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Quantitative approach for evaluation of company's changeability based on feedback data

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1. Introduction

A goal-oriented configuration of the production system in dynamic markets is essential in order to be successful in a market with an increasing number of complexity drivers. The increasing complexity is related to difficult planning and control processes as well as to organizations and information systems that require a high coordination effort. The complexity drivers can be divided into internal and external influences. External influences on companies are high market dynamics, volatile customer`s demand, short product life cycles and increasing product ranges. Since companies focus on customer`s value, companies have to master increasingly individualized product solutions, short lead times at the lowest possible cost while markets underlie high dynamics. At the same time, the external dynamics in form of fluctuating customer demand and short-term order changes by customers increases [1]. Further changes are characterized by the rapid spread of new technologies, new and aggressive competitors, a dense network of material and capital flows. Internal influencing factors on companies are short-term changes of production planning and priorization of orders, difficulties in order release and overload of capacities as well as intransparent production control logic and IT-systems. The challenge is to design a production system that, on the one hand, lasts for decades but, on the other hand, is adaptable to changing requirements of the dynamic market environment.

Within the following paragraphs, the deficits of established methods of changeable production systems will be discussed and a new perspective of evaluation of company’s changeability based on feedback data is presented. This new approach focuses on the evaluation of the current changeability of companies in order to derive recommendation for future investments.

2. Changeable Production Systems

A production system can be seen as a socio-technical system that transforms input like material or energy in a value-added output such as a fabricated or assembled product. The production system and its structure represent the foundation of production processes. They determine the layout and arrangement of machines, the organization of production processes as well as the information and material flow.

Due to increasing market dynamic, theoretic approaches which intend to realize a robust and efficient production require a changeable production [2]. In this context, Nyhuis defines changeability as a potential to adapt organizational, technical and logistical properties outside of the flexibility corridor with only small investments [3]. A changeable production system can be adapted to different dimensions of change as the product quantities, technology, quality, time, product and cost structure. The ability to change goes beyond the concept of flexibility. In flexible production systems, expected changes such as variations in production volumes or product variants are already considered in the planning phase. In doing so, it has to be ensured that these expected changes can be realized by the production system within a pre-rigidly fixed bandwidth without much effort. This pre-rigidly fixed bandwidth of flexibility is also called flexibility corridor. For example, flexibility is achieved when a machine is able to produce different product variants.

Summing up, changeability enables production to react to change drivers in an efficient way. These changes go beyond flexible changes, which are pre-defined for example by facility planning. Changeability of production systems provide an appropriate solution space to respond to changes in the turbulent company environment .

2.1. Change drivers and change enablers

Disturbances produce at all levels of the production system a pressure for change and are called change drivers [4]. The source of the disturbances may arise from various fields like technology (e.g. changes in product life cycles), environment (e.g., resource consumption increasing scarcity) or the economy (e.g. changes in demand behavior). In this context, external and internal disturbances can be distinguished. Disturbances that affect the production system from its environment are identified as external turbulence. In the case of internal disturbances, the causes lie in the company itself. For example, changes in the internal organizational structure and performance fluctuations destabilize the production system from inside the company. In order to produce successfully despite increased external volatility, flexible and versatile production systems are necessary that can adapt to new demands quickly [5].

With regard to these change drivers and in order to respond appropriately, a production system needs defined properties. These properties should enable the production system and thus the company to change [6]. Therefore, these properties are called change enabler. Among these features, which characterize a versatile production system, five primary change enablers can be indicated: universality, mobility, scalability, modularity and compatibility [3]. Other authors like Eggert add interoperability and availability [7].

2.2. Barriers to achieve a changeable production systems

The company's need for changeability is reflected by an empirical research by the Laboratory of Machine Tools and Production Engineering (WZL) in 2011 [8]. In this survey, around 80% of participating companies underline the importance of changeability in production. Nevertheless, companies have difficulties to realize needed changeability. The insufficient support of IT

systems is a major problem for the implementation of changeability in production. Four-fifths of the surveyed companies see the insufficient data quality and the poor intra- and inter-company data provision as an essential obstacle to realize changeability. Due to insufficient data, the actual situation of production cannot be analyzed correctly and it is difficult to measure and compare changeability due to upcoming production scenarios that are not ultimately definable [9]. Furthermore, the lack of data analysis and conclusions complicates possible potential for improvement. In addition to the bad data quality, the lack of IT integration hampers the ability to change. Today, software vendors are not able to interconnect software elements of different providers sufficiently. It requires simple, modular structures with standardized interfaces to realize a simplified handling with these systems for the user and to realize changeability in the production. Depending on external influences, it should be possible to adapt IT systems quickly and easily to a new framework. In addition, a lack of employee's knowledge and a missing awareness for change hinders changeability. Often, employees are not able to analyze processes properly and to improve process. The realization of versatile production systems is therefore limited by three main deficits: inadequate IT systems and their integration, insufficient employee understanding for the processes and a lack of awareness for change within the company.

3. Quantitative approach for evaluation of company's changeability

The need for changeability leads to various approaches in literature. Some existing approaches focus on the evaluation of defined change objects and their properties such as size or weight of a machine [4]/ [6]/ [10], other approaches concentrate on the comparison between current and target state of the production flexibility [11]/ [12]. These approaches analyze changeability in a qualitative way. As a quantitative approach, Gronau/ Wildemann/ Zäh developed a software tool which supports the evaluation of adaptability of Enterprise Resource Planning (ERP) systems

[13]. So far, there is no adequate solution for the barriers for realization of changeability within production defined within chapter 2.2: a sufficient software, capable of being integrated and to support employees in their decision making process referring changes within production.

The key objective of this paper is to introduce an interactive tool to enable employees to better understand the influences on their production processes better and to evaluate current changeability of their production.

3.1. Interactive visualization

The WZL has developed several web-based solutions (cf. Figure 1). The tools support analysis of shop-floor activities and are divided into two groups: tools for structural visualization and tools for monitoring logistical targets. To analyze data with these tools, input data in csv-format can be uploaded via a defined interface. The user can select the level of detail manually by the input data and by a filter function within the tool. The core idea of these tools is to balance the need of structuring and control functions induced by external factors in combination with the skills of the employees. Using the developed principles and software tools, operators have the possibility to bring their own knowledge into the improvement process and to analyse production processes interactively. Since these tools create a high transparency of shop floor activities, the operators are enabled to handle disturbances better.

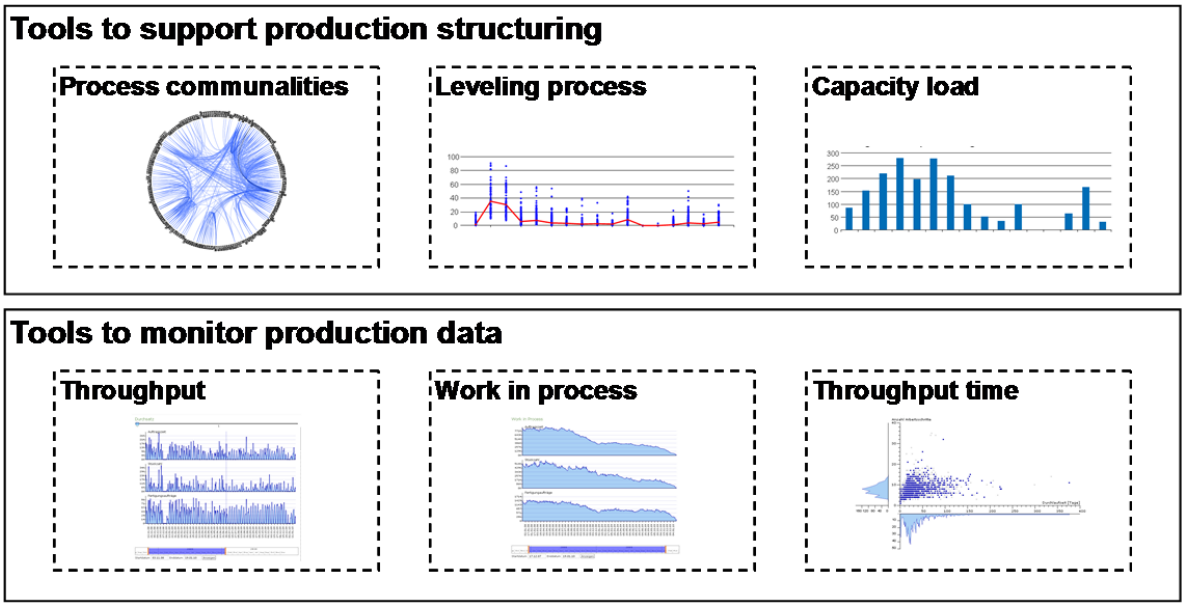

Figure 1: Web-based tools to support production process analysis [14]

3.2. Comparison of realized changes and effort

As an extension of the already developed software tools, the tools shall support the evaluation of changeability. The main idea of this approach is to use feedback data of production and to visualize them with software tools. By making use of the feedback data, the operator should have the possibility to analyze which production changes were already realized referring to a certain effort. For example, the company has realized the production of high product quantities as the expense of higher resource capacities.

The definition of changeability by Nyhuis provides implicitly a structure for visualization. According to Nyhuis, changeability requires the potential for changes, to adapt organizational, technical and logistical properties while taking only small investment under consideration. Thus, there are two sides: on the one hand the realized changes relating to a certain time and on the other hand the effort which is needed to realize these changes.

$$\text{Degree of changeability} = \frac{\frac{\Delta \text{ changes}}{\Delta \text{ time}}}{\text{effort}}$$

The realized changes which can be derived by feedback data are for example the number of orders, the number of items or the variety of products. These values are influenced directly by the market or by the customer order. Dependent of orders, the production time and the number of processing steps within orders differ, which can also be important for production performance. Furthermore, the resulting throughput time can be monitored by the difference between start and end of production of an order. The time frame of the data analysis can be selected manually within the tool by a time bar.

To realize these changes, a dedicated effort is needed. First of all, the production requires resources in form of machines and employees. These resources represent the available capacity of a production which can be measured either in the number of machines and employees or in maschine- and employees-hours. Depending on the number of orders which have to be produced on available capacities, the resources have a certain capacity utilization and in front of the machines and between the process steps is a certain work in process (WIP). An important factor for production's performance is the number of different products and referring to this the amount of setup time. The user should have the possibility to select different parameters separately in order to compare the realized changes on the one hand and the needed effort on the other hand. Since user might have different interest of focus, the parameters should be separately selectable. The selectable parameters are shown in Figure 2.

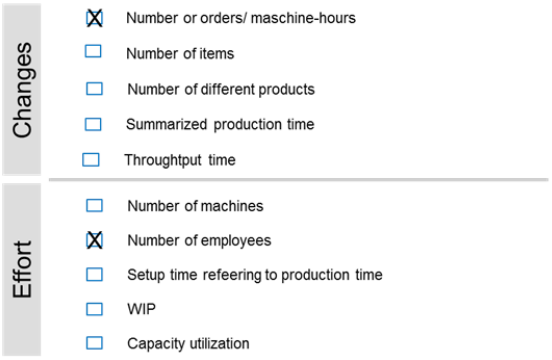

Figure 2: Selectable parameters for visualization

Consequently, the visualisation tool should be able to show the realized changes and the needed effort for these changes in parallel. The idea is to visualize these two sides like it is done in Figure 3. The example shows the comparison between the orders measured in operating hours as a realized change and the operating hours of employees as effort within a time period of about three months.

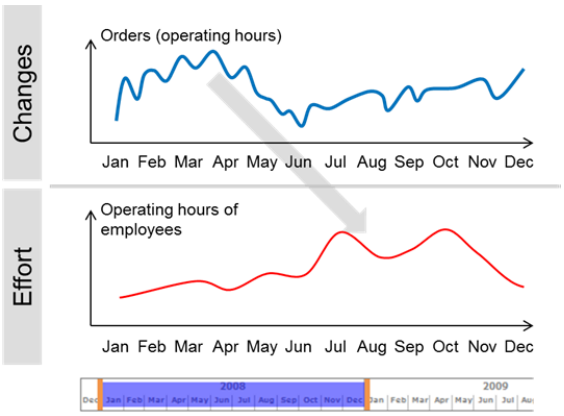

Figure 3: Visualization of realized changes in comparison to needed effort

In this example, the orders measured in operating hours were quite high in March and April and decreased in the following time period. The operating hours of employees, however, were quite high in August and October. By analyzing these two curves, it is obvious that the company was

not able to adapt its employee capacities quickly. It took four month till the company increased employee's capacity. In an ideal scenario, the curves progression would be similar and simultaneous.

3.3. Quantitative approach as a basis for decisions

The main benefit of this quantitative approach is the sufficient basis for analysis and subsequent decision processes by using feedback data of production, based on facts. The simultaneous analysis of realized changes on the one hand and needed effort on the other hand supports the analysis and evaluation process in an interactive way. Since the parameters for realized changes and needed effort are selectable, operators are able to investigate different views on production and to prove their own gut feeling. The tools complete these subjective perspectives of operators by addition of confirmation data. The simple handling of these tools enables operators to identify their production situation easily and develop common solutions. The potential enabled with such interactive visualizing tools is long awaited by a reference group of users from the machinery and equipment industry. Summing up, the presented tools based on feedback data are very suitable to analyze current changeability of the production.

To derive recommendations for further investments, the target status of changeability has to be defined. Regarding the production's capacity, different options to increase or reduce capacity are possible. An additional machine, for instance, would help mitigate this problem of bottleneck resources. Furthermore, labor time models can be created flexible so that employees have to work longer in times of high demand and less in times of decreasing demand. In order to estimate the effects of these and other arrangements, a simulation can be developed in order to analyses effect on logistic targets.

4. Conclusion and outlook

This paper demonstrates the need for the realization of a changeable production. Today's companies are not able to react to the turbulent environment in an adequate way. Current approaches refer to the evaluation of change object's properties, but only in a qualitative way. For the first time, a new quantitative approach is developed to evaluate the current changeability of a production based on feedback data. Software tools support operators to visualize realized changes and the needed effort. The visualization raises awareness of operators for the weaknesses within the production. In addition, operators are able to evaluate the current changeability.

Further research is needed to advance the quantitative approach in terms of simulation based decision making and to derive proper recommendations about further investment and it's needed flexibility corridor.

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