MANAGERIAL FUNCTION IN THE PROCESS EFFICIENCY MONITORING AND MEASUREMENT[1]

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Abstract

One of the structural sections in control process model is monitoring and measuring of the processes. Under this model, the process manager can control processes, that means, systematically monitor and assess he efficiency of processes and pursue a correction action in the case he find out incongruity within required outputs. It´s feedback, which advises, whether the process of control is harmonious and perfect. This article reports the summary of the universal figures and methods, which should be not only known, but applied by process managers. Within those indicators we can name the time realization of product, process costs, OEE, indices level of satisfaction and loyalty consumers, benchmarking etc. Another methods and approaches used to process monitoring and measuring are the abnormalities control, Six sigma, EFQM model etc.

Keywords*: Quality control process, universal indicators efficiency of process, basic approaches to monitoring and measuring of the processes.*

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[1] **Monitoring is applied predominantly** to phenomena and qualities which are very difficult to measure such as behaviour, conduct, creativity, reactibility, adaptability, thought, flexibility, sense of responsibility, motivation, cooperativity, loyalty, etc.
Measurement is applied predominantly to relations between X factors (raw materials, materials, processes ...) and their impact on Y factors (customer satisfaction, company returns, losses, expenses, etc.). The **subjects of measurement** are**:** predictors, results, efficiency, effectiveness.

1. INTRODUCTION - INTERNAL PROCESS CONTROL

The fundamental mission of process managers is to ensure the operation and improvement of the processes with the control of which they were charged in order to maximize the satisfaction of process customers (both internal and external ones). The managers need to carry out several indispensable activities to accomplish their mission. These are as follows according to ISO/DIS 9004 international standard ("Performance Improvement Guidelines"):

- Monitoring actual inputs and outputs of controlled process;
- Monitoring intra-process activities;
- Setting objectives based on requirements for:
  - outputs (product objectives) for customers and
  - utilization of potential (potential objectives) with respect to the opportunities and competition
- Analyzing root causes of non-conformances;
- Adopting corrective actions to eliminate non-conformances;
- Managing changes improving controlled processes (continuous: e.g. KAIZEN, discontinuous: e.g. work reengineering);
- Assessing achieved objectives and motivating employees.

The renowned US expert Juran describes the quality control process loop in *Juran's Quality Handbook* (Horálek, 2000) covering the above activities in a simplified form.

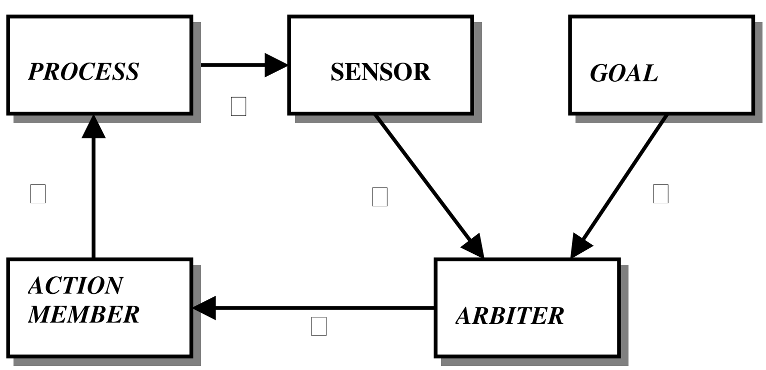

Figure. 1 *Juran's QCP (Quality Control Process) model*

According to Juran each process has outputs which need to be monitored using the sensors (1). Each output must lead to the achievement of objectives which have been set for the respective process and its outputs. The compliance of the monitored process outputs with the requirements for process objectives is assessed by so-called arbiter based on the comparison of the data obtained from the sensor and the set objectives (2 and 3). If the arbiter identifies any non-conformance he or she asks the action member (4) to search for the causes and prepare and implement actions (5) to eliminate the causes from the process.

2. PROCESS CONTROL LOOP

Thanks to its simplicity and applicability in practice the Juran's QCP model became a heart of the process control model. The model was elaborated, supplemented and designated as **process control loop** (see fig. 2 on next page).

This loop allows systematic process control monitoring and assessment at any corporate level and will serve as a basic framework to create the managerial competence model for process control.

The process managers can apply the loop to control their processes, i.e. consistently monitor and assess the process performance and take corrective actions in case of any non-conformances with the required output identified by them. It is a kind of **feedback** advising if the process is controlled so that all its parts work in a harmony and without any errors or not.

Panade, Neuman and Cavanagh (Nenadál, 2001) present an illustration relating to the feedback issue. The illustration can be described as follows:

"Let us imagine our child learning to ride on a bicycle and expecting a help and encouragement from us. Both the child and we wish to be successful. We seat the child on the bike, push him and observe his nice straight ride for the first few metres. Proud of his performance, he is crowing: "Look how I am riding!". But in no time he diverts from the path falling in a bush and suffering some bruises. There occurred an event which could be anticipated. And because we know children often find themselves out of the path when learning we lift them up, we explain them what they have done right and what they must avoid encouraging them and pushing them again and again."

In case of managers it is similar but there is a difference consisting in the fact the means of movement is corporate processes instead of bike. In certain circumstances they find themselves out of their routine track, too and similarly to children they may suffer bruises." However, if they are able to react properly and in time they can alleviate or even avoid this impact. To enable that those managing the company need a feedback just like the child riding a bike. The feedback principle is not difficult. The feedback is to provide the output data on the system behaviour (bike riding ended up by a fall) back to the input. This allows to reconsider the existing behaviour and more sensitively correct the "staggering" connected with a danger of fall.

The internal impulses providing the feedback include indicators not only obtained from the activities inside the processes but also relating to the manner in which the activities are managed (chained, integrated). The external information indicates how the company performance is perceived by the external entities and usually expresses the extent to which the objectives (profitability, customer satisfaction, etc.) are achieved.

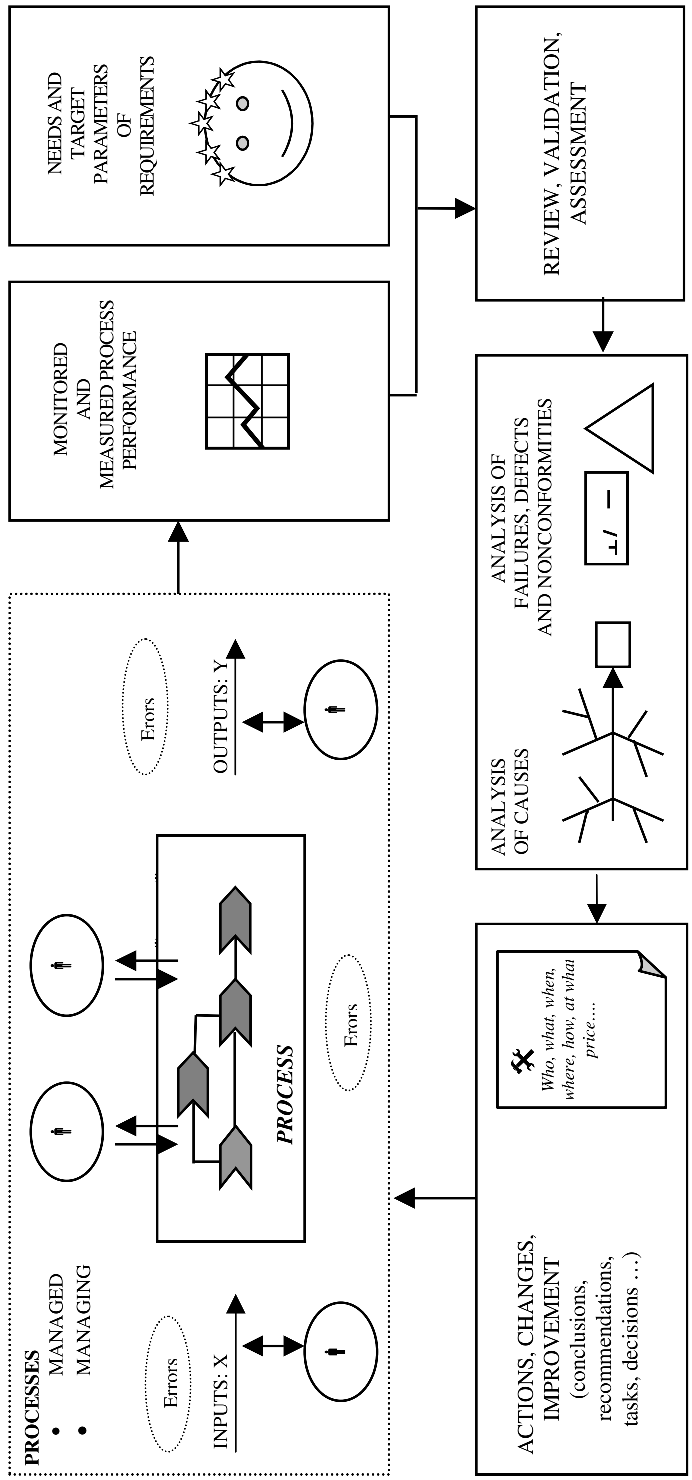

Figure. 2 *Process Control Loop (Kovács, 2004)*

More detailed description of the different structural components of the control loop can be found in Kovacs doctoral thesis (Kovács, 2005). Since it is quite extensive the following is focused on a component which, unfortunately, is not popular among the managers due to its requirements for mathematical, statistical and other analytical methods and techniques. This control loop component is the process performance monitoring and measurement (see the research results below).

3. RESULTS OF RESEARCH OF CONTROL LOOP APPLICATION BY ZTT VIADRUS, ŽDB BOHUMIN MANAGERS

A research was conducted at ZTT VIADRUS, ŽDB Bohumín (Czech Republic) to find out if and to which extent are the different control loop components applied by the process managers in order to determine the level of their ability to apply the control loop in practice. The overall result in the process control is shown by the following diagram.

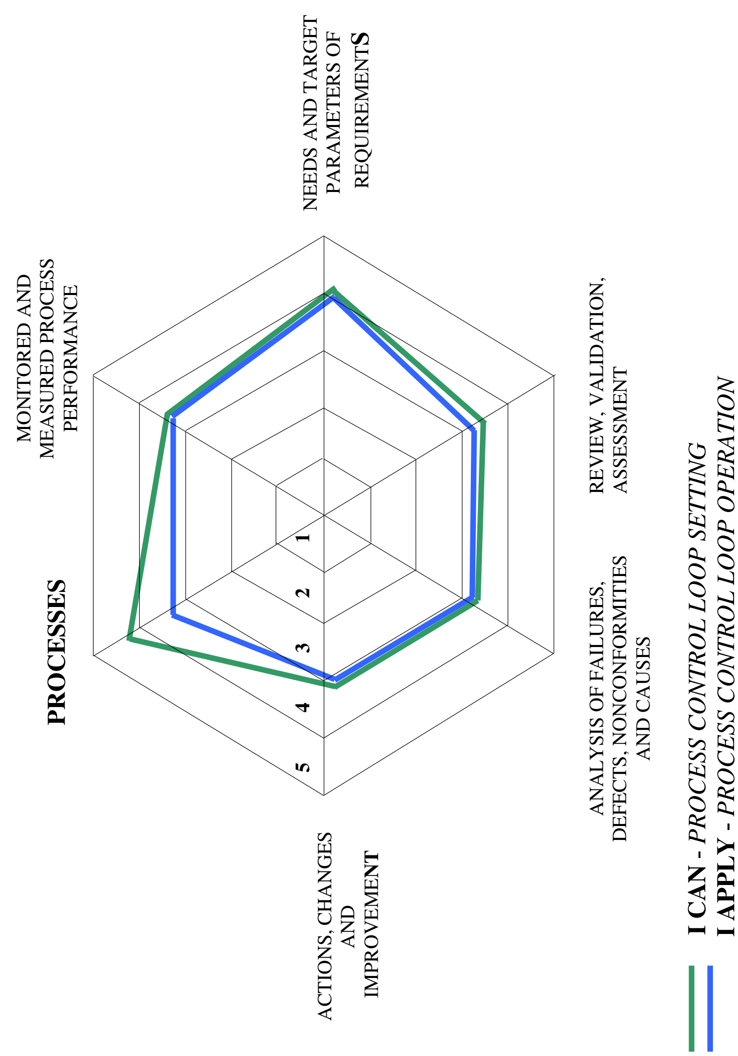

Figure. 3.1 *Overall result of self-assessment of managers' competence level within all the control loop and VIADRUS plant (average of macro processes, business units and plant director)*

The diagram indicates the best results were achieved by the managers in the knowledge necessary to understand the control of their processes, e.g. knowledge regarding the supplies/inputs, structure of their processes, structure of customers and suppliers, applicable standards and guidelines, etc. They acquitted themselves very well also in the sphere of satisfying the needs and achieving the target parameters of requirements from the internal and external customers and other interested parties. The average result of the assessment shows a high knowledge level.

In other control loop components the average assessment result is only at a mid level or a little above it. It will be shown by the diagrams depicting the self-assessment of the different managers that the knowledge level is varied in these components. The average knowledge is only at an acceptable level suggesting there is a substantial improvement potential.

As concerns the assessment of control loop operation, the managers tend to focus their activities on the *satisfaction of needs and target requirements of customers and other interested parties* where they achieved a high level in general. Other answers oscillated between *"from time to time"* and *"often"* . This level is acceptable in general. Any improvement would depend on the competence items which should be applied, the frequency of their application and the number of process managers (all or only some of them) to apply them.

Based on average values and combined rating it can be stated the rating of the process control by ZTT VIADRUS managers is "high level" and "acceptable level" with the latter prevailing (see the table below).

Control loop components	**Combined rating for all loop**
No component	5 - outstanding level
Knowledge of processes, needs and target parameters of requirements, satisfying the needs and achieving the parameters	**4 - high level**
Other control loop components	**3 - acceptable level**
No component	2 - low level
No component	1 - unacceptable level

Note: The combined rating relates only to the "I can" and "I apply" results.

Table 3.2 *Levels of competences – knowledge, skills, behaviour and conduct of all company managers according to the different process control loop components*

4. OUTLINE OF UNIVERSAL PROCESS MEASUREMENT AND MONITORING METHODS AND TOOLS

The outputs, process capabilities, customer satisfaction and items required by other interested parties are to be monitored, measured and assessed by the process owners - process managers or persons nominated by them - in appropriate intervals. This activity requires competences such as recording, collecting, analysing, summarizing and communication of relevant data needed to improve the company process performance. The processes cannot be objectively controlled without processing the process performance measurements.

In practice, however, it appears not all companies can properly determine the monitoring and measuring object, method, place and time and the responsible person so that the related activities are not an unnecessary encumbrance and the employees do not say that all is measured including what needs not to be measured, and, on the other hand, so that the measurement is not too limited and the employees do not make important decisions without the necessary information and data. In this context, the view of Nenadal (Kaplan and Norton, 2000), an expert at system measurement dividing the measurement into two groups, can be helpful to the process managers:

1. **Technical measurement**
   The purpose of technical measurement is to determine the value of a variable relating predominantly to the tangible process outputs, i.e. products. This group includes measurement of dimensions and mechanistic and other properties of materials. The measurement is relevant for the competences to the extent its results are necessary for the system measurement.

2. **System measurement**
   The system measurement enables to understand and define the organization system behaviour. Its results are key inputs for the decision making at various process control levels. The monitoring and measurement structure and scope are prescribed by ISO 9004:2000 standard where the following basic system measurement areas are specified: satisfaction of customers, employees and other interested parties, performance of processes, quality management system, organization and suppliers, costs associated with processes and process quality (including financial measurement), audits and self-assessment.

In order to prevent the occurrence of extremely high or low extent of monitoring and measurement the process managers need to clarify the following with the employees:

A) Preconditions of process performance monitoring and measurement

The process character will determine the shape of the monitoring and measurement procedure. The process management experts identify the following preconditions to be met if the managers want to develop and implement a procedure for their processes:

- The change of outputs depends on the change of process performance.
- The process performance measurement must be based on preset target performance values.
- An efficient performance measurement must meet requirements such as validity, completeness, adequate particularity, frequency, accuracy, proper timing, capability to discover gaps in the performance, invariability of the measurements in time, comprehensibility of information and responsibility for the measurement results.

B) Selection of indicators for process performance monitoring and measurement

Before the monitoring and measurement the process owners need to identify criteria and objectives, i.e. they need to know the right and reliable indicators relating to the performance. To this end, they should identify (e.g. generate using brainstorming) together with the process control team1 and quality manager which sensors, indicators, statistical methods and measuring tools will be needed by them to collect and analyse the data including the methods to verify process activities and parameters of products or services. It is important to make sure the selected statistical methods and tools can be efficiently applied to their processes and are not too expensive.

Nenadal (Juran, 2000) and Kovacs (Kovács, 2005) recommends that the process managers take the following steps to select the process performance monitoring and measurement indicators:

1. Define precisely which process (which level of the process complexity) is to be subjected to the performance measurement.
2. Set up a group of experienced employees and have them generate various indicators using group cooperation techniques.

[1] **Process control team** transforms (converts) the inputs received in its business process to outputs which ensure the achievement of business objectives and required competitiveness level satisfying the needs of all customers at minimum transformation process cost. It is a highly autonomous team within the company with delegated power necessary to carry out the internal and external business activities and responsibility for the achievement of the required corporate and customer objectives. It has horizontal and vertical network links to the other teams at the company deployed and coordinated by the process owner (IDOV principle).

3. Select the most appropriate indicators, i.e. the indicators whose application would not result in an inefficient work expenditure and would keep their maximum capability of indicating the actual performance of the respective process.
4. Propose mathematical, statistical and econometric relations for the calculation of the selected process performance indicators.
5. Determine the required information inputs for the calculation of performance indicators in your capacity as the process owner.

This task is more difficult for the owners of so-called macro-processes and their teams than for their peers in production processes where most of the indicators have already been introduced. Though the character of many indicators will be connected with the uniqueness of their processes it can be stated there are certain performance indicators of universal character which can be used in a wide range of monitoring and measurement applications. Below are some of the universal indicators which could or should be included by the process managers into their competences or the competences of the process control team the responsibility for which was assumed by them:

a) **Duration of product realization** is a time which elapses from the receipt of inputs in the process to the exit of outputs and can generally[2] be calculated using the following formula:

$$T_p = T_{zpr} + T_{ov} + T_{man} + T_k \qquad \text{[time units]}$$

where:
T_p = total process duration,
T_{zpr} = duration of input processing, i.e.: $T_{zpr1} + T_{opr}$,
T_{zpr1} = duration of first processing,
T_{opr} = duration of processing during repairs,
T_{ov} = duration of various verification activities within the process,
T_{man} = duration of handling within the process,
T_k = standstill duration (time for which the products or services are left in warehouses, on tables, etc. without any activity being performed on them).

b) **Efficient use of process duration (V_{ef}):**

$$V_{ef} = \frac{T_{zpr1}}{T_p} \, . \, 100 \qquad [\%]$$

The efficient use of process duration can be "shocking" for some managers, in particular if they find out its value ranges between 10 and 20 %.

[2] This indicator is analysed in greater detail in production logistics.

c) Total process costs (N_p):

$$N_p = N_{sp} + N_{np} \quad [€]$$

where:
N_{sp} = costs for process conformity,
[including but not limited to costs for assessment of conformity of both the internal processes (checking, review of documentation, systems, IS/IT support, etc.) and external processes (costs for obtaining product approvals, product and service certification, services from external companies, etc.), purchase and maintenance of measuring devices, evaluation, review of evaluation records, etc.]

N_{np} = costs for process non-conformance,
[including, for example, costs for defects arising during production or service provision, poor quality, irreparable defects, deteriorated material, repairs, disposal of irreparable rejects, etc.]

d) Efficient use of costs (V_{efn}):

$$V_{efn} = \frac{N_{sp}}{N_p} . 100 \quad [\%]$$

For explanation of the abbreviations see the formulae above.

e) Process non-conformance rate (P_n):

$$P_n = \frac{O_n}{O_c} . 100 \quad [\%]$$

where:
O_n = volume of non-conformances identified during process verification,
O_c = total volume of conforming outputs from process for certain time.

f) Total capacity utilization percentage (CVK):

$$CVK = VK_1 \,.\, VK_2 \,.\, VK_x \,.\, 100 \quad [\%]$$

where:

CVK = capacity utilization percentage expressing probable percentage of conforming outputs (products or services) produced by the concerned process as a whole,

VK = capacity of individual operation which can generally be calculated using the following formula:

$$VK = O_{ps} : 100$$

where:

O_{ps} = probable number of conforming products per 100 units produced by the respective operation.

Panade, Neuman and Cavanagh (Mikušová, 2006) highlight one more process capacity utilization percentage indicator, i.e. gross capacity utilization percentage (VK_h) which depends on the total number of produced units and expresses the actual loss rate within the process.

g) Number of registered non-conformances in the process

It is the simplest process performance measurement indicator which enables to determine which non-conformances prevented to achieve the required process performance level. If the non-conformances are analysed in detail using, for example, Ishikawa method and Pareto principle 20/80 then not only their potential causes can be revealed but those of them which affected the process performance most severely can also be identified. And such information is of vital importance for process improvement.

The managers as process owners can study a variety of other process performance measurement methods. Some of them are listed below for convenience:

- QFD, FMEA, FTA, process capability evaluation
- Measurement according to Sigma capability
- Techniques and tools included in BSC performance measurement system, etc.

The process performance measurement is not the only measurement to be applied by the process owners. The measurement of **external performance of**

quality management system is of the same importance. Of the wide range of options offered in this area the following ones may be found useful:

h) External customer satisfaction index

$$U_{usz} = \frac{I_{rzs}}{I_{osz}} \cdot 100 \qquad [\%]$$

where:
U_{usz} = external customer satisfaction index,
I_{rzs} = actual value of customer satisfaction index determined *at certain time*,
I_{osz} = optimum external customer satisfaction rate[3].

i) External customer loyalty index:

$$U_{mlz} = \frac{U_{sz1}}{U_{sz0}} \cdot 100 \qquad [\%]$$

where:
U_{mlz} = external customer loyalty index,
U_{sz1} = customer retention rate for period 1,
U_{sz0} = customer retention rate for period 0, i.e. the period preceding period 1

and U_{sz} can be calculated using the following formula:

$$U_{sz} = \frac{Z_{kr}}{Z_{zr}} \cdot 100 \qquad [\%]$$

where:
Z_{kr} = number of customers at the end of current year,
Z_{zr} = number of customers at the beginning of current year.

The managers would undoubtedly be pleased if this quality management performance indicator is positive at all times and its value continuously increases.

[3] The perception of customer satisfaction can be analyzed using the Likert's multi-item scale and it is necessary to determine the weight of the different satisfaction §§indicators using some of the expert techniques such as the paired comparison, allocation method, etc.

j) Customer value index:

$$U_{MHPZ} = \frac{MHPZ_1}{MHPZ_0} \cdot 100 \quad [\%]$$

where:
U_{MHPZ} = customer value index,
$MHPZ_1$ = customer value index determined for period 1,
$MHPZ_0$ = customer value index determined in the same way for period 0, i.e. the period preceding period 1

and *MHPZ* can be calculated using the following formula:

$$MPHZ = U_Q \cdot w_Q + U_C \cdot w_C$$

where:
U_Q = quality index perceived by market (taken from quality profile[4]),
w_Q = quality element weight taken from customer value tree[5],
U_C = price competitiveness index which was defined by price profile[6],
w_C = price element weight according to record from customer value tree.

Similarly structured indicators can be applied in companies producing consumer goods or providing services.

k) Complaint settlement rate:

$$U_s = \frac{P_{s48}}{P_{sc}} \cdot 100 \quad [\%]$$

where:
U_s = complaint settlement rate,

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[4] **Quality profile** – a tool to analyze the customer value (table showing the analysis of quality §§indicators of our product and at least one competitive product)
[5] **Customer value tree** – a diagram intended to summarize the customers' opinions of the different customer value elements (price, design, quality, availability, service ...) including §§subindicators.
[6] **Price profile** – a tool with a purpose analogous to that of the quality profile but designed to analyze customer attitudes and perception towards the economic §§indicators defined by the customer value tree (purchase price, maintenance costs, insurance, bonuses, discounts, etc.)

P_{s48} = number of settled complaints within 48 hours from their first registration by the supplier for certain time (The 48 hours' period is intended as an illustration of the target response time.),
P_{sc} = total number of complaints registered for the same time.

This indicator is applied in practice predominantly to the complaints of customer claim character. If it is to comprise all critical inquiries from external customers then its value would obviously be different.

There is also a specific performance monitoring and measurement method called "**benchmarking"**. This technique enables the process owners to continuously and consistently compare and measure own products, processes, employee capabilities, management system or any other item within the organization with the best-in-class who have been recognized as fit for the measurement in order to define the objectives for improvement of own activities.

l) Benchmarking index:

$$U_b = \frac{P_v}{P_k} . 100$$

where: U_b = benchmarking index,
P_v = own performance parameter,
P_k = best-in-industry competitor performance parameter.

5. EXAMPLES OF PROCESS PERFORMANCE MONITORING AND MEASUREMENT

Nenadál (Kaplan and Norton, 2000), Kaplan and Norton (Juran, 2000) and Panade, Neuman and Cavanagh (Mikušová, 2006) recommend several procedures which could be employed to measure the performance of both manufacturing and non-manufacturing processes in the managerial practice. Of the multitude procedures the three to which most attention is paid by experts and company managers are presented below:

a) Performance measurement by deviations

Šnapka (Nenadál, 2001) and Tyrlík (Nenadál et al., 1998) claim it is important for the managers to learn to manage any undesired events upsetting the balance in the company behaviour which can occur in the endeavour to fulfil the objectives. These undesired deviations[7] are caused by both internal and external disorders. Such deviations giving rise to emergencies in management must be acted upon by the managers who are required to make changes with a view of regaining the balance in the target behaviour which can be considered as "normal" status. In the context of the occurrence of undesired deviations, it is to be decided which criteria are to be used to discern between the normal status and emergency. Šnapka recommends a pragmatic criterion in the form of specifying the required target values in the company behaviour and the tolerances assigned to them. This approach represents, in fact, a definition of allowable deviation (tolerance) limits for the achievement of the required values of indicators quantifying the course and objectives of the business process implementation. In case tolerance limits are applied by the manager in the process control system and the undesired deviation level is within the tolerance limit it is a normal status where the manager should apply the **management by objectives** method in conjunction with the **management by deviations** method. Any undesired deviations exceeding the limit constitute emergencies which can be managed by a **crisis solution.**

A precondition of successful application of this method is meeting the requirement to carefully record all phenomena and factors which can be regarded as deviations.

b) Process performance index determination

This technique is based on appropriate performance indicators whose calculation method must be known (see the list of indicators above). It is useful in the monitoring of continuous process improvement project or corrective action implementation. According to Nenadál (Kaplan and Norton, 2000) the application must be divided into two stages:

Stage 1:	development of a printed form for performance index determination
Stage 2:	performance measurement

Although quite simple this technique requires not inconsiderable efforts to develop the printed forms for monitoring and measurement to determine the performance indices.

c) Performance measurement using Sigma capabilities

Unlike the aforementioned process performance measurement techniques, Six Sigma method has high requirements for the applications. This term is derived

[7] The term "deviation" is understood as any diversion from normal or planned conditions for process execution which affects the fulfilment of defined tasks or performance indicators (Nenadál).

from the process control mode which shows up to 3.4 defects per one million opportunities.

Panade, Neuman and Cavanagh (Mikušová, 2006) indicate the Six Sigma programmes are intended to achieve a condition where the standard deviation value (σ) reaches only such magnitude which would guarantee the coverage of tolerance field of the concerned parameter at least within 12σ. This requires that actions substantially eliminating the process variability and remarkably strengthening the process stability are taken. Horálek (2000) states the achievement of this objective guarantees the non-conformance extent reduction to negligible 0.0000002 % yielding substantial economic effects. It is a goal which is achieved by a few companies and processes in the world.

The process performance measurement using Sigma capabilities comprises the following steps:

1. Determination of number of process input units
2. Determination of number of conforming process output units
3. Determination of capacity utilization percentage of process inputs
4. Determination of ratio of non-conformances to process inputs
5. Determination of number of potential causes of non-conformance within the process (variability points)
6. Calculation of number of non-conformances per potential cause
7. Calculation of non-conformance rate in *ppm*
8. Conversion of non-conformance rate in *ppm* to Sigma capability degree (based on tables)

The process performance measurement techniques above are generally recommended for application in companies.

d) Process performance measurement according to EFQM model and ISO standards

Both the EFQM model and ISO 9000:2000 standard itself require process performance measurement - a type of system measurement. In addition, ISO 9001:2000 stipulates that all processes included in the quality management system, i.e. not only the manufacturing ones and direct services but also those of non-manufacturing nature (macro-processes) are subject to this measurement. For companies, this implies not only additional demands for resources and development of methodologies for the measurement but also extension of competences of the process owners themselves as well as their employees. This process will involve learning and embracing, through behaviour and conduct, a variety of other system measurement methodologies and tools.

The requirements for system measurement above are specified in EFQM model and ISO 9000:2000 standard where the necessity of performing a number of untechnical measurements is also highlighted. Annex No. 1 provides a chart showing an overview of the measurements for EFQM Model Excellence.

4. REFERENCES

Horálek, V. (2000). Co jsou procesy s jakostí +-6σ?. *Svět jakosti*, , č. 2, s. 22 – 26.

Juran, J. (2000). *Juranś quality handbook*. Fifth Edition, New York: Mc Graw Hill, 48 section. ISBN 0-07-034003-X..

Kaplan, R.S., Norton, D.P. (2000). *Balanced Scorecard.* Praha: Management Press, 267 s. ISBN 80-7261-032-5.

Kovács, J. (2005). *Model manažerské kompetence pro řízení procesů.* Disertační práce, EkF VŠB TU Ostrava, 2005, s. 151 bez ISBN.

Mikušová, M. (2006). Performance Management: House Model. In: *International Review of Business Research*. Melbourne: World Business Institute Melbourne, 2006, vol. 2, no. 3, p. 59-71. ISSN 1832-9543

Nenadál, J. (2001). *Měření v systémech managementu jakosti*. Praha: Management Press, 310 s. ISBN 80-7261-054-6.

Nenadál, J., Noskievičová, D., Petříková, R., Plura, J., Tošenovský, J. (1998). *Moderní systémy řízení jakosti.* 1. vyd. Praha: Management Press, 283 s. ISBN 80-85943-63-8.

Panade, P.S., Neuman, R.P., Cavanagh, R.R. (2002). *Zavádíme metodu Six Sigma.* 1. vyd. Brno: TwinsCom, 416 s. ISBN 80-238-9289-4.

Šnapka, P. (2003). Krizový management a řízení odchylek. In sborník *Krizový management*. Univerzita Pardubice. Vítkovice v Krkonoších 2003, 90 s. ISBN 80-7194-597-8.

Tyrlík, O. (2003). Adaptivní řízení jako nástroj krizové prevence. In sborník *Krizový management*. Univerzita Pardubice. Vítkovice v Krkonoších 2003, 90 s. ISBN 80-7194-597-8.

Annex No. 1 *Types of System Measurements for EFQM Model Excellence*