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Resilience of productions systems by adapting temporal or spatial organization

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Abstract

Turbulent changes of the production program regarding the variation of the number and type of products challenges the suitability of the operating point of the production system. This can result in a lack of efficiency and productivity of a formerly mature configuration of a production system. In this case, the logistic positioning in terms of a proper operating point becomes obsolete. Therefore, a periodic monitoring of the system configuration is necessary to ensure a resilient production. This refers to an adaption of both the temporal and spatial structure of the production system. To cope with those challenges, this paper introduces an approach which evaluates strategies in terms of adjusting the system configuration. In this context, measures regarding capacity alignment and adaption are taken into account. On the one hand, this refers to control strategies influencing the temporal organization and thus the system´s behavior. On the other hand, also a variation of the spatial organization in terms of the layout of the production system (system structure) is considered in order to detect the ideal operating point of the system. For this purpose, the characteristic curves of relevant parameters are scaled to the point that a comparison of different system configurations is enabled. After the explanation of the detailed approach, the application is shown using several use cases. For different production systems effects of a changed production program on the system configuration and its resilience is explained and adequate measures for adapting the temporal or spatial structure are evaluated. Finally, the suitability of taken strategies is verified in terms of the identification of new ideal operating points.

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Keywords: Temporal structure; Spatial structure; Operating point; Production system configuration; Resilience; Structural quality

1. INTRODUCTION

The production industry – mainly due to the globalization of sales and purchase markets – is faced with new kinds of general conditions, resulting in decreasing quantities of similar products and, at the same time, increasing numbers of customer-specific variations.

A clear change is noticeable, from multi-variant large-scale production towards customer-specific batch production, which comes as a result of this very individualization of the customers' demands.

This often leads to short-cycle adjustments within the factory and production structure, since mastering these types of production largely depends on the implemented system structure.

As for the operating routine, there is no objectively measurable parameter to verify the appropriateness of the installed system structure: The Structural Quality, the development of which is currently undertaken by several research activities at the Otto von Guericke University in Magdeburg.

2. SCIENTIFIC BACKGROUND

The systemic approach is a very reliable method when it comes to addressing complex issues concerning the setup and procedure of productions.

According to system-theoretical definitions, a system is an area of objective reality distinguished by certain aspects. It is regarded as

- an entity of elements,
- the interrelations existing between these elements and
- the respective characteristics of these very elements and interrelations.

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Based on the production-technical approach under focus here, a factory can be defined as a production site providing an efficient manufacturing of goods. Production in this context is the system itself as the location where the actual manufacturing takes place [1].

In principle, production systems are sociotechnical systems, since during the manufacturing process the elements of the technical subsystem (machines and plants) together with the elements of the social subsystem (people) enable the internal production process (from material input over material transformation up to material output) [2]. In order to simplify the structural approach for these kinds of production systems, the subcomponents of the technical and social system will be regarded as the smallest system units in form of work systems in the following [3].

As a matter of fact, production systems exist – as any field of known matter – in space and time and are classified; thus, they do possess a structure (Figure 1) in terms of a certain organization of the system (System Configuration).

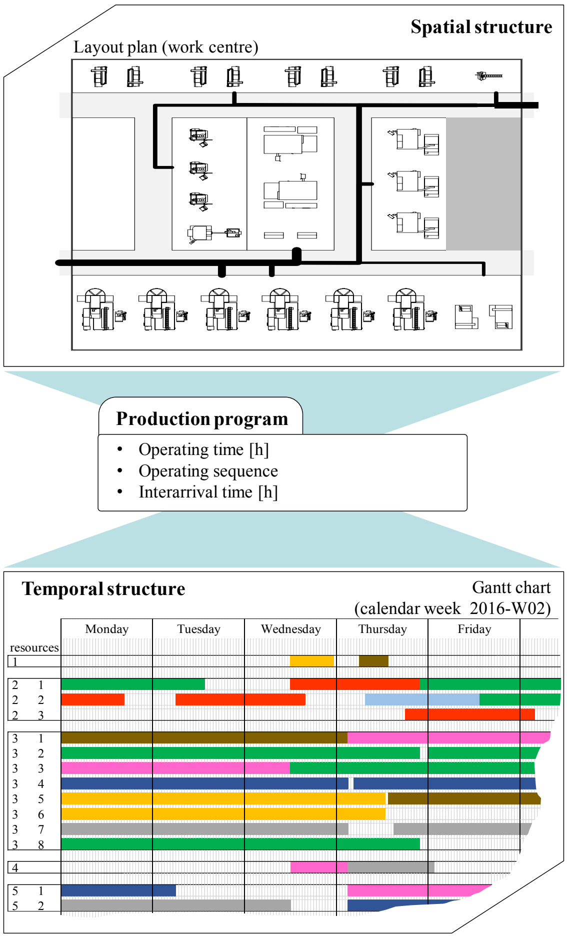

Fig. 1. Spatial and Temporal Structure.

Based on the system-specific type and number of system elements (the so-called System Composition), a structure describes the basic order of a system (the so-called System Setup) depending on the existing system interrelations. As a result, it determines the function of the system (the so-called System Behavior).

The System Setup is, therefore, determined by the existing System Composition, i.e. the type and number of all system elements, depending on the type, orientation and intensity of the system-inherent, physical interrelations between the system elements. This preferably economical arrangement of system elements for implementing the processing sequences (transformation process) is called Spatial Structure [4].

The System Behavior is characterized by the type, number and order of any kinds of processes that might be implemented through the functional linking of the system elements (processing sequences). The chronological structuring of the processes into segments and their timely interaction is called Temporal Structure [1].

In the context of manufacturing and assembly systems, resilience is the ability of the system to cope with changes of all sorts [5]. This concept refers to the System Behavior and the System Setup in terms of both, rapidly and flexibly re-configuring the operating states of a production system or enduring to changes due to the preservation of a stable system configuration [6]. In particular, the property called robustness that allows a system to maintain its functions despite external and internal perturbations [7], is important due to an adequate response to turbulent market and customer changes.

Analytical approaches for checking or evaluating an installed system structure are contrasted by design approaches to pre-determine flexible system structures in the context of factory and production structure planning. Deficits in such structure configurations are mainly provoked by the mostly one-sided observation of the spatial aspects of structuring (before Start-of-production – SOP), since the temporal component will usually only be determined by the time sequence of the production processes (after the real SOP) [8, 9]. Only the temporal dependency of type, number, linking and arrangement of the system elements is considered with the help of dynamic structuring approaches [10].

A fact often ignored is that, besides the arrangement of the system elements, it is also the manner of their interactions which defines an entire system structure. Therefore, an evaluation of the structure's appropriateness is necessary which considers both the spatial and the temporal aspects of production structures.

3. MODEL FOR STRUCTURAL EVALUATION

Following the previous remarks, the evaluation of the Structural Quality should be based on the System Setup as well as the System Behavior.