Diagnostics of management and organisational systems

Diagnostika řídícího a organizačního systému

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Abstract: The term "diagnostics" is normally used to refer to the process of identifying some incorrectly operating components in a particular system. The fault symptoms are, however, usually discovered in a different part of the system than that in which the fault occurs. On those occasions when it is not possible to identify the source of the fault based on the principle of absolute logic, it is necessary to apply a formal procedure. This contribution presents a new methodology, by the means of an application systems approach, for diagnostics of management and organisational systems.

Key words: diagnostics, structural parameters, diagnostic parameters, combination function, model, distinguishing level

Abstrakt: Výrazu „diagnostika" se obvykle používá ve významu nalezení nesprávně fungujícího nebo vůbec nefungujícího komponentu určitého systému. Přitom symptomy poruchy se obvykle vyskytují v jiné oblasti systému, než v které je zdroj poruchy. Při takovémto stavu, kdy není možné identifikovat poruchu na základě logicky nepochybných zásad je potřeba aplikovat metodický postup. Tento příspěvek prezentuje prostřednictvím aplikace systémového přístupu novou metodiku pro diagnostiku řídícího a organizačního systému.

Klíčová slova: diagnostika, strukturní parametry, diagnostické parametry, kombinační funkce, model, rozlišovací úroveň

THEORETICAL BASIS AND PRESENTATION OF OBJECTIVE

Inductive methods are usually applied by the present-day management when the general conclusions are based on experience. The application of the deductive methods also seem to be useful, though firstly it is generally right to use practice. There are general significant principles for the configuration and behaviour of systems, which we can develop and modify according to its specific conditions. As a consequence of the foregoing, new approaches need to be formulated, which are developing new methods of application. It is possible to achieve these objectives through a systems approach application to the organisational and managerial system. **The objective of this contribution is to introduce the principle of a new methodology** for diagnostics of management and organisational systems.

The term "diagnostics" is normally used to refer to the process of identifying some incorrectly operating components in a particular system. The fault symptoms are, however, usually discovered in a different part of the system than that in which the fault occurs. On those occasions when it is not possible to identify the source of the fault based on the principle of absolute logical, it is necessary to apply a formal procedure. An methodical approach to diagnostics has been tested in many spheres (for example, in technical areas, medicinal areas, natural science etc.). However, the direct method for finding the source of a fault can be used only in those situations when the source of the fault operates as a fault detector besides its functional role. In other situations, we usually use selective diagnostics of the single components that are suspected of dysfunction. This dysfunction is probably the reason for not achieving the normal output values from the whole system.

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For an objective appreciation of the stiuation, it is necessary to differentiate between the structural and diagnostic parameters of organizational and managerial systems. Structural parameters represent the configuration of the organizational elements and their interaction. These are the most usual structural parameters belonging to an organisational system:

- Size of average organisational unit – average managerial spread;
- Relative amount of *ad hoc* decision making;
- Formalisation of work-processes;
- Degree of formal interconnection between organisational subsystems;
- Relative degree of informal communication in the workplace;
- Bureaucracy in decision making at each level of management;
- Organisational structure;
- Degree of decentralised decision making;
- Degree of specialisation.

Throughout the lifetime of the organisation, the structure of its units evolves (as reorganisation depends on the surrounding change), but if we consider an enough short period, then the structure can be taken as fixed. Nevertheless, by the fixed structure we can observe (through the changes of the organizational parameters) and consider changes of the separate structure units. An organisational system or its subsystems (or, more precisely, its elements) operate correctly if all its parameters are within the limits of tolerance – even if there are some differences from the the optimum value (nominal value).

METHODS AND PRESENTATION OF RESULTS

The designed diagnostics uses the indirect methods for measuring the values of structural parameters because it is difficult to measure them directly. We do not measure the structural parameters, but rather the external effects – organisation parameters of objective positions which exist in each real organisation. Many relationships apply (informative, materials, energetic and mixed resources) during an organisational system operation. These relationships can be modified either by the environment influences or by the values of structural parameters. It is considered that the stability of the situation influences organisation diagnostics, so functional changes of the organizational processes are generated by the changes of the structural parameters. It is possible to divide some of the functional processes into working (mass conversion, information utilisation, etc.) and the associated processes (using separated structural parameters). It is natural, that the associated processes affect the working processes. For this reason, it is important to be able set the value of the single structural parameter, but also to be able to modify its values as the reaction of transformation process failures. As was described above, it is always impossible to measure permanently the values of the structural parameters, therefore we have to use the **diagnostic parameters** to check the structural parameters. From one diagnostic parameter (disturbances symptom), it is impossible to identify the specific structural parameter fault. For the definite identification of the structural disturbances, we need a sufficient number of symptoms. Before we show the diagnostic system design, we should define the general diagnostic parameter. The diagnostic parameter (symptom) is that measurable quantity of the transformation process, which meets the following conditions:

- Every adverse parameter which matches a value, or the combination of values, of diagnostic parameters.
- Diagnostic characteristics must be sensitive to the changes of structural parameter (that means, the variation field of each of the diagnostic parameters must be wide enough for the diagnosis in all areas of structural factors).
- The measuring of a diagnostic parameter must be simple and in the exact enough terms – ideally comprising the elements of the business.

Now, we can go on to the design of system. It would be necessary to identify all symptoms plus their relationships to create a universal diagnostics system. For the sake of brevity, we will design the systems demonstration for three structural characteristics namely for:

Formalisation of procedure ($\boldsymbol{S_1}$), Decentralisation of decision making ($\boldsymbol{S_2}$) and Specialisation rate ($\boldsymbol{S_3}$).

For diagnosis of the residual disturbances of structural parameters, we would proceed in a similar manner to that below:

In the first step, we define the set of diagnostic parameters which answer the three above-mentioned conditions. For example, let us choose diagnostic parameters such as:

- Non-achievement of targeted costing ($\boldsymbol{D_1}$);
- Excessive production of substandard products ($\boldsymbol{D_2}$);
- Excessive time lost in production ($\boldsymbol{D_3}$);
- Non-achievement of planned levels of human efficiency (ie: effectiveness of human resource) ($\boldsymbol{D_4}$).

The diagnostic system be will based on the minimisation of **logical (combinational) function**, as a tool for measuring reality. A logical approach to measuring reality is based on the principle of two conditions: it is necessary to perform an action / is not necessary to perform an action etc. It is therefore possible to convert all similar diagnostic parameters into a two-valued form. This access to parameters valuation is given either by:

– The actual binary condition of a diagnostic parameter, or
– A binary condition, representing whether the diagnostic parameter is above or below specific values (outside of tolerance limit).

The implementation of the binary method for valuation organisational components is expressed by values 0 and 1 (these are variables dictum logic).

To express the problem of developing the diagnostic system in words, we will implement seven binary variables:

Firstly, we define the inputs to the dignostic system in binary format:

Diagnostic parameter $D_{1,2,3,4}$

where: $i \in \{1,2,3,4\}$ and $D_i \in \{0,1\}$

$$D_{1,2,3,4} = \prec {0 \atop 1} \succ parameter \prec {\text{parameter is within tolerance} \atop \text{parameter is outside tolerance}}$$

Secondly, we define the outputs of the diagnostic system in binary format for diagnosis of organisational failures:

Structural parameter of organisational system S_i

where: $i \in \{1,2,3\}$ and $S_i \in \{0,1\}$

$$S_{1,2,3} = \prec {0 \atop 1} \succ parameter\, 1,2,3, \prec {\text{parameter is within tolerance} \atop \text{parameter is outside of tolerance (fault condition)}}$$

So we find three functions of four input variables

$$S_{1,2,3} \approx f(D_1, D_2, D_3, D_4)$$

and we can satisfy every possible case, that may arise.

The maximum number of possible situations which might occur, if we have ***n*** inputs, is given by the sum of the binomial coefficients:

$$N = \binom{n}{0} + \binom{n}{1} + \ldots + \binom{n}{n} = 2^n \qquad (1)$$

So the maximum number of possibilities for $n = 4$ is $2^4 = 16$. A summary of all possible conditions is shown in Table 1, where it is indicated whether the

Table 1. Combinational values of the diagnostic parameters with relevant values of structural parameters

Situation	INPUTS				OUTPUTS			SYNTHESIS OF OUTPUTS		
	D_1	D_2	D_3	D_4	S_1	S_2	S_3	$S_1 \approx f(D_1, D_2, D_3, D_4)$	$S_2 \approx f(D_1, D_2, D_3, D_4)$	$S_3 \approx f(D_1, D_2, D_3, D_4)$
1	0	0	0	0	0	0	1	$D_1 + D_2 + D_3 + D_4$	$D_1 + D_2 + D_3 + D_4$	$\bar{D}_1 + \bar{D}_2 + \bar{D}_3 + \bar{D}_2$
2	1	0	0	0	0	0	0	$\bar{D}_1 + D_2 + D_3 + D_4$	$\bar{D}_1 + D_2 + D_3 + D_4$	$\bar{D}_1 + D_2 + D_3 + D_4$
3	0	1	0	0	0	0	1	$D_1 + \bar{D}_2 + D_3 + D_4$	$D_1 + \bar{D}_2 + D_3 + D_4$	$\bar{D}_1 + D_2 + \bar{D}_3 + \bar{D}_4$
4	0	0	1	0	0	0	0	$D_1 + D_2 + \bar{D}_3 + D_4$	$D_1 + D_2 + \bar{D}_3 + D_4$	$D_1 + D_2 + \bar{D}_3 + D_4$
5	0	0	0	1	0	0	0	$D_1 + D_2 + D_3 + \bar{D}_4$	$D_1 + D_2 + D_3 + \bar{D}_4$	$D_1 + D_2 + D_3 + \bar{D}_4$
6	1	1	0	0	0	1	0	$\bar{D}_1 + \bar{D}_2 + D_3 + D_4$	$D_1 + D_2 + \bar{D}_3 + \bar{D}_4$	$\bar{D}_1 + \bar{D}_2 + D_3 + D_4$
7	0	1	1	0	0	1	0	$D_1 + \bar{D}_2 + \bar{D}_3 + D_4$	$\bar{D}_1 + D_2 + D_3 + \bar{D}_4$	$D_1 + \bar{D}_2 + \bar{D}_3 + D_4$
8	0	0	1	1	0	0	0	$D_1 + D_2 + \bar{D}_3 + \bar{D}_4$	$D_1 + D_2 + \bar{D}_3 + \bar{D}_4$	$D_1 + D_2 + \bar{D}_3 + \bar{D}_4$
9	1	0	0	1	0	0	0	$\bar{D}_1 + D_2 + D_3 + \bar{D}_4$	$\bar{D}_1 + D_2 + D_3 + \bar{D}_4$	$\bar{D}_1 + D_2 + D_3 + \bar{D}_4$
10	1	0	1	0	0	1	0	$\bar{D}_1 + D_2 + \bar{D}_3 + D_4$	$D_1 + D_2 + D_3 + D_4$	$\bar{D}_1 + D_2 + \bar{D}_3 + D_4$
11	0	1	0	1	0	0	0	$D_1 + \bar{D}_2 + D_3 + \bar{D}_4$	$D_1 + D_2 + D_3 + D_4$	$D_1 + \bar{D}_2 + D_3 + \bar{D}_4$
12	1	1	1	0	0	1	0	$\bar{D}_1 + \bar{D}_2 + \bar{D}_3 + D_4$	$D_1 \times D_2 \times D_3 \times \bar{D}_4$	$\bar{D}_1 + \bar{D}_2 + \bar{D}_3 + D_4$
13	0	1	1	1	1	0	0	$\bar{D}_1 \times D_2 \times D_3 \times D_4$	$D_1 + \bar{D}_2 + \bar{D}_3 + \bar{D}_4$	$D_1 + \bar{D}_2 + \bar{D}_3 + \bar{D}_4$
14	1	0	1	1	1	0	0	$D_1 \times \bar{D}_2 \times D_3 \times D_4$	$\bar{D}_1 + D_2 + \bar{D}_3 + \bar{D}_4$	$\bar{D}_1 + D_2 + \bar{D}_3 + \bar{D}_4$
15	1	1	0	1	1	0	0	$D_1 \times D_2 \times \bar{D}_3 \times D_4$	$D_1 + \bar{D}_2 + D_3 + \bar{D}_4$	$D_1 + \bar{D}_2 + D_3 + \bar{D}_4$
16	1	1	1	1	1	0	0	$D_1 \times D_2 \times D_3 \times D_4$	$\bar{D}_1 + \bar{D}_2 + \bar{D}_3 + \bar{D}_4$	$\bar{D}_1 + \bar{D}_2 + \bar{D}_3 + \bar{D}_4$

structural parameter $D_{1,2,3,4}$ is in failure condition ($S_{1,2,3}$ = 1) or not ($S_{1,2,3}$ = 0) .

Combination function for output S_1

According to Table 1, synthesis in the form of the sum of the products has only four combinational lines, compared to 12 lines synthesis in the form of the product of the sums.

Below, we want to identify all situations of the combinational function when the structural parameter S has a fault. Therefore, we are interested in combinations of the diagnostic parameters for S_1 =1.

Consider the 12th, 13th, 14th, 15th and 16th lines of Table 1. We combine the requirements expressed by the lines 12, 13, 14, 15 and 16 for combination function of the fault structural parameter, obtaining S_1. So:

$$S_1 \approx f(D_1, D_2, D_3, D_4) = \overline{D_1} \times D_2 \times D_3 \times D_4 + D_1 + D_1 \times \overline{D_2} \times \times D_3 \times D_4 + D_1 \times D_2 \times \overline{D_3} \times D_4 + D_1 \times D_2 \times D_3 \times D_4$$

With the help of Boolean algebra identities, we can simplify the output function so that we can ignore the redundant operations or redundant inputs. At first we separate the input D_1 that is in logical conjunction in relation to every sum, and then we remove the redundant members by application of this rule:

$D_i + \bar{D}_i = 1$ *always!*

where: input $\bar{D}_i$ presents negation of input D_i

$$\begin{aligned} S_1 &= D_4 \times \left(\overline{D_1} \times D_2 \times D_3 + D_1 \times \overline{D_2} \times D_3 + D_1 \times D_2 \times \overline{D_3} + \right. \\ &\quad \left. + D_1 \times D_2 \times D_3 \right) = \\ &= D_4 \times \left(\left(\overline{D_1} + D_1\right) \times D_2 \times D_3 + \left(\overline{D_2} + D_2\right) \times D_1 \times D_3 + \right. \\ &\quad \left. + \left(\overline{D_3} + D_3\right) \times D_1 \times D_2 \right) = \\ &= D_4 \times \left(D_2 \times D_3 + D_1 \times D_3 + D_1 \times D_2\right) \end{aligned}$$

It is noticeable from the final form of the function, that it would be necessary for the diagnostic parameter D_4 to be equal to 1, and at least two of D_1, D_2, D_3 to be equal to 1 – for fault of structural parameter S_1.

Combination function for output S_2

Synthesis of the combinational function is concerned with the claims of the 6th,7th,10th and 12th lines of the table. The combinational function for the structural parameter S_2 is produced by combining the four lines, thus:

$$S_2 \approx f(D_1, D_2, D_3, D_4) = D_1 \times D_2 \times \overline{D_3} \times \overline{D_4} + \overline{D_1} \times D_2 \times D_3 \times \times \overline{D_4} + D_1 \times \overline{D_2} \times D_3 \times \overline{D_4} + D_1 \times D_2 \times D_3 \times \overline{D_4}$$

This formula, describing output S2, can be simplified step by step by using the Boolean algebra:

$$\{D_1 \cdot D_2 + D_1 \times D_3 = D_1 \times (D_2 + D_3)\}$$

$$\left\{(D_1 + D_2) + \left(\overline{D_1} + D_3\right) = D_1 \times D_3 + \overline{D}_1 \times D_2\right\}$$

$$\begin{aligned} S_2 &\approx f(D_1, D_2, D_3, D_4) = \overline{D_4} \times (D_1 + D_2 + D_3) \times \\ &\quad \times \left(\overline{D_1} + D_2 + D_3\right) \times \left(D_1 + \overline{D_2} + D_3\right) \times \left(D_1 + D_2 + \overline{D_3}\right) = \\ &= \overline{D_4} \times (D_1 + D_2) \times (D_2 + D_3) \times (D_1 + D_3) \end{aligned}$$

As a result, there is an interesting dependence between fault identification $S_2 \approx f(D_1, D_2, D_3, D_4)$ decision-making decentralization, and diagnostic parameter (D_4) (effectiveness of human resource). The necessary conditions to maintain the decentralisation within tolerance are disturbances in capacities of the human resource. It means, that we can decentralise when lower-grade workers are freed from their jobs, so that they can perform decision-making and coordinative activities.

Furthermore, the situation detector of disturbances of the structural parameter S_2 has an inverse function.

Combination function for output S_3

We can obtain the combinational function synthesis for S_3 output by utilizing the combinational claims from 1st and 3rd lines of the tables 1. We can use the rule for its minimization and $D_i \times \bar{D}_i = 1$ *always!* and the further rule of absorption: $D_i + D_i = D_i$.

$$\begin{aligned} S_3 &\approx f(D_1, D_2, D_3, D_4) = \\ &= \overline{D_1} \times \overline{D_2} \times \overline{D_3} \times \overline{D_4} + \overline{D_1} \times D_2 \times \overline{D_3} \times \overline{D_4} = \\ &= \left(\overline{D_2} \times \overline{D_3} \times \overline{D_4}\right) + \left(\overline{D_2} \times \overline{D_3} \times \overline{D_4}\right) \times (D_1 \times \overline{D_1}) = \\ &= \overline{D_2} \times \overline{D_3} \times \overline{D_4} \end{aligned}$$

The above-mentioned rationalised form of the output shows that the structural parameter – working specialisation S_3 is only possible to modify the situation, when diagnostic parameters D_2, D_3 and D_4 are within their limit (i.e. so they do not indicate the failure). It is not otherwise possible to modify the level of specialisation in individual units of the organisation. Nevertheless, there is no relationship between the diagnostic parameter D_1 and function S_3 – as shown by the elimination of variable D_1.

Diagnostics of managerial systems at the first distinguishing level

"A managerial system (Ř) is an organisational subsystem that is characterised by people (L) in managerial positions and by an informational structure (I). An informational structure represents relationship (more precisely, subordination and cooperation of each other staff member). That is an integral subsystem of single organisational units" (Hron 2004a). If we receive an input from the lower units of integration of the main function of managerial system, then we will need to define a control procedure for this integration. We will use the previous methodology for this control procedure. We will investigate the organisation at the lowest distinguishing level – on the first distinguished level. The first distinguished level informs us only about the fact that an organisation exists without a look inside its structure. In system theory it is called a "**black-box investigation**" (Hron 2004a). From the point of distinguishing level, there is a maximum distinguishing level – the opposite of the black-box approach (when all inputs and outputs are distinguished) (Hron 2003). "Quantitative and qualitative analyses of structural arrangement of business subjects, factors and standards and their resulting behaviours, prove clearly that each business enterprise is a unique entity. Its manager's qualification plays a decisive role" (Hron 2005).

We introduce a transfer from the methodology of the black-box approach to the methodology of the second distinguished level, through a divisional model of the organisational structure. We will investigate the efficiency of the managerial system through the level of the integration between particular divisions. In the first step, we define an investigated model of four divisions' structure and use a description of the principle coordination and specialisation for this definition.

The informational channels of the structure are configured according to its contribution to the added value of outputs. The division of labour principle is in the direction: inputs to outputs, so the activities connected with certain output are joined to the one whole complex – division.

The working specialisation is not so closely specified as in the functional type of structure (universal skills are preferred, rather than specialised skills for the complicated and complex operations). Staff work according to the working activity description instead of working place description. Activity coordination is in the place of decision-making and generally the director of working activities, and makes the decisions. Delegation of decision-making competence is in the bottom-up direction.

The present divisional structure has (beside advantages) certain disadvantages. The greatest disadvantage is the risk of any division before it can be absorbed into the rest of the organisation during the process of time (Mintzberg, Ahstand 1998). Thanks to this independence, the divisional objectives are not subordinate to the strategic steps, so a division can go against the organisational politics (for example it can compete with other divisions with a rival product, or it can maximize its short-term revenues at the expense of the long-term company objectives).

Let us try to send up the insufficiently integrated division for the whole organisational strategy. We will use the black-box model to represent the whole company. Measurable strategic objectives of each division are the inputs of the black-box and strategic objective of the company – it is the output of the black-box. These controllable objectives can be for example: uniform policy to the suppliers, application of the same ISO quality standards etc. We verbally define five binary variables again (Kaplan 1999):

Table 2. Values of the organisation results depend on the single division results

j	X_1	X_2	X_3	X_4	Y
1	0	0	0	0	0
2	0	0	0	1	0
3	0	0	1	0	0
4	0	1	0	0	0
5	1	0	0	0	0
6	0	0	1	1	1
7	0	1	1	0	0
8	1	1	0	0	1
9	1	0	1	0	0
10	0	1	0	1	0
11	1	0	0	1	1
12	0	1	1	1	1
13	1	1	1	0	1
14	1	0	1	1	1
15	1	1	0	1	1
16	1	1	1	1	1

Objective of single division 1, 2, 3, 4, X_i

$$X_{1,2,3,4} = \prec \begin{matrix} 0 \\ 1 \end{matrix} \succ \textit{division objective } 1,2,3,4 \prec$$

$$\prec \begin{matrix} \text{is not achieved during the time period} \\ \text{is achieved during the time period} \end{matrix}$$

Company objective Y

$$Y = \prec \begin{matrix} 0 \\ 1 \end{matrix} \succ \textit{company objective} \prec$$

$$\prec \begin{matrix} \text{is not achieved during the time period} \\ \text{is achived during the time period} \end{matrix}$$

We need to determine the time period to obtain the summary of combinative results, (we can choose, for example, a period of 3 months). Next, we find out when the objectives were achieved (if it was before the end of the time period $Z = 1$ or after the time period $Z = 0$). We need to verify the stability of the situation conditions at the end of investigation. If we find some situation changes (for example by the entrance of a new competitor to our market), then it is necessary to annul the achieved result of input value.

An illustration of the above mentioned procedure is in Figure 1, and Table 2 includes the results of the combination conditions.

Combinational function synthesis Y output has to be obtained by the merger of the combinational claims repesented in the 6th, 8th, 11th and 12th lines of Table 2. We can use the Karnough's map method for its minimisation.

It can be seen from the rationalised form of the combinational function, that the division which has

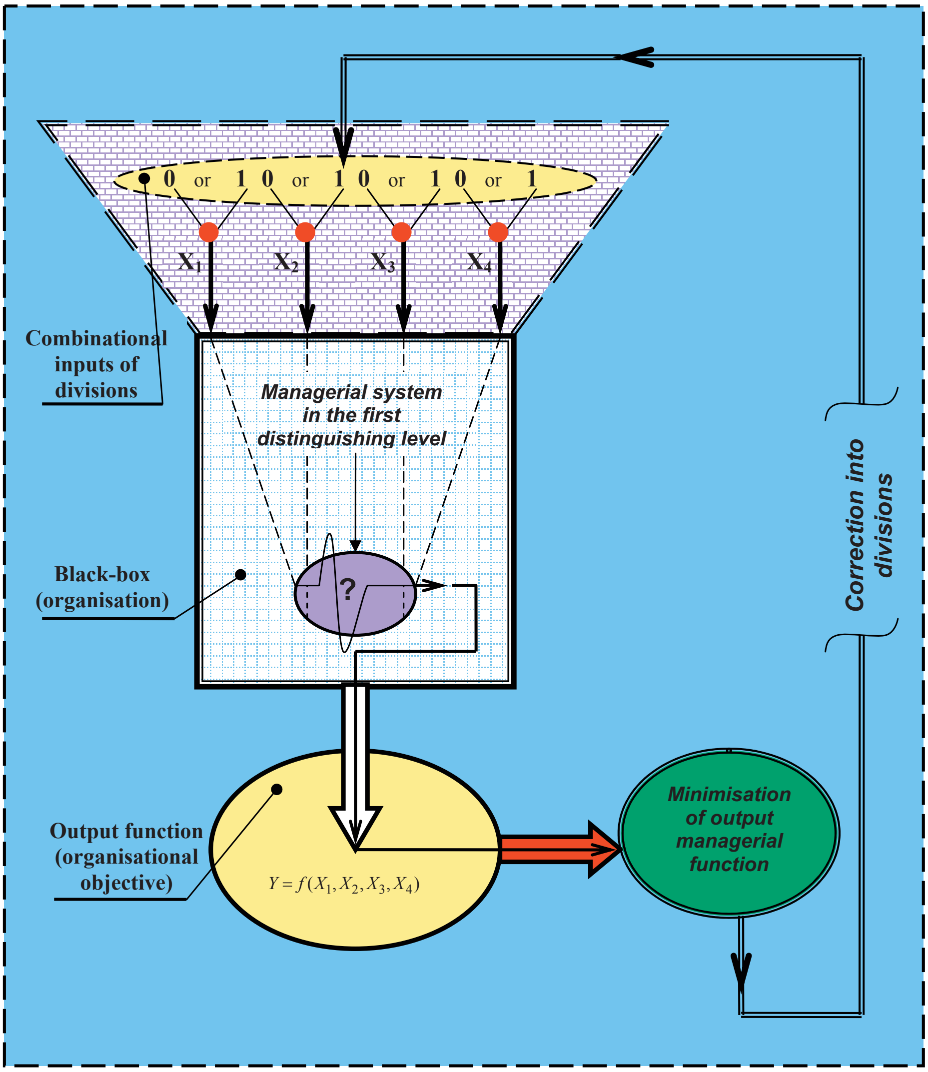

Figure 1. Black-box model utilisation for identification of the non-integrated division to organisation

Note: Principle of the Karnaugh's map is based on the K-map representation, in that it is defined by the binary of the output by values 0 and 1.

X_2 input, has no effect on the output values, therefore that division X_2 is not integrated into the organisational structure:

$$Y = X_1 \times X_4 + X_1 \times X_3 + X_3 \times X_4$$

DISCUSSION – CONCLUSIONS

This contribution deals with the technique of a new methodology for the diagnostics of managerial and organisational system. After the general theoretic starting points, a diagnostic system has been designed, based on the combination allocation of the diagnostic parameters to the structural parameter. Some of the diagnostic parameters were then removed by rationalisation of the combinative function (these parameters do not play any role in the fault diagnostics). The symptoms of structural parameters are illustrated – diagnostics parameters in their negated forms (that means fault is signalled by the diagnostic parameter which is within the limit of tolerance). The black-box model for organizational diagnostics is subsequently introduced.

The specific contribution of the designed diagnostic approach is a practical method of fault detection of an organisational system without knowledge of the internal channels (through black-box methodology). The second effect is based on the prediction of future faults by the help of the last combinative condition of diagnostic parameters.

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