To Build a Bridge: What Significance Does Complexity Management Have for Production?

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Today's production systems are complex and difficult. The variety and the dynamics within the systems, as well as the sheer amount of design parameters are just barely manageable. Especially when the product spectrum is very broad and profound and the production facilities located globally, most known optimization approaches fall short. These approaches usually miss the integrated view from market to product to production, and thus neglect the complexity and dynamics of the system.

When examining production plants, normally a multitude of procedural and structural deficits can be found. The problems manifest themselves in long lead times, poor internal and external delivery performance, too much inventory, and unit production costs that are too high. The occurrence of those deficits varies by industry. To circumvent them, the automotive industry introduced so-called "production systems", which claim to perfect production including all elements without waste. The first example that comes to mind is the "Toyota Production System". Other global corporations have used the same ideas and implemented them to fit their systems (e.g. MercedesBenz, Ford, Siemens). The majority of companies in other industries, (such as machine tool manufacturing and pharmaceutical), are currently just in the beginning stages of implementing such programs. However, these approaches often fall short of anticipated results because the complexities and dynamics of the systems are not captured. This article describes a universal framework with focus on the significance that

Complexity Management has in the production environment, showing how existing lean-approaches can be expanded to make them actually work.

Today's Production Systems Are too Complex

The cause for these symptoms lies often with the unmanageable complexity of a production system. The complexity is triggered by the variety, individualization, and market volatility where the products are offered. Furthermore, production systems rely on sub-systems that are hierarchically structured (Fig. 1). The production contains a variety of elements that are dependent and influence each other. Therefore, constant change is common within the production system. On the top level, a production system is described by its network and its (allocated) value creation. On the lowest level of the hierarchy are the single work places.

The configuration and mastery of the variety of different elements and their relationship require a holistic and system-oriented design approach within production environments. The advantages of a system approach comprise the description of sub-systems that reduce the complexity of the whole production without neglecting the interrelations between the different system elements. Schuh & Company utilizes the system theory of the St. Gallen Management Concept (Fig. 2), promoting a purposeful distinction between the normative, strategic, and

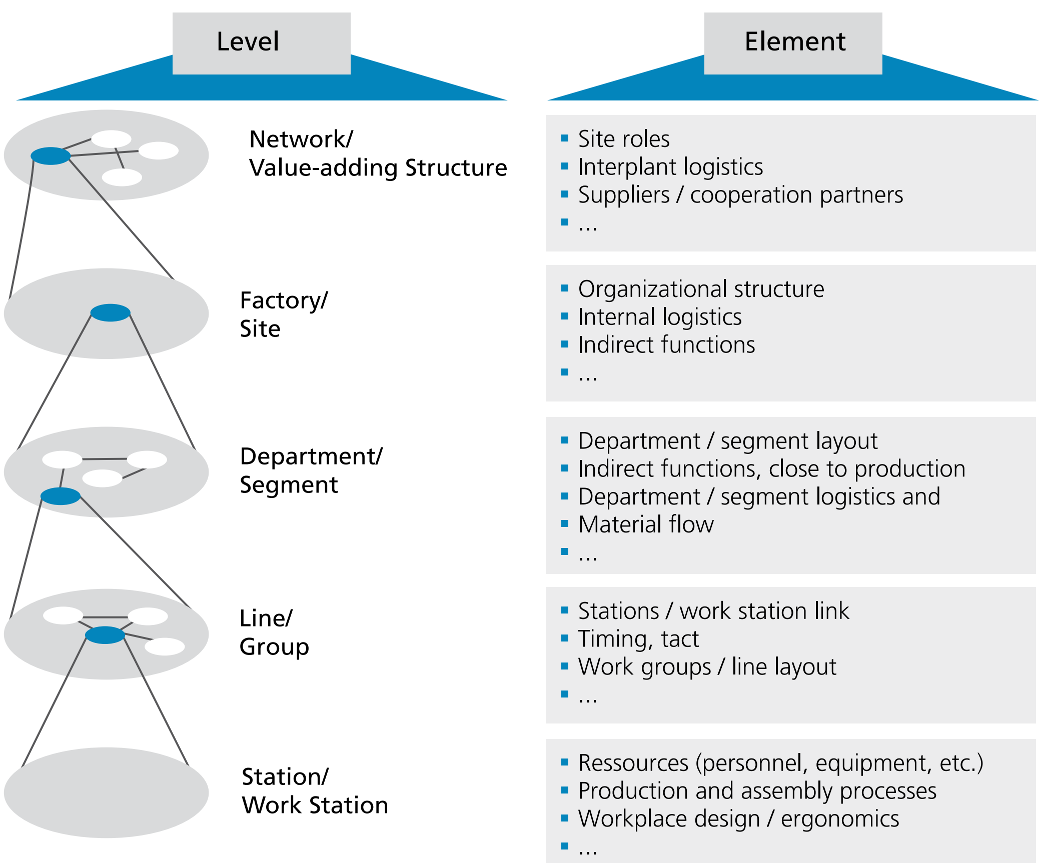

Figure 1: Different Levels Describe the Production

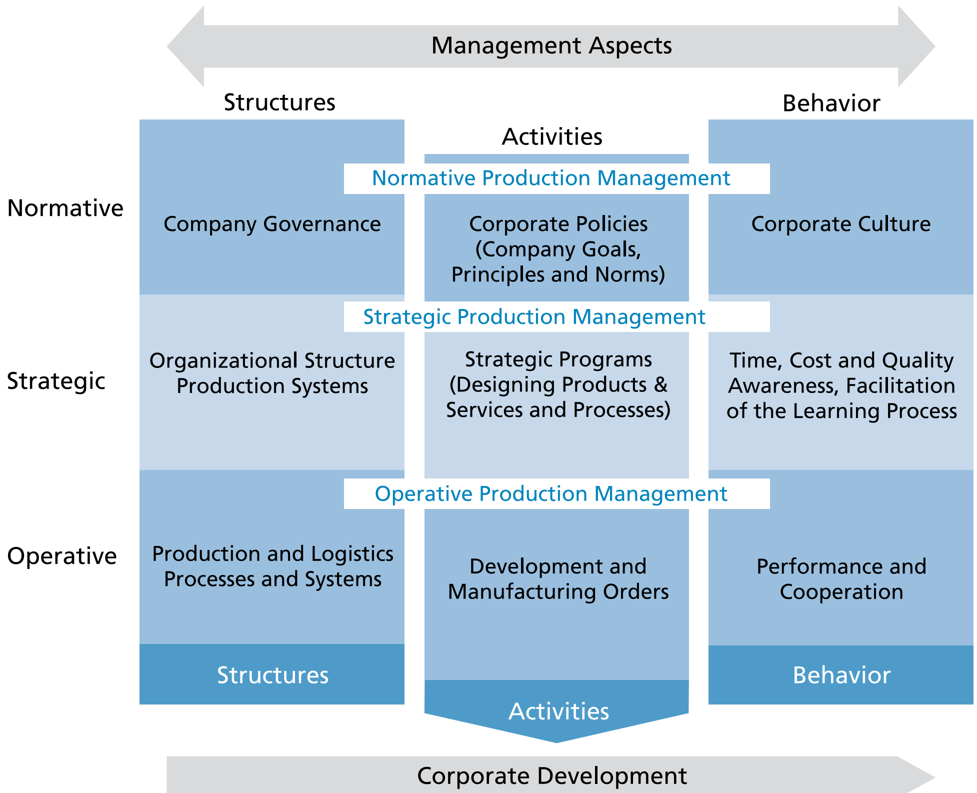

Figure 2: Production Management with the St. Gallen Management Concept

operative levels. The levels themselves are composed of activity, structural, and behavioral aspects, which allow for a comprehensive observation of the production environment.

Based on our project work experience, three problem areas can be deduced within production environments from a Complexity Management point of view:

1. Variety within the production system

- Product diversity: Heterogeneity of the products and their variants
- Process variability: Variances in the configuration of value-adding processes locally or between sites
- Resource diversity: Heterogeneity of resource demands with restrictions on resource allocation

2. Dynamics of the production system

- Variant flexibility: Reduction of product life-cycles and changing customer requirements
- Volume flexibility: Fluctuation in demand and decreasing order lot size

3. Instability of the production system

- Demand / Orders: Type and amount of orders
- System behavior: Susceptibility to interference of processes and resources

Variety-Induced Costs Increase

In industrial applications, the above described problem areas have an enormous influence on the production cost of manufacturing companies. Because of the product variance, augmented tool costs and an increased effort in logistics and planning occur. The process variance and the global allocation of value creation processes drive transportation, control, and re-work costs in particular. A variable resource demand leads to fluctuating capacity utilization, and this in turn leads to either high idle and/or down times, or to the utilization of additional cost intensive resources to adjust for peak loads. The increased need for flexibility manifests itself in increasing equipment and changeover costs. Uncertainty in the system primarily increases malfunctions, for example control problems, material supply problems, accidents, and emergency stops.

Even if the described interrelations are well known, we often observe in our consulting projects that, depending on the industry, the implemented product design is ineffective. The complexity is simply dismissed. Despite simultaneous engineering efforts, the design is poorly adapted for production. The continuity and the holistic examination of the market-product-production relationship from a Complexity Management point of view is often incomplete and consequently, the implementation ends prematurely. Production departments therefore try to face the (product) circumstances with technical, organizational, and ergonomic approaches from the large selection of lean methods (e.g. local performance increases, part specific batch size planning, isolated activity analysis). The knowledge of complexity-oriented approaches diverges by industry. Companies in the automotive industry currently rely on principals such as modularization of products through production segmentation, shifting the variant creation towards the end of the process, and the optimization of vertical integration through module allocation.

To Build a Bridge: Two Starting Points – One Approach

The approach that describes the context of existing insights as well as precise solutions for the complexity-suitable production design, encompasses four basic elements (Fig. 3).

A) Production Strategy. The main task of the production strategy is the establishment, utilization, and maintenance of strategic success positions. The task is implemented through product and business processes. The main focal point lies on shaping the production program and determining the depth, as well as the breadth of value creation within the production network ("Global Footprint"). With regards to the depth of value creation,

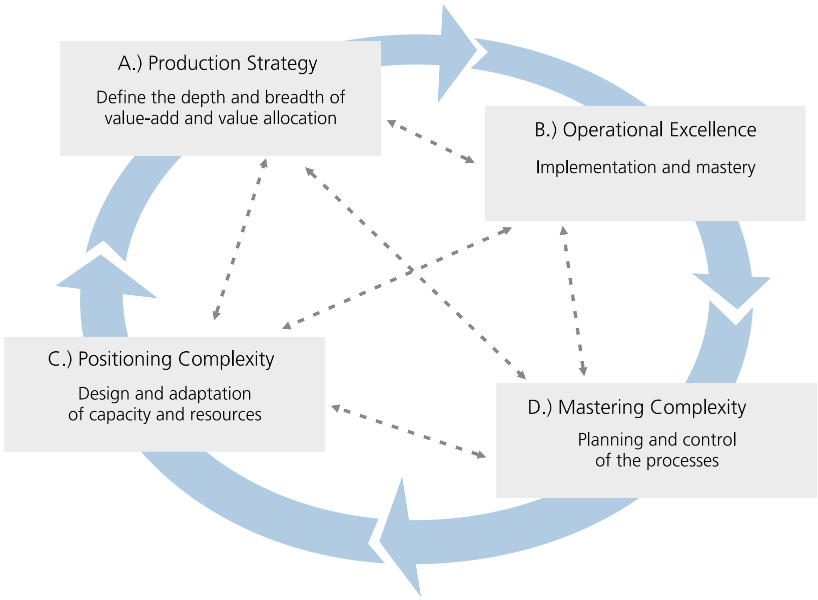

Figure 3: Measures for Complexity-Suitable Production Design

decisions about the conflicting demands of expansion and reduction have to be made, while for the depth the conflict between differentiation and standardization of pre-, semi-finished and end product has to be solved. After all, the allocation of value creation determines the role of single sites and plants.

The efficiency, with which the given production complexity can be regulated and mastered against the background of system dynamics and unpredictable instability, arises from the interaction between capacity and resource design as well as the planning and regulation of the processes.

B) Operational Excellence. The foundation of the production design with optimal complexity is built on the core elements of Lean Management, which Schuh & Company together with the Lean Enterprise Insitut communicates and applies. The pharmaceutical industry for example uses the reference model of "Operational Excellence" to optimize production (Fig. 4). The model was utilized within the scope of the largest study on the topic of Operational Excellence in the Pharmaceutical Industry. 110 companies participated and currently a succeeding study with approximately 160 participating companies is in progress. It analyzes and evaluates the implementation after the introduction of operational excellence initiatives.

C) Positioning Complexity. Designing capacity and positioning means to separate the existing process variety into volume, type, and process order. This takes place with the parallelization of processes into (partly) redundant resource groups, workload balancing, division of labor as well as the decoupling of processes.

To design and adjust the resources means to decrease the resource cost rate and the disproportionate increase

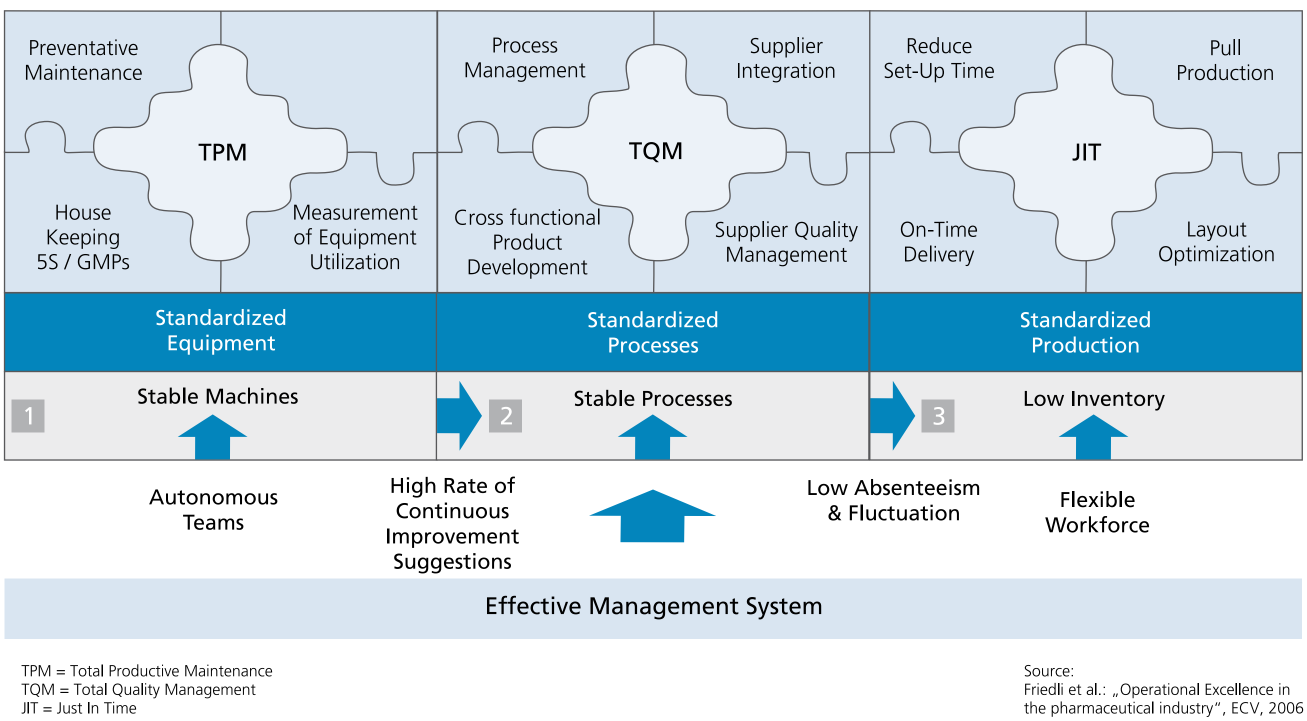

Figure 4: Operational Excellence for the Pharmaceutical Industry

of the resource consumption compared to the process diversity. This can be achieved through the transition to flexible work force models, which allow for a need-driven approach of capacity. Alternatively, it is realized through the adjustment of the degree of automation, technology, and complexity of the utilized equipment (including tools and installations). Production structure matrices, for example, can aid the mapping of production variance onto the process variance.

D) Mastering Complexity. Mastering complexity of (varying) processes is coordinated via planning and control mechanisms within structurally specified degrees of freedom. Today's ERP systems and simulation application cannot depict the complexity and dynamics within the system despite enormous computing power. Planning against limited capacities is still foreign to many applications. Furthermore, adjustments of the planning parameters in the system on a short notice are nearly impossible. In this case, the production system has to be temporarily disabled and the approved orders can then be manually steered through the production.

Thus, future systems and controlling processes have to be extremely adaptable to be compliant with dynamic constraints. This encompasses capacity orientation including robust, simple, and quickly implemented controlling systems, which enable the adaptability of the value creation structure.

In principle, the three dimensions order classification, sequencing, and material and information provisioning are differentiated when discussing complexity management. The classification of orders and resources provides an optimization question within the boundaries of redundancy of a volume and variety intense production system. Within controlling, the degrees of freedom created through redundancy have to be used in order to make favorable order sequencing possible. This is usually the case when the variety of capacity requirements is minimized. From a complexity standpoint, especially the sequencing of manufacturing varying products is decisive, because the combination of variant groups and the variation of tact time has to be planned and regulated.

Implementation and Recommended Actions

We apply the described design and solution approaches within our consulting projects through the typical phases of analysis, evaluation, measure definition, and implementation. Process variants induced by the market and product lead us to focus on production capacity, production resources, as well as planning and control methods.

Based on our experience the following recommended actions for production design along optimal complexity arise:

1. Your production has to be strategically linked to the company's objectives and structure

2. Clearly define the core competence of your production, plants, and sites

3. Organize your entire value creation structure towards future demands of flexibility

4. Consider the continuity of market-product-production for your production design

5. Strengthen simultaneous engineering teams during product development

6. Consider the influence of complexity in terms of variety and dynamics on all levels of your production system and reduce your tolerance for process variance.

7. Focus your production on an easily implemented operational excellence initiative including all basic elements of Lean Management.

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