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TWO TIERED TIMING MODEL FOR INCREASING PROCESS EFFICIENCY IN ONE-OF-A-KIND PRODUCTION

Abstract: Rising competitive pressure in connection with rising heterogeneity of customer wishes has led to the assumption that in the future, an increased focus will be centered on one-of-a-kind production. The relevance of one-of-a-kind production in different branches increases. Hence, it is necessary for job shop and single item producers to increase their competitiveness by focusing on technology and boosting their process efficiency. The challenge now is to question existing added value structures and to pursue attempts to profoundly improve productivity. A feasible approach to tackle this challenge is lean production.

Keywords: Lean Production, one-of-a-kind production

1. Introduction

Requirements to the design of production systems are modified by current mutations in product managerial aim systems. Formerly, prime importance was given to operating-oriented goals such as approaching to full production capacity and the reduction of inventory turns, whereas nowadays market-oriented goals, such as short product cycle times and a high adherence to schedules gain significance (Schuh *et al.* 2008). This development is induced by an improved customer orientation, especially regarding the scope and the degree of innovation of the offered range of services. A broader range of products could become a relevant driver of complexity. A high degree of variance not only affects the amount of required materials, but also their procurement, disposition, production and manufacturing process as well as required technologies and resources (Lindemann, Gronau 2009). In one-of-a-kind production, existing product and process complexity is additionally increased by changes in construction and a high number of special models.

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In order to respond to the modified requirements to the design of production systems adequately, suitable production concepts have to be employed. For an overview on relevant production concepts confer Figure 1. When evaluating relevant production concepts their differences and similarities become clear. For some concepts, the overlap of the goals and operating range is apparent.

Each production concept increasingly addresses market-oriented goals, such as short processing times or a high adherence to schedules. Social and ecological goals are rather subordinate, with the exception of Lean Production and Ecology Manufacturing (Fig. 1). Differences between these concepts can mainly be found in the applied instruments for reaching mentioned goals. To give an example, the standardization, tact and flow principle of lean production or the implementation of CAx components to support information and data integration of CIM concepts can be considered.

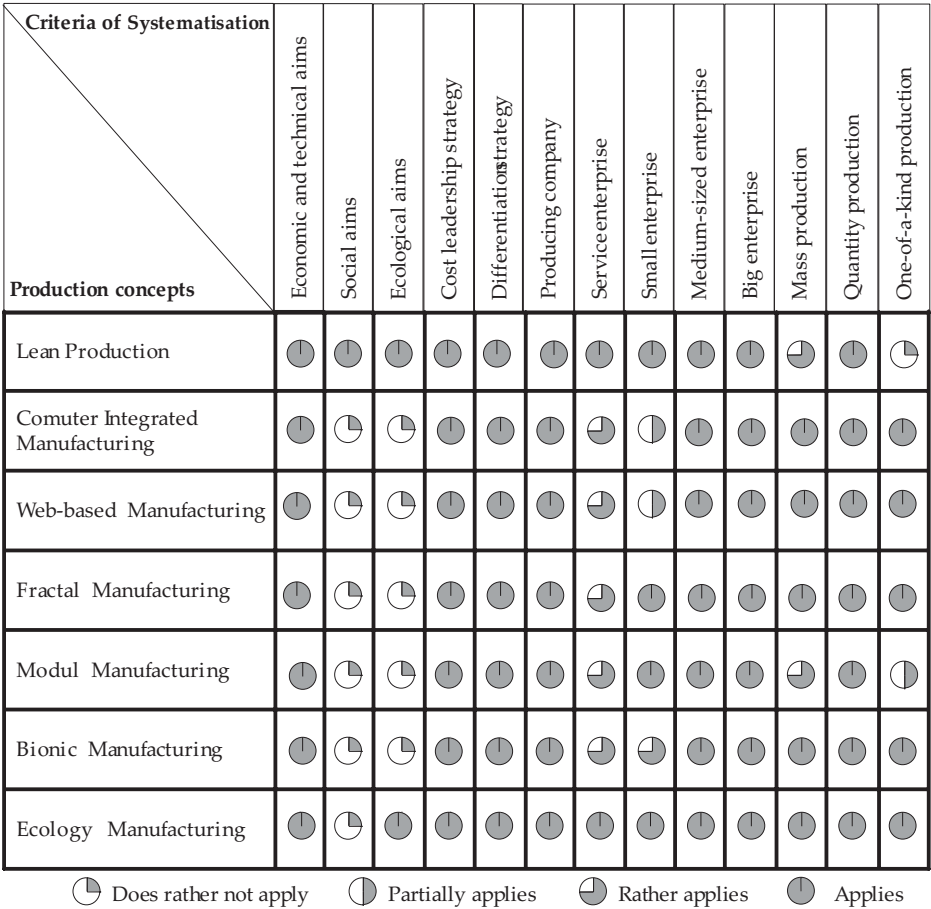


Fig. 1. Systemization of general production concepts
Source: own depiction, referring to Acka (2005)

Despite the high degree of implementation for single production concepts, differences in the application of concepts in various production types emerged. It is to mention that even though the lean production concept has a considerable record of success in serial production (Womack *et al.* 1992, Müffelmann 1998), it is hardly applied to single item production (Schuh *et al.* 2007).

The limited usage of the lean production concept is specifically caused by the existing conflict between the specific characteristics of one-of-a-kind production and the usage prerequisites of lean production. These are illustrated in Figure 2. By solving existing contradictions, a transfer of lean production on one-of-a-kind production seems promising.

Since takt and flow principles are the main concepts of lean production, fundamental changes in the production and systematic management of the one-of-a-kind production have to be realized. A profound change of corporate structures is assumed when switching from job shop to takt-oriented production.

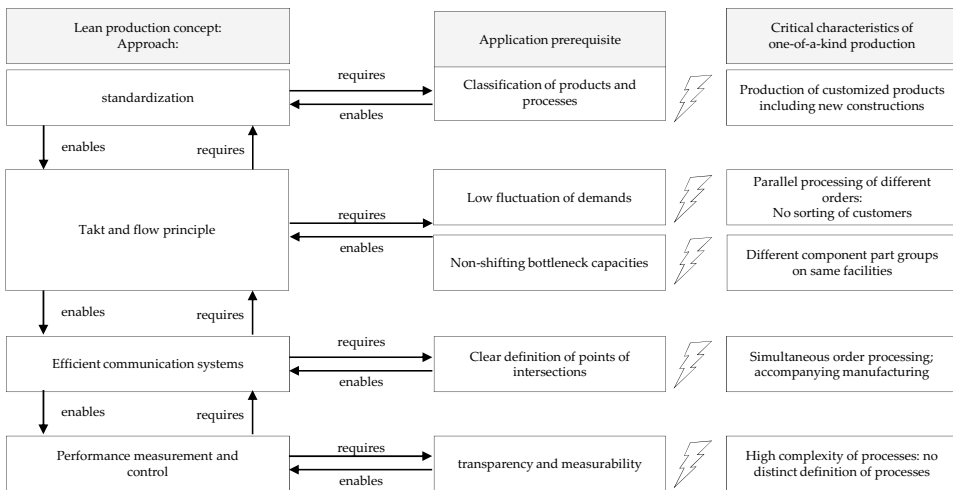


Fig. 2. Contradictions between characteristics of the one-of-a-kind production and application prerequisites of lean production

To solve the depicted dilemma, a two-tiered timing model for the one-of-a-kind production is proposed. The fragmentation of the classical takt into macro and micro is the basis of the model.

2. Process competence center as foundation of design

As a first step, Process Competence Centers (PCC) are built. This is the basis of implementation for the takt principle and material flow. Each PCC consists of several working steps, each focused on a specific production- or machining method. Within

each working step, several activities can be completed. The aim of building PCCs is to bring separate working steps into a sequence that does not have to be changed for each different finished product. The chain-linkage of PCCs creates a superordinated machining sequence for product categories. As a support to the building of PCCs, classical solving approaches (Müffelmann 1998) such as parallelization, outsourcing, and deferment can be considered. Another possibility can be found in constructive modifications of the product.

The definition and introduction of PCCs is based on product and process standardization. The idea of product standardization seems to be unfeasible in the context of customized production and broad ranges of products within one-of-a-kind production and would thus constitute a revolutionary initiative. However, this does not hold for the final product, as product standardization could be executed on the single component level. The utilization of standard parts and interchangeable parts is fundamental. By defining and establishing a product assembly kit with standardized parts and few individual components, a high degree of customization of products can get achieved.

When designing PCCs, the following premises apply:

- All end products of a product category have to be manufactured in the same order. Different manufacturing sequences are possible, however, they have to be separated locally.
- Not every product of a product category has to necessarily go through all process steps (PS) within a PCC. A manual order placement control that can either place or reject orders is permitted.
- Each product, by category, does not have to be processed in every PCC.
- Defined PCCs can feature a parallel chain of events, in particular for assembling processes.
- A transition from sheer customer orientation to process orientation is assumed.

An abstracted model of PCC is depicted in Figure 3.

The level of details that the PCC has depends on the amount to which Lean Production has been incorporated. When defining PCCs, an emphasis is put on the area of construction, production preparation and manufacture. Another important issue constitutes the administrative areas with information processes ranging from the first customer request to the completed documentation of a customized item. The model can get deployed both in administrative and in productive areas.

Within the PCC, the working steps focusing on production and machining methods bear a customer – supplier relation. The customer is not merely understood as a purchaser of a good, he is rather the recipient of a service on both an external and corporate-internal level. Furthermore, performance is only rendered, when the downstream station demands it. The agreement on a transaction can take place by reference to e.g. the amount, time, quality and the price and can be measured by key performance indicators. Planning and control of the customized performance happens by employing a two-tiered timing model.

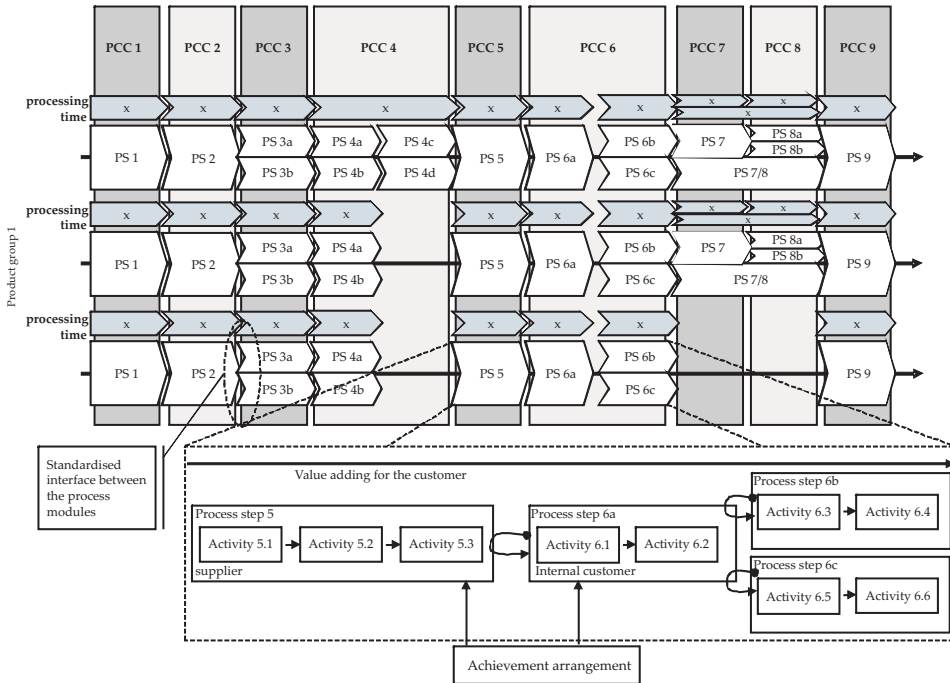


Fig. 3. Systemization of general production concepts

3. Control systematics employing a two tiered timing model

Long-term production program planning is coarsely made on the basis of cost. It encompasses amount and scheduling as well as capacity verification for the designated processing timeframe. Short term order scheduling is conducted in a decentralized way on basis of exact values. Decentralized detailed planning covers the length of macro takts at the maximum, so that production management personnel can make use of accurate target data.

The introduction of both planning steps is related to an avoidance of high planning cost. Control of the entire order processing is taken over by the macro takt. It defines breakpoints in the process and enables progress control as well as the surveillance of budgets at the project management and multi project management levels.

Production control on individual project level is undertaken by the micro takt. Within a micro takt, several PCCs of different process agitators can proceed simultaneously. This leads to the need to introduce another dimension in form of takt phases. Takt phases enable a transparent control of the progress made for all order processing stages. Takt phases are understood as a planning element. This transparency enables the simultaneous control of several process agitators. As an example, process agitators can be thought of as departments of construction, production planning, or production. Each time limited micro takt can be divided in several PCC takts. Whereas a PCC has an organizational disposition, a takt phase has a temporal disposition.

Particular work packages for a corresponding order processing stage comprising of corresponding work hours, manufacturing documents (including NC programs), materials, and required production facilities, are assigned to takt phases.

Work packages have to be completed before the individual micro takt is finalized. An earlier actual finish time is permitted. Detailed planning for the allocation of particular activities to available resources on the lowest operative level takes place in a decentralized way when, for example, establishing day or shift targets. Detailed planning constitutes the basis for the determination of the processing stage and its visualization with suitable tools.

The described control system is depicted in a simplified way in Figure 4. It shows that scalability of systematics is given on all levels. The level of details depends on the complexity of examined processes. The introduction of pure PCC takts allows monitoring processes on the lowest planning and control level, as for example on the level of single tasks/activities/process steps/ PCC. The lowest planning and control level depends on the complexity of the order processing process and not all elements of the PCC are necessarily realizable. The level of details is scalable at will.

The pursuit of the treatment stage happens by employing different key figures, such as forecasted/ actual comparisons of hours, number of completed manufacturing documents or availability of materials, and is supported by visualization tools such as a color coded alert systems.

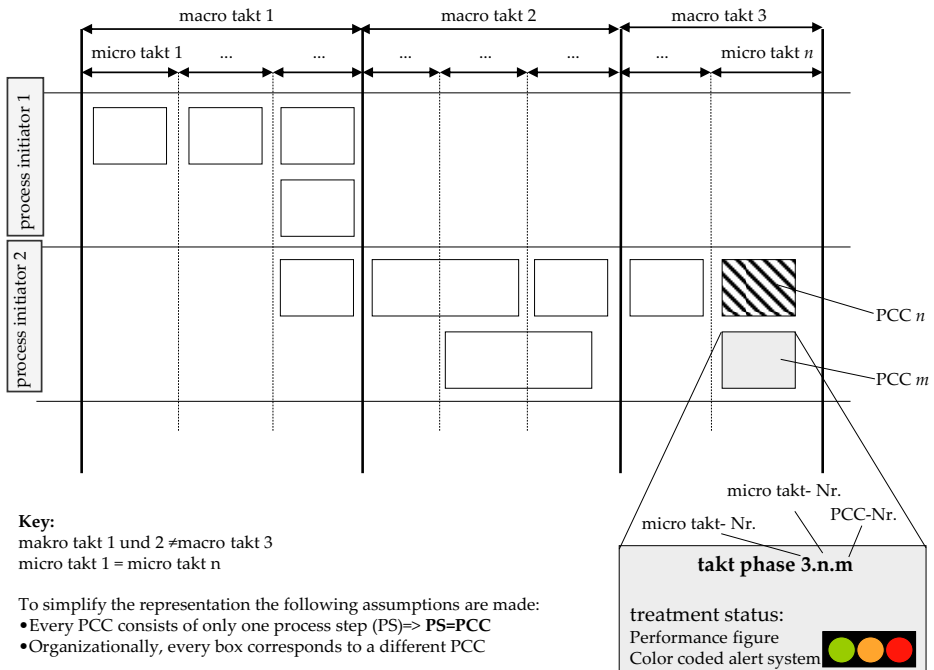


Fig. 4. Two-tiered timing model

Finally, the developed control systematics is a suitable control mechanism to choose the flow of information and materials.

The traditional mechanism of the one-of-a-kind production is the push principle. In order to produce a product, selected orders with a defined finish date are started continuously, and then pushed through production depending on information and material availability as well as on time pressure. Contrary to push production, a requirement for pull production is a demand-oriented production. When manufacturing according to the pull-principle, a product is only produced when it has been consumed from a section downstream on the supply channel, it might be that this is the next process step. To manufacture a new product, a predefined range of products is required. Each product in the supermarket is related to a particular customer. It is a premise of the pull-principle, that the customer triggers the production process only in an indirect way. The final product is oriented to a predefined supermarket that constitutes a post to sort products according to customer's needs. Each consumed product causes a renewed order to replace the missing product in the supermarket; however, the production order is not corresponding to the customer order.

Companies with a one-of-a-kind production meet the criterion of a demand-oriented production, because the production process is triggered by the customer's order in any case. Nevertheless, the final product cannot be gathered from a predefined supermarket since for one-of-a-kind production the production order corresponds to the customer's order. As each product depicts a customized solution, the customer and the actual production cannot be regarded as unrelated.

When aiming at a pull- control, another problem of the one-of-a-kind production is changing bottleneck capacities. The pull principle is based on a pacemaker process that constitutes the mentioned bottleneck. The bottleneck determines the amount of orders to process and thus the number of final products to be manufactured. The goal is to define the total capacity of the pace making process in such a way, that residual resources can get adjusted to it. In single item production, order sizes can vary depending on the product group and the way each product characteristic goes through a PCC within a product group. Consequently, it is not possible to define a concrete pace making process.

Since a sorting of customers and a definition of a pace making process are both unfeasible, a mixed control mechanism is proposed for the one-of-a-kind production. In this context, a division between the material flow level and the order flow level is implemented.

By product standardization on the level of sorted parts, the concept of PCC-building can be realized. In an ideal situation, PCC can build a standardized production sequence. Thus, each requisition can always succeed to the last PCC. Further, a requisition is equivalent to the customer order. In consequence, the flow of orders is handled according to the pull principle. By contrast, material is moved within the PCC, thus over the whole production process, in accordance with the push principle. The push of materials is significantly a result of the individualized product spectrum in production. Due to the diversity of variances, a build-up of supermarkets in between PCC cannot be realized in a useful way.

4. Generic planning model on the basis of timing systematics

The structuring, trimming and reorientation of processes within order processing constitute the base for the implementation of the lean production concept in one-of-a-kind production. Once the PCCs are defined, macro and micro takts can be determined, control rules be developed and a systematic depiction of essential processes in suitable IT-Tools can ensue. The IT-technical depiction of processes should not only exhibit the visualization character on an operative base. To a greater degree, a planning model that is adapted to the concept of a two tiered timing model is required to be able to perform consistent planning and control. Moreover, operational, business and logistic planning elements have to be considered. Each takt phase holds a temporal and capacity volume.

By performing an allocation of single working packets, the available volume is reduced continuously, until the upper capacity bound is reached. The planning and control of operations within a takt phase occurs in a decentralized way when, for example, establishing targets for weeks, days, or shifts. Before matching single working packets to a takt phase, a reconciliation of capacities and times has to be made. The need for planning on a higher level results from varying processes of time for the production of different widgets. It is to mention that not all products are being ordered and processed at the same time, which means that in the same calendar week, products can be situated in different takts. Thus, a multi project management vision is demanded (Fig. 5).

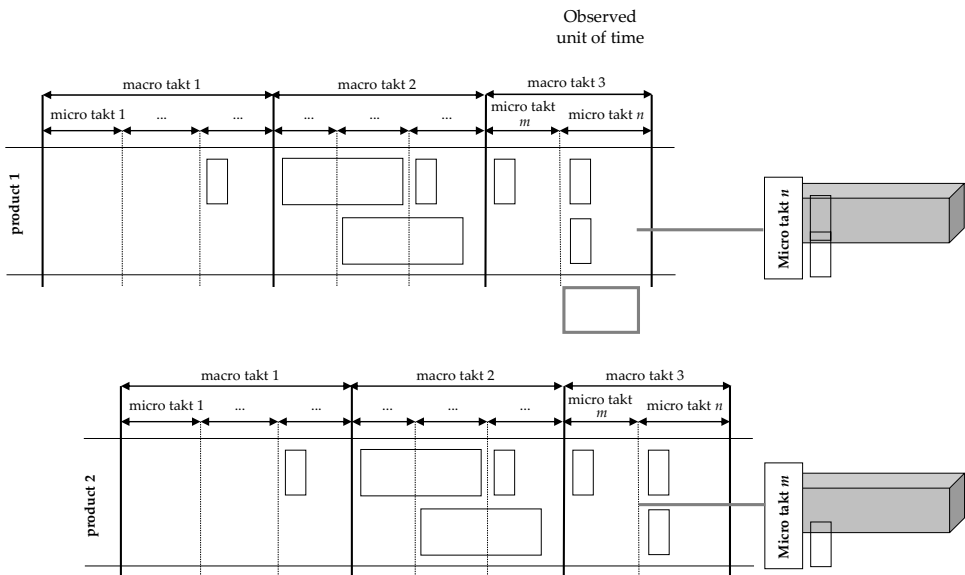


Fig. 5. Planning logics for several products

All micro takts situated in one observed time period are planned separately while taking available capacity into account. Planning principles are constituted by

target order figures. By product comprehensive planning and control, key numbers cannot only be tracked within a takt phase, but they can also be tracked in a cumulative way for all products. Besides the planning and control of operational tasks, the integration of business and operations elements is necessary for consistent planning and controlling. A linkage between the particular working packets and the costs allows budget control across projects, early recognition of budget overruns, and comparisons of surplus hours.

From a logistic viewpoint, the allocation of medium term material demands to macro takt dates in a homogeneous system provides the essential visibility in terms of required dates, material availability, and spare parts management. A distinct allocation of required materials to work charts on an occupational level enables short-term order picking by the micro takt date. Connections between the operative, logistic and business aspects within the planning model are depicted in Figure 6.

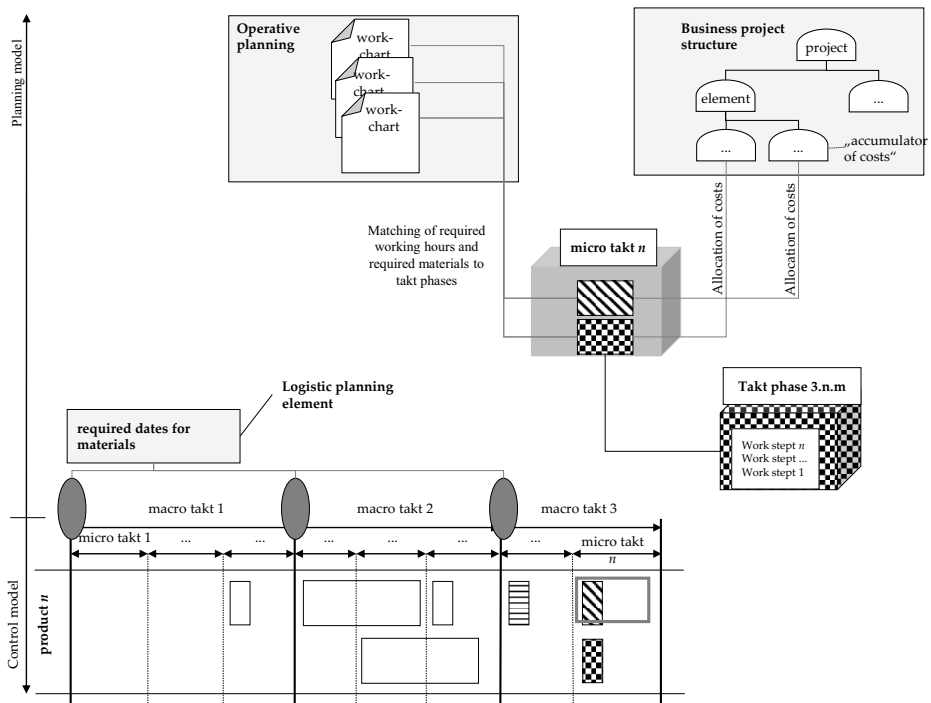


Fig. 6. Generic planning and controlling model on the basis of the two-tiered timing model

5. Conclusion

A critical performance analysis of lean production clarifies that industrialization in the midst of the paradigm of lean approaches has reached a generally accepted status. The success of lean production is usually assessed in "lean-compatible" businesses, especially in the area of serial production.

Previously, lean production for companies with one-of-a-kind production operations could only be scarcely applied. Specific characteristics of such companies can be seen as a reason for this deficiency. High customer orientation, a broad array of products and thus a high complexity and individuality of processes engage in conflict with the approach of value creation design. Hence, the focus of the manufacturing organization in job shop production is mostly on technical work. The limited availability of information, from construction and manufacturing preparation, causes production to work with a low level of details in documents. However, these shortcomings can be compensated by an organization of the shop floor.

Despite of existing contradictions between the approaches of lean production and the characteristics of one-of-a-kind production, lean approaches can get deployed as an aid to configure one-of-a-kind production. The formation of product group oriented, flexible assembly lines allow an orientation of material flow. Introduced macro and micro takts with phases controlled in a decentralized way render a positive contribution to reducing complexity and augmenting transparency.

The model of configuration reorients the focus of value creation in a new way, without limiting the choice of products for the customer. The presented concept is understood as a lean approach to foster productivity in companies with a one-of-a-kind production.

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