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## **Simulation based configuration of value stream oriented production control**

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## **1. Introduction**

The dilemma of production planning and control is to achieve high process efficiency, low throughput times and good planning confidence in spite of a turbulent environment with short product-lifecycles, an increasing variety and a growing individualization of demands [1].

Most companies have reacted by increasing internal flexibility and accelerating business processes. One common approach is to reduce inventory and work in process (WIP) to minimize queuing times. Due to the continuous reduction of safety buffers, both in terms of material stocks and throughput time, processes have become strongly coupled. As a result, any deviation from plan strikes through to subsequent process steps and causes immense instabilities. Consequently, the fulfillment of planned production schedules becomes more difficult in such environments and process transparency as basis for correct reactions to deviations is crucial.

To overcome this transparency problem more and more IT-tools are put into operation: Supply Chain Management (SCM) [2], Enterprise Resource Planning (ERP) and Manufacturing Execution Systems (MES) [3] are examples of the various means to keep the growing complexity under control. In particular, the growing penetration of Advanced Planning and Scheduling Systems (APS) shows that many companies see a necessity to improve their capability of mastering high dynamics in processes and demand. The basic idea of these systems is to use real-time feedback from production to continuously adapt the production schedule to any kind of turbulence [4].

Within the following paragraphs, the deficits of established methods of production planning and control will be discussed and a new perspective on production control, named "Simulation based configuration of value stream oriented production control" is presented. This new approach

thrives for an adaptive configuration of production control based on external and internal conditions.

## **2. Challenges in Production Control**

Quality and performance of production can be achieved either by highly stable and repeatable processes or by the capability of reacting to deviations in coherence to overall performance targets [5]. Planning and control activities are in their quintessence optimization problems of matching multiple order fulfillment with limited resource capacities [6] [7]. Therefore three main challenges of production control will be addressed: the Paradox of Choice, transparency about predictably irrational behavior and the shifting to a new target system of production control.

### ***2.1. The paradox of Choice***

Today's solutions in production planning and control are numerous. For most problems a large number of tools and methods following different philosophies are available in industrial environments [8]. These solutions are often promised to be holistic approaches, but only work stable under certain conditions which are not transparent to the user. Complex interdependencies have the effect to couple processes although they have statistical variations, so that decision makers are left with an insolvable amount of choices [9].

Due to the fact that most approaches tend to fulfill every control task and optimize the whole value chain as one segment, the adaption to internal and external changes is poor. Universal solutions pay for their generality with inefficiency in changing environments. The dynamics and market complexity call for more flexible and accelerated business processes [10]. Solutions that did fit on yesterday's demands are inadequate today. The only way to achieve process efficiency in those conditions is by following nature and increase the diversity of production control logic in the value stream, building an ecosystem of production control that can level internal and

external complexity. That again leads to more choices that need to be supported. The challenge is to master the complexity of production environment by making the next step towards a dedicated diversity of processes.

## ***2.2. Predictably Irrational Behavior in Production Control***

The second challenge is to increase transparency about the installed control logic and to extend an understanding why solutions have been installed. Regarding the configuration of production control in industry a number of predictably irrational decisions are made. These decisions are counterproductive to the tasks already fulfilled by the control logic and lead to a poor performance of logistic targets in production. The most common pitfalls leading to such a behavior are for example the wrong understanding of pull or push principles and controlling the production by installing a tact time.

The principles of push and pull have lead to many confusing definitions in the field of production management [11]. For production control the definition of Hopp and Spearman who separate between strategic and tactical pull is most useful: A pull production system is one that explicitly limits the amount of work in process that can be in the system. By default, this implies that a push production system is one that has no explicit limit on the amount of work in process that can be in the system.

The wrong understanding of tact time is a further pitfall which leads to a poor performance in production. In many cases tact time is understood as directly variable, so that it can be changed during the production process. But in fact tact time is a structural index that is inherent to the production system and the mixture of the production program. Tact time can be changed for example by changes of the production times in the work plan or changes of lot sizes.

Another common misunderstanding is the effect of smoothing resource capacities by using standard products when under-utilization occurs. This effect of production smoothing can only be implemented by the explicit release of an order right from the beginning, which is often not seen as an autonomous function in production control. This decision is made in many companies by the production foreman on the shop floor.

The challenge is to develop a framework of production control that avoids irrational configuration and that make inconsistency visible.

### ***2.3. The New Target System of Production Control***

The past years of production control have been dominated by constantly growing markets and an insufficient supply of production capacity in many industry sectors. In that environment inventory seemed not that important and industry focused on adherence to delivery dates and resource efficiency. This target system inhibited the improvement of logistic skills which can be seen in many companies who increased inventory even though sales decreased. Thus a new target system must focus on the plasticity of business processes rather than on the logistic targets itself. Change processes in production control need to become much faster in the future. The core problems in achieving this target are long throughput times caused by inventory and the missing ability of organizations to afford change processes in social systems.

### **3. Condition based Configuration of Production Control**

Condition based configuration of production control describes the approach to manage the need for plasticity of production induced by environmental changes and dynamics. The approach provides a systematic framework to support configuration decisions for production control and makes grown structures visible that cause inconsistent control functions.

The core idea of condition based configuration of production control is to balance the need of control functions induced by external factors with the skills of the organization and control system. The approach will be described in five steps:

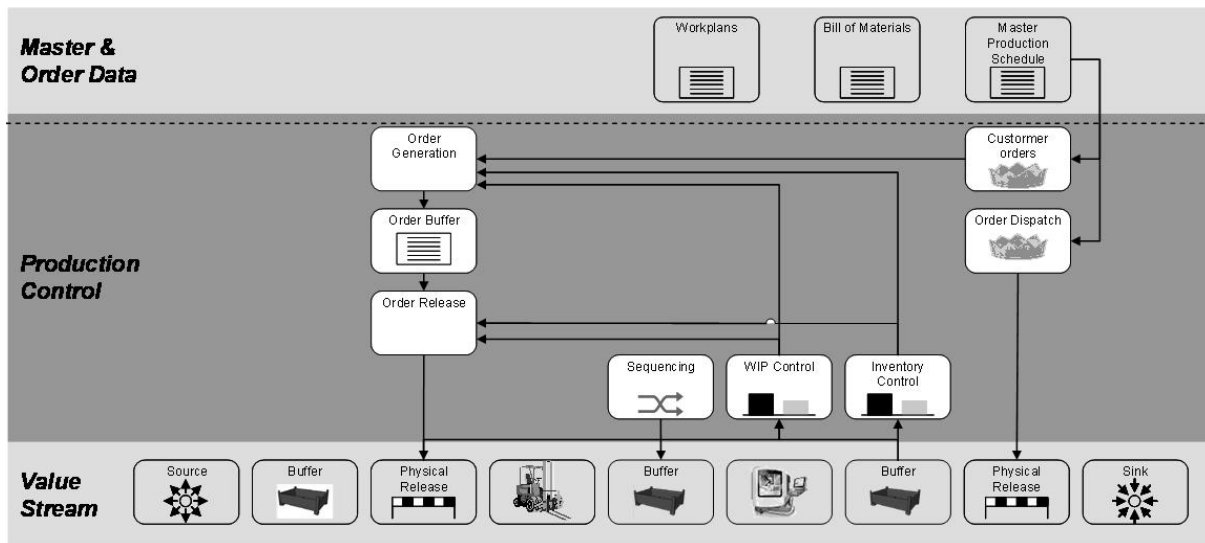
- The three layer model of production control
- Designing control segments of the value stream
- Monitoring Production via Key Performance Indicators (KPI's)
- Configuration of control tasks
- Simulation

### ***3.1. The three layer model of production control***

The basic framework for the condition based configuration of production control is a three layer model that starts with the value stream on the shop floor (see Figure 1). The value stream is the representation of the production process. The focus is to represent segments of equal production control configuration along the production process. The method of defining control segments is described in the following section. Even though in classical value stream mapping only single products can be visualized the different focus allows visualizing even complex job shop departments.

The production control layer describes the configuration of the production control and the information needed both from the master data and order data and from the shop floor. It gives a simplified visual pattern of the configuration of the production control, which can be described by the fulfillment of only four tasks. These tasks of production control will be described in detail later.

Manufacturing master data and order data are the input for all planning and control activities. They consist of work plans, bill of material and customer demands represented in a master production schedule. The third layer allows the link between changes in the configuration of production control or on the shop floor and changes in master data, as data inconsistencies are often the origin of many problems in production control.



**Figure 1.** Three layer structure of simulation model

### **3.2. Designing control segments of the value stream**

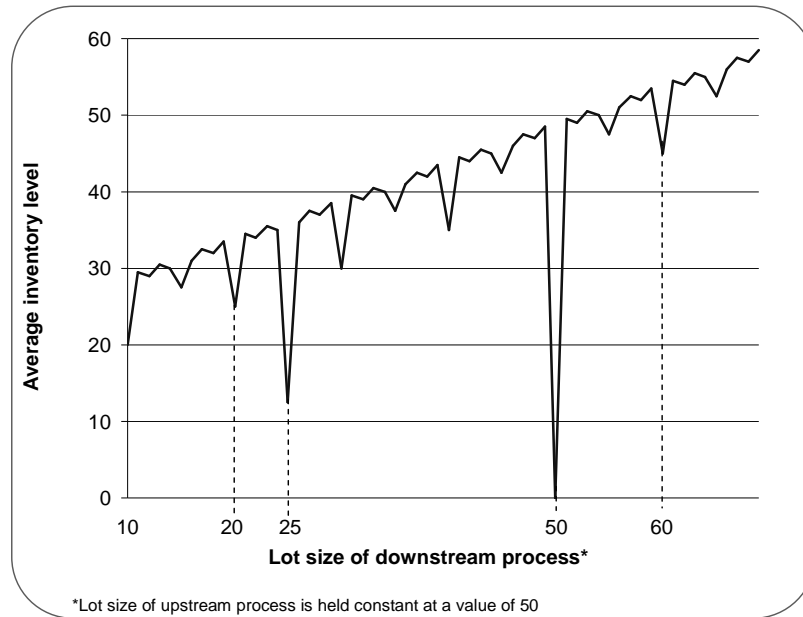
The first step in condition based configuration of production control is the design of control segments. The advantage of control segments is that the possible diversity of control patterns along the value stream can be increased. This leads to a reduction of complexity and therefore the paradox of choices can be reduced.

One reason for the problems with material requirement planning (MRP) is the generalized perspective of the value stream. Especially in upstream processes the missing planning accuracy of market demands combined with long replenishment lead times result in dispensable inventory

and increased manual rescheduling of activities. To meet these challenges the design of control segments is based on three main principles:

- Decoupling process variety by inventory
- Defining the customer penetration point
- Defining push and pull segments

Designing decoupled control segments is one of the fundamental principles of production control and the basis for configuration patterns that are able to meet the requirements induced by market changes. Decoupling processes means to install buffers, which provide a chronological autonomy. At the same time the main target for designing buffers has to be the minimization of inventory due to costs and throughput time. One tool for the condition based configuration of production control is the calculation of necessary inventory levels based on process stability, synchronization, demand and lot sizes of up and down stream processes. Based on the results inaccurate dispatching parameters can be adjusted. But even more important is the transparency about causes for inventory that can be used to determine measures to increase process stability and improve synchronization. Especially lot size changes are a major and underestimated reason for inventory levels. The synchronization level of up and down stream processes strongly dependent on the deviation of lot sizes. The effect of different lot sizes in sequent processes on the inventory level can be seen in Figure 2.



**Figure 2.** Average inventory level dependent on lot sizes

Very important for the configuration of control segments is the position of the customer penetration or customer decoupling point. Traditionally the customer penetration point is considered as being a static point in the value stream. This perception limits the possibility to develop the production system unnecessarily severe. The approach of condition based configuration of production control considers the order penetration point as movable within the production process. The target is to relocate the penetration point determined by the delivery lead time, the variant formation point and the throughput time.

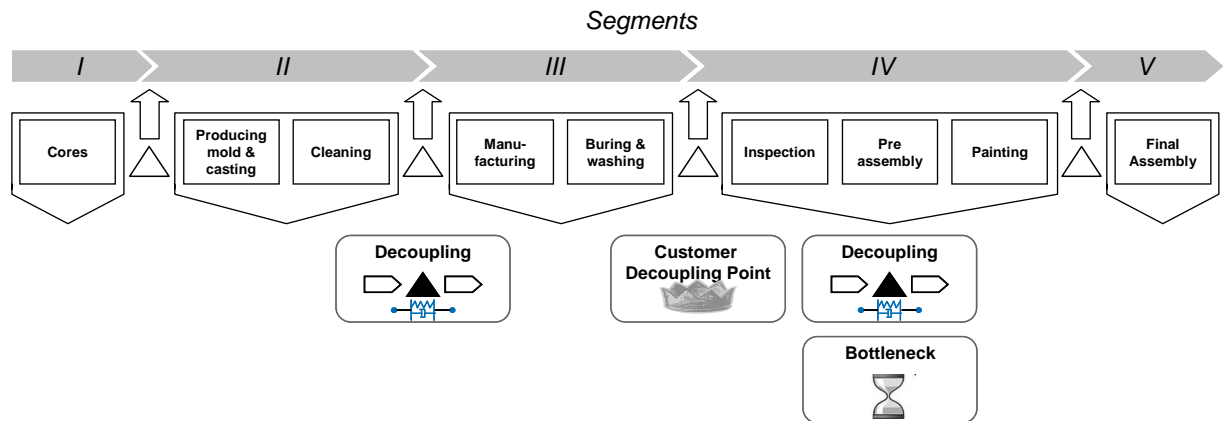
The customer penetration point has a major impact on the generation of orders. Upstream of the customer penetration point orders are generated without specific customer orders based on stock level or forecast. Downstream orders are generated by customer demands. This fundamental difference influences the configuration of control tasks. Frequent changes of the position are inevitable and require comprehensive skills of the organization.

The third aspect is the misleading use of definitions for pull systems in the context of production control. The concept of condition based configuration of production control follows Hopp and Spearman who define pull as explicit limitation of work in process [11]. The main question for the definition of push and pull control segments is: What are the determining conditions that require pull strategies?

In the same way as the customer penetration point determines the order generation the bottleneck of the value stream determines if a section needs to be pulled: Upstream of the bottleneck process pull systems are advised, downstream push systems are sufficient in most cases. An exception for this rule is if the control segments are massively decoupled from each other. In this case the influence of the bottleneck in the segment on the production performance becomes stronger and requires pull strategy, too.

Another important aspect is the assumption that pull strategies lead to continuous load of production resources. This assumption is not true. The fact that the work in process is limited does not mean that the workload is constant. In fact pull systems often lead to very fluctuating work load. If capacity limits are reached longer throughput times can result. This can be critical for the configuration of Kanban processes for example.

Figure 3 shows exemplified a segmented value stream after the former described criteria. This structure now allows to configure a dedicated production control concept for every segment and to prove via simulation that the interaction between the segments is able to fulfill the external requirements.



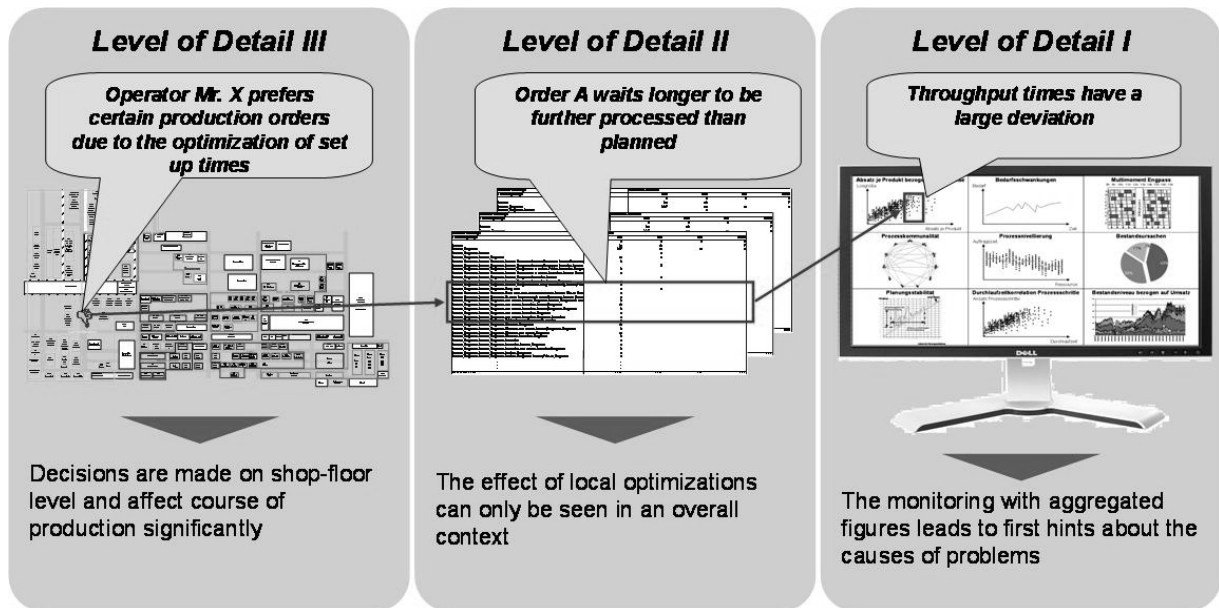
**Figure 3.** Control Segments

### **3.3. Monitoring Production via Key Performance Indicators**

Today activities on the shop floor are only predictable up to a certain level of accuracy. Planning and execution are therefore two conditions which have to be brought together. Characteristic numbers like key performance indicators (KPI's) are often used to monitor certain trends and give hints to problems. In production control the use of KPI's is quite poor. Although most shop floors have quite a complex structure due to manifold operational interconnections between many resources, a lot of decisions are made just by gut instinct or local optimization purposes. The effect of such decisions to the overall production process performance is not transparent.

Based on this a few key figures who represent the situation within the production system have to be defined. One example is the distribution of throughput times dependent on the number of operations or the lot sizes. Although this seems not to be entirely new, it has not been installed into a continuously running monitoring process so far. Via already implemented feedback systems like production data acquisition or machine data recording such information are generally available.

The challenge is to enable a fair according to the causes involved, if deviations occur. This requires the interpretation of less aggregated data to gain an understanding of cause-and-effect relations. Figure 4 shows an example of how this cascaded monitoring process is operated within the configuration of production control concept.



**Figure 4.** Cascade Monitoring process

Next to the throughput time eight other figures have been defined so far. Due to their level of aggregation and the complexity of the condition to be displayed, common visualization tools like Excel cannot be used. Using data interactively will be a major advantage and help to enhance the transparency in production control.

### **3.4. Configuration of control tasks**

The third step of the condition based configuration of production control is the configuration of control tasks in each segment. The configuration of control tasks follows the four functions of

production control defined by Lödding [12]: Order generation, order release, sequencing and capacity utilization control.

The order generation has got the main influence on the inventory level of the production. The main difference between the methods of order generation is whether they rise from customer order, forecasting or inventory changes. Methods of forecasting need to be handled with care because psychological effects on the one hand and missing transparency of parameters on the other hand can lead to major bullwhip effects in the value stream. Another important point is the determination of lot sizes at the order generation. The influence on inventory has been discussed before. Furthermore the variety of lot sizes has a big influence on the distribution of throughput times and thus on the ability to control production processes.

An industry case showed that the bisection of the lot sizes of only 5% of the biggest orders can result in a reduction of throughput times up to 20%. On the other hand the work load did only increase by 3% caused by additional setup times.

The importance of explicit order release is underestimated in industry. Thereby especially lean production principles like Kanban or Heijunka focus on order release. In principle order release does influence work in process and capacity utilization and does thus determine the average throughput time of orders.

It is remarkable that IT-Systems that support work in process levels in production are still very rare. Even though lean production philosophy and the OPT-Systems of Goldrath [13] try to control WIP these principles did hardly enter modern IT-Systems for production control. The main problem is that most manufacturing execution systems (MES) and advanced planning

systems (APS) core function is the prioritisation and sequencing of orders in front of the machines. At that level of control an active work in process control is not possible any more.

The sequencing of waiting queues has the main influence on the distribution of throughput times and thus the adherence of delivery dates. MES and APS systems focus on the sequencing of orders. Complex methods of sequencing become necessary if:

- the structure of the production process becomes more complex
- the variety of processes increases, caused by instable processes or a high variety of lot sizes
- the volatility of the market demand is very high.

The more stable and predictable the production and the less work in process the simpler the sequencing method can be. On the other hand it is possible to force stabilisation of production by using simple priority rules like FiFo (first-in-first-out) even in complex production environments.

Capacity utilization control has the main influence on productivity and production cost. The concepts of capacity utilization control focus on two directions. On the one hand the systematic expanding of bottlenecks, if they get to the capacity limit. On the other hand a systematic disconnection of automated production processes and manual production processes also known as Jidoka. This disconnection increases the flexibility of labour work.

### **3.5. The Simulation Model**

In production simulation models are used to predict the effect of certain changes in a system. According to the previously described three layer model the simulation has a similar structure which consists of the value stream, the production control logic and master and order data. The

new approach is that objects and control logic are separated from each other, so that different control concepts can be applied. This allows an easy configuration of the processes and the implementation of a control concept library.

#### **4. The Production Control Loop for Configuration**

Every element introduced before is important to realize a Condition based Configuration of Production Control. The three layer model together with the control segments are structuring the production modular and therefore enable selective changes of single elements. Building such a structure is essential to visualize and understand the initial situation, e.g. how the control tasks defined within the model are currently fulfilled. During operation the production is monitored via several KPI's. They indicate if the performance of the production system for example in terms of through-put time, commonality of processes etc. is sufficient enough or adaptations have to be made to improve the performance of production control. Based on these indicators the real causes for the performance losses have to be identified, so that adequate changes in terms of order generation, order release, sequencing or capacity utilization can be made.

During Configuration these four tasks of production control are configured for each segment. Configuration means that first a mechanism has to be chosen, which is able to fulfill the task. For example Kanban as a mechanism to generate and release orders by emptying a box. Additionally there are certain conditions taking into consideration under which such a mechanism works stable. For Kanban the variation in replacement time should not exceed a certain value. The last step in configuration is to parameterize the process, in case of Kanban the number of boxes and the box content. Before the configuration can be applied to the real production system it has to be tested and validated via simulation. Different scenarios will be applied to evaluate the production control configuration.

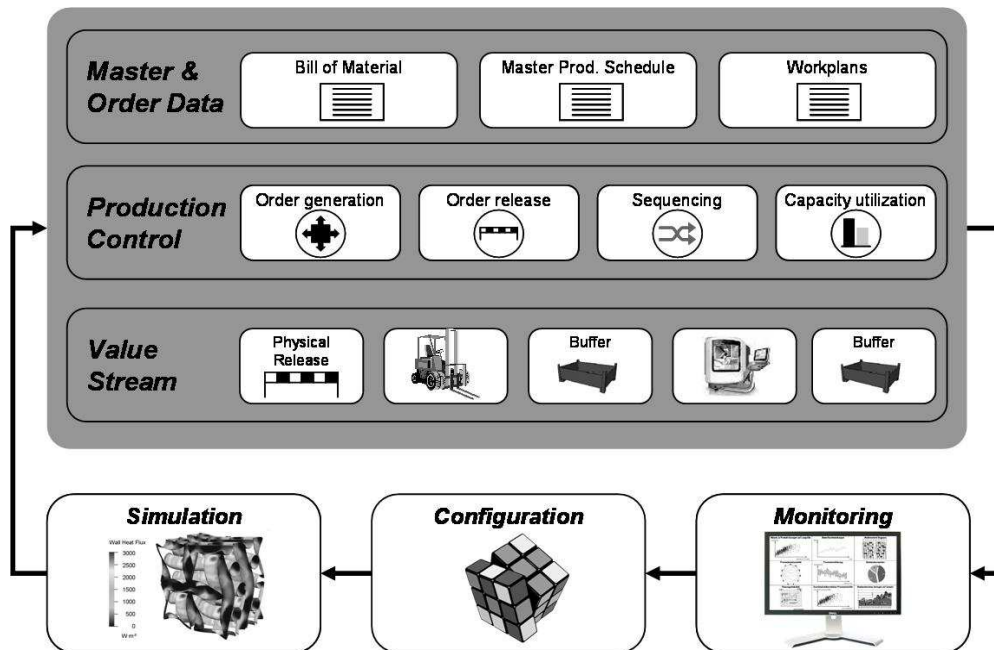


Figure 5. Production control loop of configuration

## 5. Case of Production Control Configuration

The application of the condition based configuration of production control in more than 10 industry cases in 2009 have shown the great potentials of the approach and has lead to unexpected new solutions combining known control principles in new ways. It has lead to drastically reduced inventory levels and throughput times in the companies. The transparency about control processes decreased the inhibition threshold of workers and management to initiate change processes in their production. Radical changes of the configuration of production control have been realised in only a few months. That shows that dedicated diversity of control segments can decrease the barriers for business process plasticity.

## 6. Acknowledgement

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