Determination of management capacity

Určení řídící kapacity

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Abstract: This paper deals with the creation of a procedure to make it possible to evaluate the adequacy of the span of control (number of immediate subordinate staff). The maximum span of control depends on the complexity of the coordinating mechanism. In developing this procedure, information theory (more precisely – law of necessary variety) will be used. This paper contains a brief review of information theory and of the conventional approach, before moving on to the application part, to develop a method of determining the optimum for the managers' span of control.

Key words: span of control, capacity of manager, organisation, information theory, variety, informative indeterminism

Abstrakt: Tento příspěvek se zabývá vytvořením metodiky, která by umožnila zhodnotit dostatečnost řídící kapacity u vedoucích pracovníků, a to v závislosti na jejich rozpětí řízení a složitosti koordinačního mechanismu. K určení řídící kapacity bude využita teorie informace, resp. její část, která je známá pod označení teorie nutné variety. Před samotným určením řídící kapacity vedoucích pracovníků bude ve stručnosti pojednáno o teorii informace a také o teorii organizace (tedy, o předešlých přístupech určující optimální počet podřízených pracovníků).

Klíčová slova: rozpětí řízení, řídící kapacita, organizace, teorie informace, varieta, informační neurčitost

THEORETICAL BASIS AND PRESENTATION OF OBJECTIVE

The term "organization" is defined in various ways. For example, organisation can be considered as a system of communication – an instrument, which makes decision making possible. Additionally, organisations can be considered as social systems, and also as systems, that from the cybernetics point of view include many interrelated uncertain quantities. In reality, organisation covers all these components. For practical purposes, we can define and characterise "organisation" simply as a process which:

1. facilitates the achievement of a specific task, to be performed within defined aims,
2. divides necessary activities into small parts, so that they could be managed by one person only (group manager),
3. safeguards the coordination in such a way as not to waste resources and in order to bring together activities of corporate members.

It is generally possible to classify these factors into four subsets: an internal factor subset (influencing the size of organisational units), an external factor subset (influencing the hierarchical form of organisational units), an integral factor subset (determined by the level of control of the process) and a forming factor subset. If we were to do a level of abstraction of single subset of organisational factors, we will find that, for example, internal factors are (according to Hron 2005) created by:

– *technical capacity* $\boldsymbol{v}$ (characterised by technical facilities),
– *organisational capacity* $\boldsymbol{o}$ (recognised as the number of productive instruments, or machines, controlled by one working manager),
– *control capacity* $\boldsymbol{q}$ (it is characterized by the level of control of the hierarchy and is recognised by the number of direct subordinate workers).

This paper focusses on the determination of maximum acceptable control capacity. To determine the

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control capacities, information theory will be utilized, (known as the "theory of necessary variety"). Before we discuss the determination of control capacity, it is firstly useful to mention the aspects of information theory as well as the previous attempts to determine the optimal number of subordinate staff. Both are briefly summarised in the second chapter of this paper.

METHODS AND PRESENTATION OF RESULTS

The method of determination of control capacity of managers can be divided into analytical methods and synthetic methods (Hron 2005). Some analytical methods investigate the average control capacity of managers in each organizational system. Among the most widely-used techniques in the analytical methods, we could include the statistical analysis of a representative file to determine the average control capacity or so-called "orientation method" (for more detail see Hron 2005). Some synthetic methods set standard specifications for control capacity in definite conditions, dependent on the complexity of the controlled actions. The conditions are usually identified by the valuation of criteria (among the most usual criteria are: the similarity of function of subordinate units, complication of the coordinative mechanism, placement of workers and others).

Because human resource management is based on informative exchanges and it is possible to remove vaguenesses of working actions, there appears a generalised information theory for practical classification of senior managers. It is possible to find out (for example, experimentally), what is the manager's capacity of information channel (i.e. how much information he/she is able to hand over to their staff during a specific time period – e.g. one working day). It can then be determined in an analogical way, what the average amount of information is necessary to manage one worker during one working day. Finally, it is possible to determine the maximum number of subordinate workers (by a formula of nonexistence of uncertainty in information exchanges between the manager and staff) a manager is able to coordinate, without exceeding the capacity of his communication channel. Thereby, we can determine a limit for the maximum span of management control according to the condition with removed uncertainty.

The current general information theory is to study all types of uncertainty (and information connected with them) that we can recognize, at least on an intuitive level. It is then necessary to develop an appropriate mathematical theory for every type of uncertainty, to study its possible practical interpretation, and also to design its methodology for informal utilisation. To make these theories of uncertainty fully operative, (according to Klir, Wierman 1999) they must be made in the following three stages:

1. The given type of uncertainty has to be correctly identified.
2. It is necessary to develop a computation progress (following an accepted uncertainty formular), whereby it is possible to handle this uncertainty.
3. It is necessary to find an appropriate method to measure the uncertainty (and hence the amount of information to remove this uncertainty), in the situation where we want to apply the information theory.

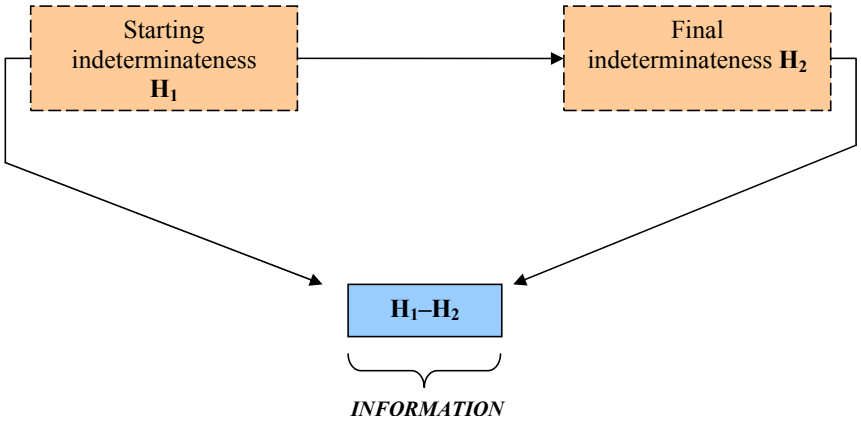

Figure 1. Purpose of the information based on uncertainty (informative entropy)

So addition or completion of the information is connected with the decrease of the appropriate uncertainty. A senior manager has to perform a specific action (e.g. he must supply a piece of information by checking, or he has to make a diagnostic test to detect a fault in the worker's progress. The result of the implemented control action enables us to reduce uncertainty (the uncertainty is based on the difference between starting determinateness and a final uncertainty (Figure 1).

The method of how it is possible to use the law of the necessary variety to determine the maximum spread of managerial control can be seen in the following example.

Methodology of variety for classification of managerial uncertainty

Variety is a term introduced by ***W. R. Ashby*** and can also be thought of as diversity. The variety concept is very closely related to entropy and information, but variety is not defined on a stochastic basis, its definition resulting from the general set theory. On the basis of the variety concept, all modern system theory is established, where system is understood as a relational of structure, and relation as a variety limitation. For the theory of HR management, it is fit to use the ***law of necessary variety***, described in the following text.

There is a process of HR management in Figure 2, showing the used set methodology. It brings a more common point of view (with utilization of set theory) on management questions. It is represented by a feedback principle of control (check of subordinate workers), and also regulation with feed forward compensation of disturbances (subordinate personnel makes decisions, the result of which is shown to the superior manager for verification). Thus we can interpret the single set according to the structure and character of quantities. Figure 2 shows:

V = set of possible influences, which can disturb the successful performance of a working process
X = set of position of worker's activities
R = set of feasible control intervention of a manager
Y = set of feasible work outputs;
Y^* = required set of performance results;
ϕ = transformation ϕ: $V \rightarrow R$
ρ = transformation ρ: $V \rightarrow R$;
ψ = transformation ψ: $X \times R \rightarrow Y$

There are many faults influencing manager and staff (manager and staff = system created by working, social subsystem and control subsystem), by the transformation of the conditions of working activities being modified and by the transformation of the control activities the outputs being modified (e.g. the quality of the product required).

We always ask for the intervention of manager so that the output value belongs to the same subset, marked ***Y*** on Figure 2. We would like to have an one-element set and that element is the desired resulting work process in the imaginary (ideal) case. Then we can express the condition of optimality as:

$$\forall v \in V : \psi(\phi(v)), \quad \rho(v) \in Y^* \; T \tag{1}$$

This way of description brings many benefits. For example, regarding quantities, it is not necessary for them to be absolutely measurable (they can be an ordinal quantity or a nominal quantity), and this is a very welcome characteristic in the human resource management area. The description of the set omits a physical control system and regulator, therefore we do not require a specified structure of the control loop for this description. Let us refer to the scheme

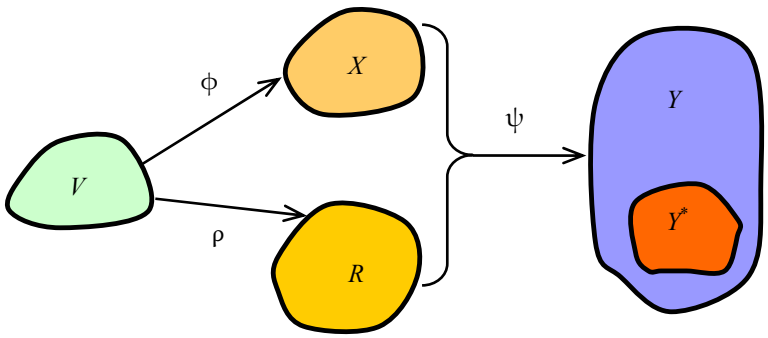

Figure 2. Description of human resource management in Set format

illustrated in Figure 2 from the information theory point of view. Let us mark the entropy set of outputs and also entropy set of objectives. Our task is to keep to the value of the outputs into the set of required values Y with the help of regulation interferences. The fact is, that the set Y^* is a subset of the set Y. Then we can write:

$$H(Y^*) \leq H(Y) \tag{2}$$

entropy decrease, i.e. quantity of uncertainty, which we will remove by the force of regulation intervention, thus:

$$I = H(Y^*) - H(Y) \tag{3}$$

Then we will formulate the transformation $\psi: X \times R \rightarrow Y$.

Let us to suppose that we can distinguish from 4 system status $X \in \{x_1, x_2, x_3, x_4\}$ and 3 possible positions of the action control $R \in \{r_1, r_2, r_3\}$.

Let us suppose that all these four values $\{r_1, r_2, r_3, r_4\}$ could exist with the same probability. Then we will want to know, what kind of control regulation setting $R \in \{r_1, r_2, r_3\}$ we will need to reach the smallest managerial uncertainty. Let us suppose that, for r_1 is $H(Y) = 1.5$ bit, for r_2 is $H(Y) = 2$ bits and for r_3 is also $H(Y) = 2$ bits.

Now let us introduce the term "***middle size reciprocal information***" for the explanation of the mathematical formular of the law of necessary variety. The *middle size reciprocal information* has been based on the statistical dependencies of the state of system X on variables Y and *vice versa*. Then uncertainty in selection values x_i based on the provision of knowledge values y_i is given by the conditional entropy $H(X/Y)$. If we interpret $H(X)$ as an uncertainty of our knowledge about the quantity x_i before receiving any news, and $H(X/Y)$ as an uncertainty of our knowledge after receiving the news y_i, then news $T(X : Y)$ will be the information carried by y quantity about x quantity. The difference uncertainty before and after receiving news is then the ***middle size reciprocal information*** $T(X : Y)$*:*

$$T(X : Y) = H(X) - H(X/Y) \tag{4}$$

With using the middle size reciprocal information we can define the law of necessary variety. It should satisfy an inequality condition according to the law of necessary variety for transformation ψ each other unknowns between the sets X and Y.

$$H(Y^*) - H(Y) \leq T(R : X) \tag{5}$$

We could verbally express the law of necessary variety in this way: The uncertainty, which we can remove with the help of informational management per time unit (defined as the difference $H(Y^*) - H(Y)$) cannot get over the capacities of information channel between R and X (Hron et al. 2007; Klir, Wierman 1999). In the second case, when transformation ψ is not unambiguous, for each other between set X and set Y, it is necessary to use formula (5) to calculate the highest limitation of an acceptable uncertainty K. In the case of ambiguous states, the capacity of the information channel will increase about values $K = \log k$, where k is the biggest number of repeated values occurring in the same line of a matrix of transformation ψ X (Hron et al. 2007; Klir, Wierman 1999).

$$H(Y^*) - H(Y) \leq T(R : X) + K \tag{6}$$

The law of necessary variety gives us its size characteristic about the parameter of the transfer performance. This law makes it possible to assess the movement of the information channel in quality form (and after making up a size of quantity even in quantified form).

It is possible to use the classification of permeability of the information channel not only in the design of a telecommunications system, but especially for classification of the efficiency of interpersonal communication in any organisation. On the basis of the understanding of informative exchanges between a senior manager and subordinated staff to him, we can (using the law of necessary variety) assess, whether there is any ambiguity in the mutual information transport. This ambiguity informative exchange between manager and subordinates shows us $K > 0$ in the formula (6). The HR management is based on emotive influencing the people, where no ambiguity is acceptable.

Ambiguity causes an increase of error rate and supports a disorderly reaction that is influencing the staff of an entrepreneurial plan in the implementation of their individual working objectives. We generally try to minimise an informative vagueness first of all, on difference from e.g. a strategic plan that is not feasible without tolerating uncertainty.

Now, after familiarisation of the law of necessary variety, we can demonstrate its application by an appreciation of control capacity in any organisation. The purpose of this process is to discover any over-designed organisational units in the spread of control, shown by the existence of ambiguity of manager's instructions. A process showing how it is possible to use the law of necessary variety to assess the maximum control spread, is given in the following example:

Mittal Steel CR is a metallurgical multinational concern as well as being involved in the engineering production.

The metallurgical production is a mass production process, whereas engineering production is mainly a serial or single-part production characteristic. Mittal Steel CR belongs to the multinational concern Mittal Steel – the world's largest and most global steel company, with shipments of 49.2 million tons and revenues of over $28.1 billion in 2005. Mittal Steel is among the most efficient steel producers in the world.

Mittal Steel is divided into three territorial divisions: Europe, Americas, and the Rest of the Word.

Mittal Steel CR is one of ten national companies in the Europe division of Mittal Steel. Mittal Steel CR has an organisational structure (in functionality) illustrated in Figure 3. Our exersize is to determine whether any particular organisational unit has an overfull managerial control capacity.

The informational channels of the structure are configured according to the contribution to the added value of its outputs (Hron et al. 2007). The division of labour principle is in the direction: inputs to outputs (the transformation process is broken down according to material flows between the functional processes). The performers of the work are then the teams created according to work specialisation. The coordination of activities is strongly centralised and the authority of a lower decision-making level is determined by a higher level. The delegation of decision-making competence is in the bottom-up direction.

Information regarding control capacity of six managers at particular levels of management are given in Table 1.

The capacity of the information channel is given by the quotient between the manager's working time and the time spent on one coordinative exercise, and the subsequent multiplication by the amount of information (in binary units) necessary to make one coordinative exercise.

The complexity of the coordinative mechanism is determined by an average count of decision-making

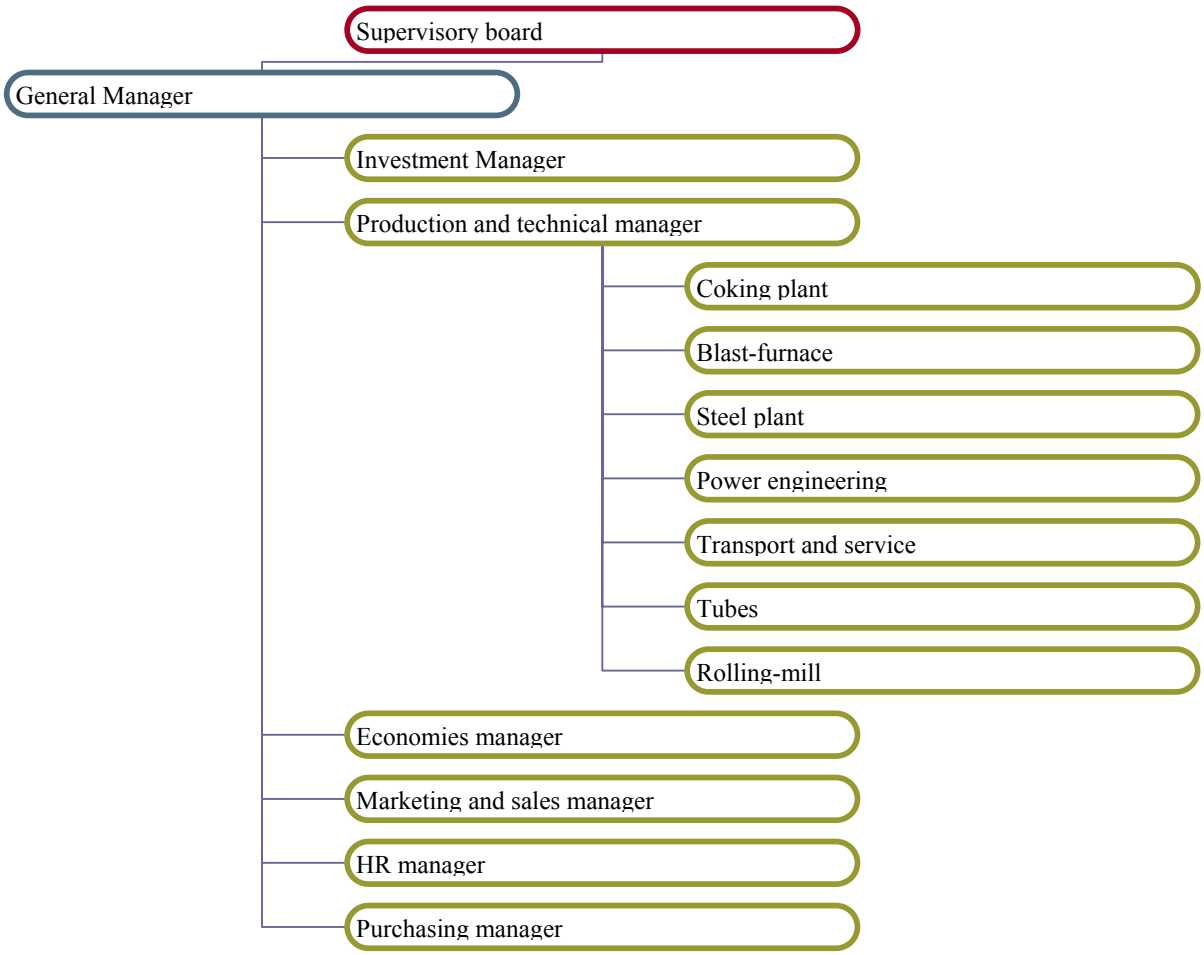

Figure 3. Diagram of management structure

Table 1. Data for sufficiency test of managers' control capacity

Seq.	Manager for	No. of direct subordinate staff	Capacity of decision-making channel per 1 working day (bit)	Complexity coordinating mechanism	Average size of information necessary to manage per 1 working day (bit)	Test result of necessary variety
1.	investment	5	25	3	7.92	capacity conform to limit
2.	production	7	25	4	14.00	capacity conform to limit
3.	economics	6	25	5	13.93	capacity conform to limit
4.	marketing	9	25	8	27.00	**substandard capacity!**
5.	HR	5	25	3	7.92	capacity conform to limit
6.	purchasing	4	25	11	13.84	capacity conform to limit

variants of each senior manager. The average size of the necessary information to the control process (marked *I*) at the i^{th} manager is determined according to formula (7) (Hron et al. 2007; MacKay 2005; Vajda 2005):

$$I_i = H(Y^*) - H(Y) = n \times \log_2 s \leq T(R:X) + K \qquad (7)$$

where:
n = number of direct subordinates
s = complexity of coordinating mechanism given by an average count of variants at managerial decision making

It can readily be seen that the control capability is overrun at the fourth manager, the Marketing Manager (Data from Table 1 used in formula (7)). There is an average size of required information equal to:

$$I_4 = 9 \times \log_2 8 = 27\ bit > 25\ bit$$

The size of uncertainty ***K*** of control at the fourth manager is equal to:

$$K = I_i - T(R:X) = 27 - 25 = 2\ bit$$

Ambiguity in any informative exchanges is not permissible when leading people, therefore, at the fourth (marketing) manager, we should remove by the appropriate intervention (delegation and decision-making decentralisation) any possibility of uncertainty.

DISCUSSION – CONCLUSIONS

As we very well know, communities in the developed (advanced) countries began to change radically after the end of the second world war. These deep social changes contributed to one effect – which is usually seen as a transformation from an industrial society to an information society. The fast-growing importance of information (suitable according to syntactical and pragmatic standards by the recipient) is a dominant characteristics of the new society. It is therefore very important to thoroughly understand the characteristics of the information and subsequently to consider new avenues of approach (gained from information theory) fit for the next development stages in the relevant fields.

The main aim of this paper was to illustrate one specific utilisation of information theory in organisational management.

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