

Production Structure Monitoring - A Neurologic Based Approach

G. Reinhart, J. Pohl

Abstract—Manufacturing companies are facing a broad variety of challenges caused by a dynamic production environment. To succeed in such an environment, it is crucial to minimize the loss of time required to trigger the adaptation process of a company's production structures. This paper presents an approach for the continuous monitoring of production structures by neurologic principles. It enhances classical monitoring concepts, which are principally focused on reactive strategies, and enables companies to act proactively. Thereby, strategic aspects regarding the harmonization of certain life cycles are integrated into the decision making process for triggering the reconfiguration process of the production structure.

Keywords—Continuous Factory Planning, Production Structure, Production Management.

I. INTRODUCTION

DURING the past decades manufacturing companies have faced a unstable production environment. Due to several dynamic factors, such as rising customer requirements, changing market demands and the trend towards product individualization, companies have had to adjust their organizational structure as well as their production processes and product portfolios continuously to stay competitive [1], [2]. Such adjustments mostly have had a great impact on the performance of production, therefore it is essential to reconfigure the production structure constantly [2].

Companies have to provide a certain level of agility to respond timely to required changes [3], [4]. Due to immense emerging costs for perpetually planning, changes have to be identified before planning the adaptation process [5]. Therefore, suitable methodologies are crucial in enabling manufacturing companies to detect the need for reconfigurations [6]. Thus, it is important to focus on the current situation and on future trends. Life cycle models, for example, provide the necessary information and help to estimate future trends [7].

Monitoring systems, which measure progress figures toward target objectives, are a potential approach for tackling

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such issues [5]. But traditional concepts are mainly based on financial operating figures consequently limited in their reactivity and not suitable for today's turbulent environment [8]. Furthermore, the existing approaches do not take strategic aspects regarding production structure into account [9]. [5] and [10] developed methodologies, which are focusing on changes and trends of operational figures, such as production volume and delivery reliability, to forecast the need for adaptation. They also assume that certain incidents, i.e. product releases or new resources, always trigger a reconfiguration process. [8] extends the indicator system by trend forms to detect small deviations within the social, political and technological environment.

All these approaches have a reactive character. Small deviations of the factors trigger an adaptation process of the production structure. These existing monitoring systems aim to minimize the time lag for reconfigurations, which, as depicted in Fig. 1, emerges from the difference between the available adaptation time due to increasing dynamics and the required adaptation time due to increasing complexity. Due to the complexity companies face a loss of time when they adapt their production structure to new requirements. This time loss is made up of the cognition time, response time and the time to take effect [11]. Each of these three time stages offer a certain potential for tackling the time lag. This paper presents a monitoring methodology that enables companies to act proactively to minimize cognition time and provides the basis for future strategic decisions regarding the reconfiguration of the production structure.

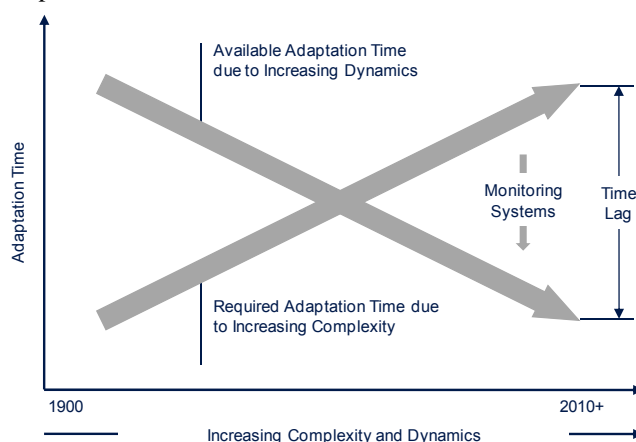


Fig. 1 Time Lag according to [12]

In this paper, classic approaches are therefore combined

with a simulation model and forecasting tools, which are a further part of a monitoring concept that operates analogous to neurologic procedures.

II. MONITORING CONCEPT

The receptor model is a key element of the monitoring system. This model is based on an analogy in the field of neurology, which describes a receptor as a reception and ingestion feature of an organism for specific stimuli [13]. Transferred to the monitoring system, this comparison makes it easier to describe impacts on the production system caused by various internal and external influencing factors, which are illustrated in Fig. 2.



Fig. 2 External and Internal Influencing Factors [7]

The receptor model postulates that several changes due to these factors are reflected in an alteration of at least one receptor. The receptors are defined as output, product, technology, cost, time, and quality [14], [15]. In using the receptor model for the monitoring process, it was hypothesized that several triggering factors for reconfiguration processes can be allocated to at least one of the receptors. Hence, the receptors can be defined as the triggers for adaptations of the production structure. The following list shows the transfer to the receptor model:

- Increasing or decreasing production volumes (Output)
- New products or changed product properties (Product)
- Integration of new manufacturing technologies or production resources (Technology)
- Lead time reduction (Time)
- Cost cutting (Cost)
- Increasing or decreasing quality requirements (Quality)

The hypothesis was proved through interviews and surveys with experts from several industries regarding the triggers for reconfiguration processes of the production structure. Another result of the interviews and surveys was a ranking of the receptors according to their frequency of triggering an

adaptation. Therein, as illustrated in Fig. 3, the product was clearly ranked first, followed by output and costs. Technology was listed in the fourth position. Quality and time were not regarded as such key factors like the other ones.

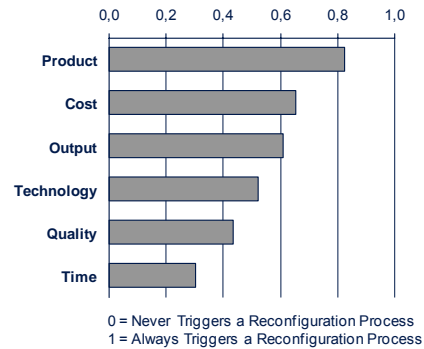


Fig. 3 Receptors Listed Regarding their Frequency of Triggering a Reconfiguration Process

As in the field of neurology, external as well as internal impulses can trigger reconfigurations. Therefore, the monitoring has to distinguish between exteroceptive and interoceptive triggers. Exteroception is about the ingestion of external stimuli and interoception describes the perception of internal stimuli [16]. Hence, the triggers differ in their local and temporal attributes, as shown in Table 1. Furthermore, the triggers are also related to the receptors. The local attributes describe the interface at which the adaptation trigger occurs and the temporal ones specify the point of time a factor initiates a reconfiguration. Thereby, several implementations, changes and eliminations of products, production technologies and resources are allocated to the exteroceptive triggers. Strategic decisions to gain competitive advantage, such as spontaneous adjustments regarding lead time, costs, quality or output for example, are also allocated to the exteroceptive triggers. A change or elimination of a product, production technology or resource is not listed as independent trigger because output is strongly connected to the product itself and strategic decisions are always connected to an implementation, change or elimination of a product.

TABLE I ATTRIBUTES OF EXTEROCEPTIVE AND INTEROCEPTIVE ADAPTATION TRIGGERS

	Adaptation Triggers	Local Attribute	Temporal Attribute
Exteroceptive	<ul style="list-style-type: none"> • Product Launch • Product Change • Product Elimination • Technology Implementation • Technology Change • Technology Elimination • Cut of Lead Time (spontaneous) • Cut of Process Costs (spontaneous) • Quality Adjustments (spontaneous) • Output Adjustments (spontaneous) 	Interface external – internal Environment Company	before/after Order Execution Process
	<ul style="list-style-type: none"> • Exceedance of Lead Time Limits • Exceedance of Process Cost Limits • Undercut of Quality Limits 	Interface internal – internal Environment Company	During Order Execution Process

Interoceptive triggers are the exceeding of lead time and

costs as well as the undercutting of quality limits. Thereby, the first two factors are ascribed to output fluctuations. On the one hand, the increase of units can lead to problems within the production capacity and the adherence to lead times, on the other hand, decreasing output results in financial problems. The undercutting of quality limits arises for example from the abrasion of resources.

To ensure a holistic monitoring system, the time frame of the monitoring is divided into reactive and proactive fields of observation, as depicted in Fig. 4. The reactive field of observation, which is tackled by traditional systems, addresses the actual production performance. Therefore, in this paper, a performance measurement system is used to control the production and to initiate reconfigurations of the production structure. Operational figures, such as lead time, failure rate or capacity utilization, are used to identify the need for change.

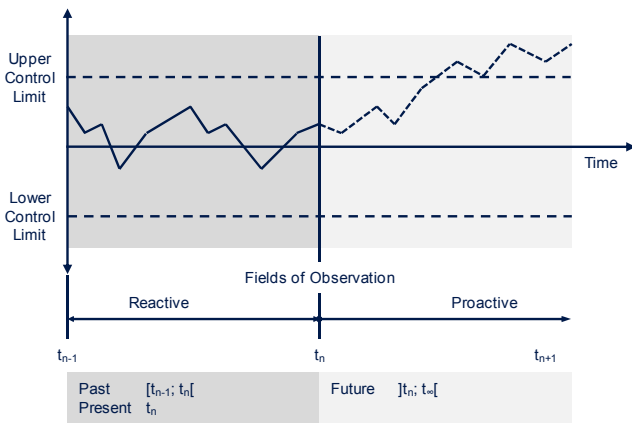


Fig. 4 Reactive and Proactive Fields of Observation

To eliminate the time loss for future adaptations, it is necessary to monitor future developments of the influencing factors that trigger the reconfiguration process. Therefore, the developed monitoring system for the proactive field of observation takes the changes of receptors into account, which are the factors causing an adaptation. Future developments of the receptors, i.e. the product portfolio and its sales volume or possible development levels of technologies, are forecasted to build future scenarios. These scenarios are used for predicting the robustness of production structure. This robustness check is done by a simulation model, which is predicated on a production structure model that maps several elements and their relations. This production structure model is described in the following paragraph.

III. PRODUCTION STRUCTURE MODEL

For the monitoring concept to succeed, it is essential to map the production structure as close to reality. On the one hand the model is used to describe the current design and to define the locations for gathering the actual and future performance data. On the other hand it provides the basis for the simulation model, which is needed for the monitoring within the proactive field of observation. Therefore, structural, functional

and hierarchical concepts based on system theory are used to describe the production structure [17].

The structural concept specifies the components of the production structure and their relations. Therefore, it is divided into four different layers (resource, workforce, infrastructure, process). Each layer contains certain information about components and relations of the production structure. After linking the layers to each other the whole structure can be holistically described. The functional concept describes the function of the system by using a black box connected to input and output parameters, such as information and product data for example. The hierarchical concept displays the structure of the system and enables the monitoring concept to select the right level of detail according to the task.

These concepts are realized by using production structure cells as the basic module of the model, as shown in Fig. 5. These cells contain the master data used for the functional and structural description, such as the amount and type of resources. They are also used for gathering performance data for the monitoring process itself and the development of life cycle models, which are part of the decision process described in the next paragraph. Furthermore, the cells offer the possibility to link themselves to one another to provide the possibility of scaling the monitoring process from one cell up to a whole department.

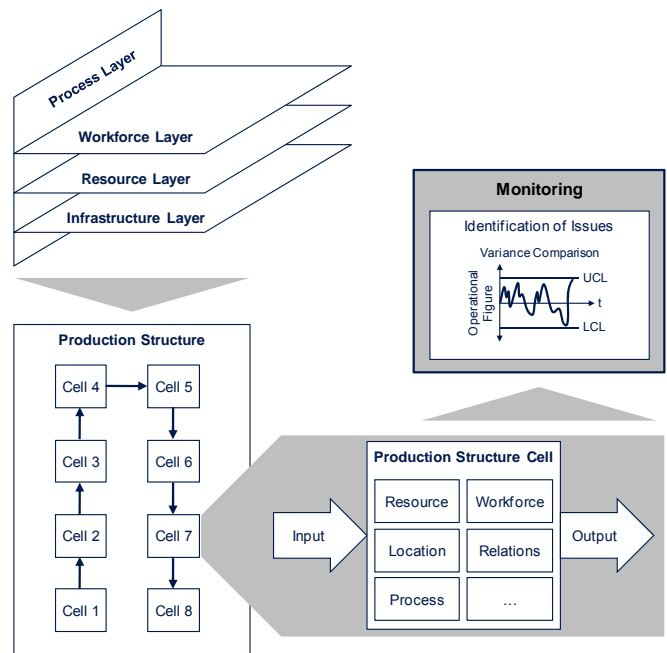


Fig. 5 Description of the Production Structure

IV. DECISION PROCESS

To provide a holistic and sustainable database for strategic decisions, it is essential that short-, mid- and long-term changes of input data be considered. The simulation allows to identify the lack of capability of the production structure to fit future requirements and to roughly constitute the planning

horizon of the adaptation process. However, variances of the performance data, caused by the turbulent development of the environment, are not the only factors for setting up the planning process. Additionally, the different occurrences of life cycles of products, technologies and resources have to be considered. These are the three strategic key elements for the production structure design process. Thereby, companies have to focus on the potential for maintaining competitiveness arising from the harmonization of these cycles, such as the implementation of a new technology at the right time. The biggest challenge for companies within the synchronization process, are the different characteristics of the occurring cycles, which increase complexity tremendously [7].

To support strategic planning, the concept presented in this paper uses life cycle models to provide additional information. Life cycle models visualize the time-reference of incidents and help to identify characteristic phases, such as the introduction, growth or maturity phase of the product life cycle. The allocation to a certain phase can be created by the development of relevant parameters, such as costs, revenue or output for example [18]. Life cycle models are derived from the finite lifetime and endurance of objects and originate from biologically observable processes and phenomena, such as the alteration of plants [19]. The models presume that situations are changing continuously [20].

By analyzing current life cycles of products, technologies and resources regarding their current stages and future developments, a manufacturer can gain competitive advantages [7]. Therefore, it is important that companies have knowledge about the occurrences of the life cycles and the possibilities of influencing them in a strategic way.

V. INTEGRATION INTO THE MONITORING CONCEPT

Fig. 6 shows how the decision process is integrated into the monitoring concept. Thereby the system is divided into the "performance measurement" and the "analysis and decision" element, which are both supported by the "forecasting toolbox".

The real production structure provides the actual performance data and the master data for modelling the digital structure model. It further maps the data for defining the phase of the production resource's life cycles. The digital model is used for simulating future scenarios. The forecasting toolbox predicts the future development of the receptors. These forecasts are converted into production data, which are the input data for the simulation model. The real and the digital production structure is the basis for performance measurement and variance comparison. The life cycle models for products and production technologies are also generated within the forecasting toolbox.

Finally the point of time for triggering the adaptation process gets concretized. Therefore, the information about actual and future variances of key performance indicators as well as the knowledge about the development of the product portfolio, the technologies and the production resources get

processed within the analysis and decision process.

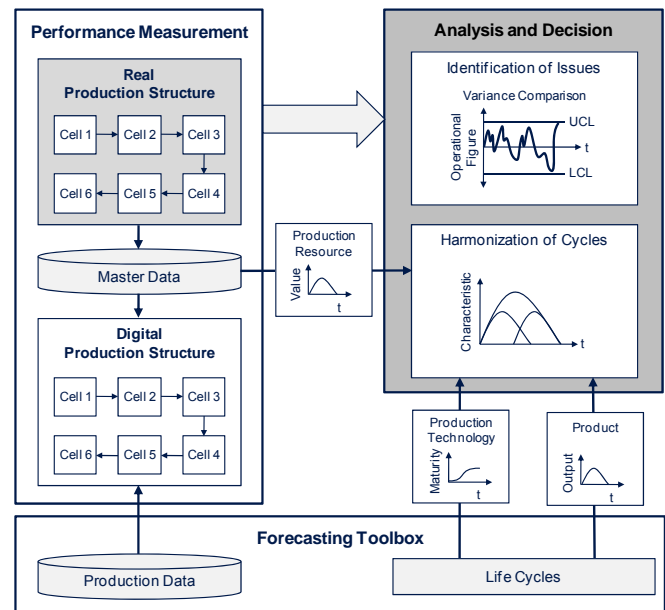


Fig. 6 Elements of the monitoring concept

VI. EMBEDDING INTO THE COMPANY

The embedding of the concept into the company also follows the neurology analogy and enhances the receptor model concepts of [14], [15] and [21]. The monitoring concept presented in this paper also compares the company with an organism and allocates organs to several departments and the processes conducted by them, as depicted in Fig. 6. Furthermore, receptors are flanged on these organs to gather intra-company data, especially in the departments for accounting and technical processing of orders. Receptors are also used to observe customer's trends and requirements as well as general changes within the environment. The monitoring system is part of the brain in the organism, which mirrors the board of management and function units. It receives variations of the receptors caused by environment or company's departments. Processing tasks are processed within the left brain hemisphere such as the definition of operational figures based on business objectives. The right brain hemisphere contains the creative processes such as the development of future scenarios. The memory is the database in which this data gets saved for the variance comparison and gets converted into input data for the simulation model.

To ensure that the controller of the monitoring's cycle loop is fed with the right data, depending on the field of observation, two control paths are established. As visualized in Fig. 7, the cycle loop can switch between the actual performance data and simulation results of forecasted scenarios to check the current and future robustness of the production structure. Furthermore, possible adaptations of the production structure can be predicted through simulation.

Through the simulation of future scenarios, forecasts and long-term planning as well as strategy can be integrated,

increasing the ability of organizations to anticipate important, forthcoming changes and their consequences, and to successfully adapt themselves to these changes and the opportunities and dangers associated with them [22]. In addition, the recognition time for reconfigurations can be minimized.

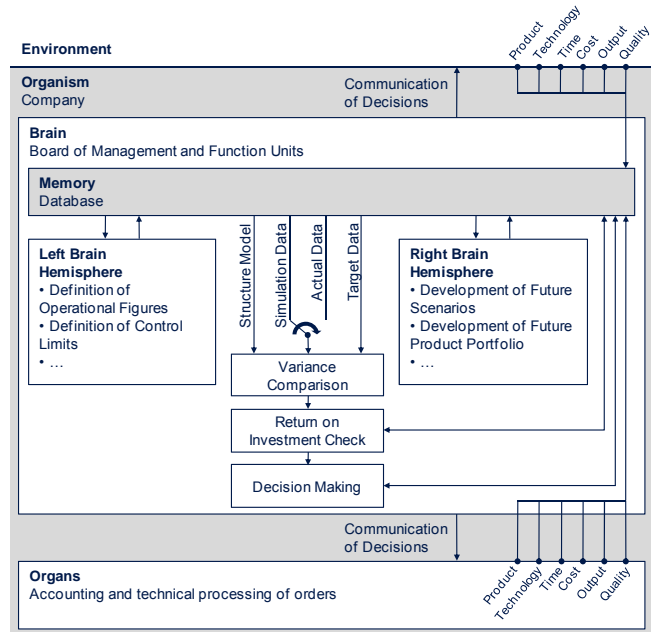


Fig. 7 Embedding of the Concept into the Company

VII. SUMMARY

Today's turbulent environment leads to production structures characterized by only temporary optimal states. Therefore, it is necessary to adapt a company's production structure continuously. Due to the fact that companies are not able to ensure continuous planning processes, a suitable methodology is needed. Using a controlling system is one way of tackling that problem. The presented approach contains a system, which follows neurologic principles. The concept enhances existing monitoring approaches and supports companies in taking timely strategic decisions regarding the reconfiguration of the production structure.

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