

# **A Key Performance Indicator System of Process Control as a Basis for Relocation Planning**

**F. Reichert, A. Kunz, R. Moryson, K. Wegener**

Swiss Federal Institute of Technology Zurich, Raemistrasse 101,  
8092 Zurich, Switzerland

## **Abstract**

Many companies build up manufacturing networks to cope with globalized competition. Among others, this requires a decision on a technical basis, which product should be manufactured at which location.

In this paper a key performance indicator system is introduced to measure a location's competence on a technical basis. This system consists of three key performance indicators: cycle time ratio, adjusted cycle time ratio, and stability of the cycle time.

The most important performance indicator in this key performance indicator system is the stability of cycle time. It indicates how experienced and stable the serial production can be managed. This indicator is defined as the ratio of the mean absolute deviation of the cycle time and the achieved cycle time.

Based on this, a company can take a more objective technical decision regarding relocation processes. The efficiency of this key performance indicator system will then be demonstrated in a case study.

## **Keywords:**

Factory and Production Planning, Networking in International Production/ Manufacturing and Logistic Networks, Process Control

## **1 INTRODUCTION**

Many companies build up manufacturing networks to cope with globalized competition [1]. However, the increase of internal production networks results in decreasing knowledge concerning production conditions in the network. To avoid this information deficit, a complex view is necessary on the production network and the transparency of the production structure.

In case of relocation planning respectively production planning, different decisions depending on the time horizon must be made. Strategic decisions deal with the question where to open new locations and have a time horizon of at least three years [2]. The time horizon of tactical decisions is between one and three years and defines where to place

production volume in existing production networks. In this paper the focus lies on the tactical planning horizon.

In order to create transparency in the production structure within production networks for the tactical production planning, the method MAE-P<sup>3</sup> (machines and equipment, processes, product, planning) was developed [3]. This method allows comparing technical criteria of production lines and process chains of products.

If the analysis based on the MAE-P<sup>3</sup> method produces a number of technical possibilities for the production of a production volume within a production network, the question arises which location has the highest technical competence within this network.

In the literature many papers deal with strategic, capacity or cost driven approaches to answer the question where to produce production volumes in an internal production network. Thus, the topic of this paper is where to produce a production volume based on a technical basis and regarding the location's competence.

## 2 OBJECTIVES

The goal of this analysis is to develop a key performance indicator system to evaluate the process control of the distributed production structure in an internal production network. Based on this knowledge, decisions of where to place production volumes can be made more profoundly.

Firstly, the term "process control" in the context of production processes and production lines in a globally allocated production network has to be defined. Secondly, a performance indicator has to be found by which it is possible to measure this process control. Therefore, different existing performance indicators have to be compared. Based on this comparison, a key performance system has to be derived.

In a practical example, the developed key performance indicator system is used to compare where to relocate a production volume of a product of a big producing company in the automotive electronic supplier branch.

## 3 THE PROCESS CONTROL PERFORMANCE INDICATOR SYSTEM

### 3.1 The Definition of Process Control

Within literature, the term "process control" is part of the term "process capability". If a process is randomly distributed between given limits and if there are no indications of disturbance, a production process can be named as a controlled process [4]. A capable process is a process in which the quality attributes suffices the tolerance requirements. The according performance indicators for process control and process capability are called  $c_p$  and  $c_{pk}$ .

The indicators '*process control*' and '*capability*' only base on the results of the process but not on time. The duration of the process, which was needed to reach the  $c_p$  and  $c_{pk}$  value is not part of the indicator. In this paper, the following approach is used to describe the process control:

“The process capability is the ability of a technical system not to exceed a certain tolerance limit, while the process control represents the ability of the user to apply the process capability of the system” [5].

Consequently, the required performance indicator in this system must fulfill the significance of the user’s ability to use the capability of a machine. But additionally, the production control should also show the user’s ability to use this capability within the required time. The user can be a direct operator or an indirect employee, who repairs or plans a machine.

### **3.2 The requests to the key performance indicator of process control**

A study of the Association of German Engineers (VDI) in the field of production controlling describes six requests to evaluate performance indicators:

- Significance
- Comparability
- Easy acquisition of the performance indicator
- Up-to-dateness and fast availability
- Clear presentation
- General understandability

The most important requests for the process control performance indicator are the first three: the significance, the comparability, and the easy acquisition. The significance of the performance indicator process control must show the user’s ability to use the capability of a technical system in terms of process quality and process time.

Beside the significance, the comparability of the performance indicator is very important. Especially within a production network, the performance indicator must be acquired identically at every location; otherwise the significance of the performance indicator is restricted.

The third important request is the possibility to acquire the performance indicator easily. If the data acquisition is easy to perform, the probability of identically collected performance indicators is high. For this paper, an automatic data collection for the performance indicator is assumed.

### **3.3 The choice of the cycle time for the performance indicator system**

With these six requests for evaluating performance indicators, different key performance indicator classes, which could have an influence on the process capability, were evaluated. A possible influence on the process capability is seen in the performance indicator classes of ‘*finance*’, ‘*process*’, ‘*quality*’, ‘*production*’, ‘*customers*’, and ‘*employees*’.

The key performance indicator classes of ‘*process*’ and ‘*quality*’ fulfilled the requests from the above. In a second comparison, the key performance indicators of these classes are compared. Mostly because of the significance, the comparability and the easy acquisition, the performance indicators ‘*cycle time*’ and ‘*processing time*’ were chosen to be the basis for describing the process control.

### 3.4 The key performance indicator system of process control

The key performance indicator system 'process control' is measured on two different levels, shown in Figure 1. First, the single process control is measured, which represents a single production process in a production line. Second, the production line control is measured, which represents the sum of production processes in one production line.

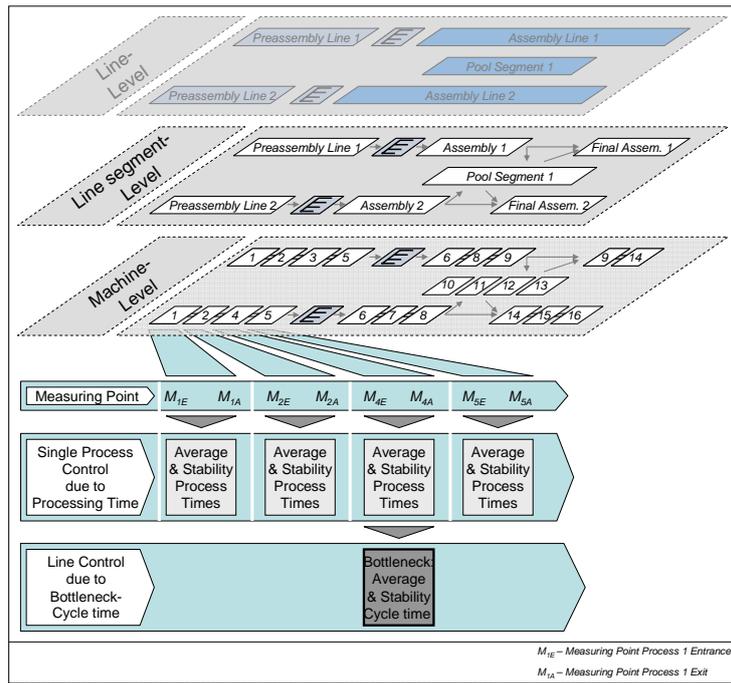


Figure 1: Different levels of the production structure.

The process control is measured on the machine level. The time stamp of every product at the entrance of every machine in a production line has to be stored, as well as the time stamp when the product is leaving the machine. With this data, the mean processing time of a product family on every single machine in a production line can be calculated. The longest mean processing time of a machine represents the bottleneck. Depending on the product, the bottleneck in a production line can change.

At the bottleneck of a production line, the cycle time can be calculated by the difference of the entrance time stamp of one product and the entrance time stamp of the next product. The measurement of the process control at the bottleneck of a production line represents the line control of the line segment level shown in Figure 2.

With this data, the process control of a single process and of a production line can be calculated. This system consists of three key performance indicators: 'cycle time ratio', 'adjusted cycle time ratio', and 'stability of the cycle time'.

### The cycle time ratio

Figure 2 shows a distribution of cycle times at the bottleneck of a production line. First, the Target Cycle Time has to be defined. The Target Cycle Time is the average of the 10% shortest processing times. The target time is realistic because it was measured, but it also contains possible measurement errors.

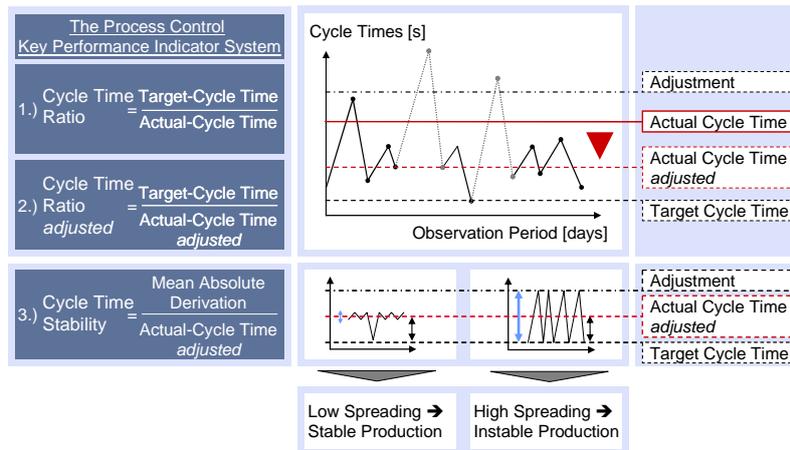


Figure 2: The Process Control Key Performance Indicator System.

The next step is to calculate the Actual Cycle Time. The Actual Cycle Time is the average of all Cycle Times in the observation period. In our case, the observation period is at least six months and is shown as monthly performance indicators.

With these two figures, the first performance indicator of the key performance indicator system can be assigned as the Cycle Time Ratio. As shown in Figure 2, the Cycle Time Ratio is the ratio of the Target Cycle Time and the Actual Cycle Time. This calculated value shows how long the production line is used over a month.

### The Adjusted Cycle Time Ratio

Within a production, there exist a lot of reasons for production distortions. Distortions like 'no material available', 'no operator around', 'machine breakdown', 'breaks', a 'non productive shift', or 'holidays' can disturb the production. In order to compare production lines at different locations, a similar basis of a working production line is needed. Therefore, an adjustment of the cycle times has to be done. The cycle times will be defined to be at the tenth of the target time. Up to the tenth of the Target Cycle Time, an operator can solve small machine problems by himself. Above the tenth of the Target Cycle Time, there is a bigger distortion.

However, within this paper the competence has to be measured and thus the working production line is of interest. The significance for the calculation is that all cycle times, which last longer than the tenth of the Target Cycle Time will be rejected from the amount of all cycle times. This will result in a new and probably lower Actual Adjusted Cycle Time.

The second performance indicator of the key performance indicator system is the Adjusted Cycle Time Ratio. This is the ratio of the Target Cycle Time and the Actual Adjusted Cycle Time.

#### *The Cycle Time Stability*

The most important performance indicator represents the Cycle Time Stability. The aim of measuring the process control is to show the competence of production lines at different locations. The competence can be explained by constant quality and reproducibility of production results. Summarizing the production has to be stable. Expressed by a mathematical equation, the production has to be stable.

The dispersion in this case does not show a normal distribution because the lowest possible value is the Target Cycle Time. The result is an asymmetric distribution. To calculate the derivation of asymmetric distributions, the mean absolute derivation is a more robust method than the usage of the standard derivation.

The third and most important indicator of the key performance indicator system is the Cycle Time Stability. It is represented by the ratio of the mean absolute derivation and the Actual Adjusted Cycle Time.

All three performance indicators are shown as percentage values and the higher the value of a performance indicator is, the better the competence of the production line is.

## **4 A CASE STUDY OF THE PROCESS CONTROL KEY PERFORMANCE INDICATOR SYSTEM**

A large automotive electronic supplier owns different plants at different locations. In the following example, an electronic product is built at three different plants in Eastern Europe, in South America, and in Asia. A further product with the same production chain, the same components and the same size should be manufactured in one of these three locations. Therefore, the technical competence has to be compared.

Regarding to a system, which stores all production data of a product with the time stamps of entering and leaving a machine in the production line, the process control key performance indicator system is calculated. The data are compared over an observation time of six months.

In the Cycle Time Ratio comparison, location 1 shows the best mean Cycle Time Ratio, meaning that the machines are best used for production. Figure 3 shows the Adjusted Cycle Time Ratio and the Cycle Time Stability. If all production lines are productive, if no errors or absences of material or workers disturb the production lines, then production line 1 shows again the best results in the Adjusted Cycle Time Ratio. Locations 2 and 3 both produce on a lower level.

The third performance indicator shows again the highest value of location one. Here, the Cycle Time Stability is at a mean value of around 70% over these six months of observation period. This value shows that the achieved Adjusted Cycle Time was reached quite stable. The production at this location has a higher reproducibility of the cycle time and produces with a higher competence.

Locations 2 and 3 show equal results in the Adjusted Cycle Time Ratio, but very different results in the Cycle Time Stability. The explanation is that the production in location 2 is quite unstable. The cycle time derivation of every product at the bottleneck process is very high. So lots of small distortions occur in the production line.

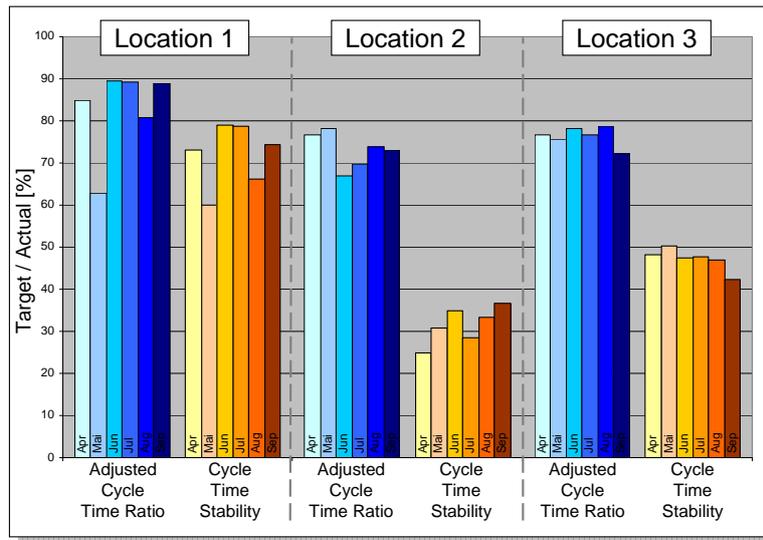


Figure 3: The Adjusted Cycle Time Ratio and the Cycle Time Stability of the three compared locations.

The recommendation for the requested question where to produce a next product volume can be derived out of a technical perspective. In this case, location 1 will be recommended because of the better usage of their existing production lines seen in the Cycle Time Ratio and in the Adjusted Cycle Time Ratio, but especially because of the highest Cycle Time Stability. This value is between 30% and 50% higher than at the other locations and shows that the mean Adjusted Cycle Time is much more often reached than at the other locations. A higher stability and reproducibility can be found at this location.

## 5 CONCLUSION

The three performance indicators of the process control key performance indicator system are able to compare the performance of production lines at different locations.

Many different parameters influence the process control of a production line, see Figure 4. The influence factors are manpower, machine, method, material and environment. The three indicators describe the sum of all influences on the process control of a production line. In the above described example, a lot of the compared parameters had an equal influence on all three locations. Since the production lines in all three examined locations are identical, the influence of the machine can be

taken out of the comparison. The used materials for the product, like the components, as well as the deployed method to run the line like the maintenance intervals are also identical. The only factor, which differs between the three production facilities, is the parameter 'manpower'. As a part of the parameter manpower the factors 'degree of education' or especially the factor 'fluctuation' have a big influence.

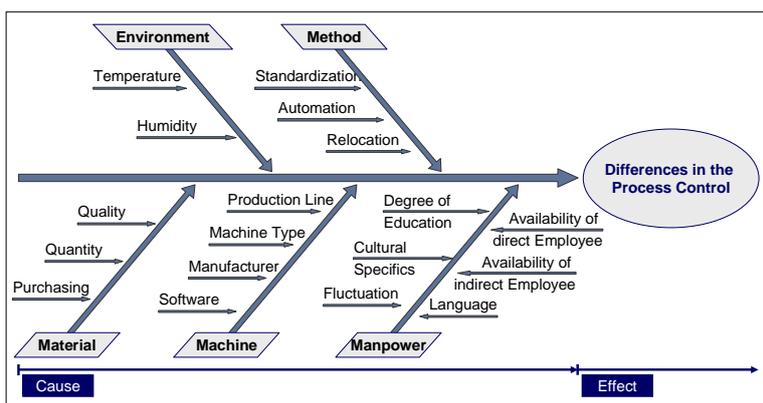


Figure 4: Parameters influencing the Process Control.

In the future, big companies with internal production networks can use this system to clarify, where to produce a production volume on a technical basis. With the key performance indicators explained in this article, the sum of all influences in the process control is described. A future work could be to analyze, how the influences are weighted to each other.

In addition, we will use this key performance indicator system not only to clarify, where to produce certain production volume in a tactical horizon. In short observation times, the process control indicator system can help. In daily observations, the stability of the cycle time can be measured and it can be analyzed why the stability may vary over a 24 hour base.

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