. First of all, it concerns the intellectual hierarchically distributed control systems which elements are allocated with ability to definition of the purposes and sets of problems of their realization.

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