Technologies and Systems for
Assembly Quality, Productivity and Customization

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Cost impact assessment of production program changes: a value stream oriented approach

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Abstract: High capital production assets require an adequate workload to benefit from economies of scale. This and an ever increasing number of product variants often lead to enlarged batch sizes resulting in heightened work in process due to safety stocks and additional changeover. In times of economic volatility, changing production programs cause fluctuations in capacity demand along the value stream. Fixed costs have to be distributed over an ever changing amount of products – batch sizes and production costs are permanently altered. To assure the success of investment decisions, various assessment methods for new machines and their capacity such as the calculation of Net Present Value or Internal Rate of Return exist. These methods imply a predicted production program and associated costs. In contrast, follow-up costs along the value stream are often undertuned in the calculation of future scenarios and pinned measures. Possible impacts of a change of the production program (volume and variants) are mostly unknown.

The aim of the developed calculation model is the estimation of the flexibility of costs (elasticity) depending on these various costs (units, variants and batch sizes). It supports the forecast of possible impacts regarding uncertain future developments and locates that section of the value stream responsible for cost related effects and where necessary measures for improvement should be located.

Keywords: Production Costs, Flexibility, Product Variants

Introduction

The capability of a production system to produce different product variants and different volume at an acceptable speed and cost results in production flexibility [1]. However, an increasing product variety causes an increasing changeover effort on existing production equipment. To assure an adequate machine workload, higher lot sizes have to be formed. This, again, is contrary to the principles of Lean Production, which demand low WIP in process (WIP) for a short throughput time and hence require small batch sizes [2,3].

"If we are trying to do is shorten the time line..."
ichiy Ohno, Toyota Production Chief after WWII

"The easiness of all wastes and the hardest to correct is the waste time"
Henry Ford, Founder of Ford Motor Company

As another apparent issue, a change of production program investments in the existing bottleneck can lead to a shift of the bottleneck in the value stream [4], which possibly changes the structures and efforts in support and logistics. Moreover, if not planned properly, investing into production equipment sometimes triggers a spiral that can be described as follows: other assets need a higher workload – batch sizes are raised, throughput time worsens while simultaneously does flexibility of the production to accommodate to different product variants [5]. A shift of the bottleneck changes the behavior of current inventory and WIP within the value stream, as well as the corresponding allocation of thereby occurred costs and the level of costs.

Due to the complexity of the relationship between changing number of product variants, its impact on the value stream and resulting costs, the estimation of these impacts and cost changes is difficult. Existing approaches to assess flexible production systems often focus on technical scope of producing different product variants at increasing quantity [6, 7, 8]. They evaluate production systems regarding an existing or predicted production program [8] or use predetermined cost factors without including their origination or shift due to changing production structures [10, 11, 12].

However, the consideration of the whole value stream is essential to model altering conditions and bottleneck situations and hence facilitate the balancing of capacities. On this account, a proceeding that describes this correlation, considers all costs along the value stream and plots them against an altered production program (product variants and volume) is needed.

\begin{align*}
\text{Product Variants} & \quad \text{Costs} \\
1 & \quad \text{Costs/Unit} \\
2 & \quad \text{Costs/Unit} \\
3 & \quad \text{Costs/Unit} \\
4 & \quad \text{Costs/Unit}
\end{align*}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{Figure1}
\caption{Approach to the method: costs per unit along the value stream}
\end{figure}
This paper describes the principles of an approach enabling the user to specify the developing of costs of each variant in the considered value stream, to reveal cost changes after a change of the production program and to localize sources of possible cost hikes along the value stream. To afford such an analysis of all relevant impacts, costs along the value stream are assigned according to their dependency on produced units, different variants and the connected batch sizes. The value stream thereby is divided in production processes and inventories (Figure 1). Moreover, support processes depending on the production can be included [5].

Compared to Activity Based Costing, which is a continuous calculation scheme, the presented method is used to forecast future costs with respect to possible scenarios in the production program. Thereby, potential over- and under loads of processes and employees are included in the cost calculation to foresee future additional costs or prevent shortfalls respectively [13].

2. Cost types along the value stream

Costs and expenses dependant on product variants are sited in the production area and its support activities. Expenses in production consist of wages, material and stock (current assets) and capital assets. The factor input needed for manufacturing is primarily dependent on the volume of manufactured product, the number of product variants, the resulting days of inventory and batch sizes (and connected number of batches). The relevant cost types along the value stream are depicted in Figure 2.

The cost units of the corresponding support processes are primarily composed of wages and salaries. The level of these expenses depends on several cost drivers, i.e. number of customer orders or timed transaction cycles.

According to the method of Activity Based Costing, all activities of these cost units can be divided in activity quantity induced (aqi) costs and activity quantity neutral (aqn) costs and will be related to the corresponding cost drivers [13]. Those cost drivers who are activated by the production process are once more the volume of produced goods, the amount of product variants and the amount of lots produced.

3. Connection of production units and product variants by the EPEI (Every Part Every Interval)

The basic concept of the described approach is the connection of production processes and inventories along the value stream and the calculation of variant-dependent costs with the help of the EPEI. If a value stream produces more than one product variant with the same production processes, usually changeover processes are needed. These changeover efforts must also be accomplished during the tact time, which represents the average customer's request frequency.

In a best case scenario, process and changeover time for one specific part or good fit into the tact time and a one-piece-flow production is possible. Since changeover times in several industries are time consuming, this presumption is not always realistic. To meet the tact time anyway, production batches are formed to reduce the number of changeovers needed. Forming batches delays the production of other product variants, since the whole batch has to pass a process before another product variant can be started [2].

Hence not all variants may be produced in one day. This relationship can be described by the indicator EPEI. It specifies how long it takes to produce all product variants in their corresponding batch sizes. It considers the daily consumption, which has to be met, but also the necessary changeover times.
4. Conjugation along the value stream

The EPEI describes the relationship of necessary changeover time for all product variants with the amount of available changeover hours. The EPEI is expressed as a function of the number of batches, which secures the scheduling of each variant. The level of the EPEI reflects the necessary changeover time for each variant. If the amount of available changeover hours is equal to the necessary hours for all variants, then the EPEI is zero. If the available changeover hours are insufficient, then the EPEI is positive and reflects the additional changeover time required for all variants.

The EPEI is defined as:

\[ EPEI = \sum_{i=1}^{n} \left( Pr_i \times PC_i \right) \]

where:
- \( EPEI \) is the total changeover time in minutes.
- \( Pr_i \) is the proportion of the total processing time for variant \( i \) in minutes.
- \( PC_i \) is the changeover time for variant \( i \) in minutes.

The EPEI is a useful tool for planning and scheduling in manufacturing systems. It helps to identify bottlenecks and optimize the production process to reduce changeover times and improve efficiency.
defined by the value stream analysis has to be mapped for all existing product variants. The result is a production program with process and changeover times, corresponding shift models and the required tact time determined by the costumer.

Further, all assets, wages, material costs and other expenses have to be compiled and assigned according to their dependency on produced units and different product variants. For the calculation of inventories in the value stream this means data generation of purchased parts and material regarding prices of retrieval, floor space required, container sizes, etc. as well as logistics efforts in time per batch.

The necessary data for production processes are divided in machine data and operator data and describe the process and changeover times for both. To cover the support areas, all activities in the relevant cost units as well as their cost drivers must be identified. General information has to contain the mentioned shift models, assets and direct costs. If the aim is a break-even-analysis, a revenue function must be dedicated.

With the help of this data basis the described cost types can be calculated and disposed to the different variants according to their different process and changeover times. If the capacity of one machine or operator is not utilized completely, all expenses have to be distributed to all goods produced by a utilization factor [13].

\[ \frac{A_{j}}{CN_{PT,j} + CN_{CO,j}} \]

\( \text{Equation 2} \)

Utilization factor

\( j = 1...m \) process \( j \)

\( A_{j} \) factor of capacity utilization

\( CN_{PT,j} \) capacity needed for process time

\( CN_{CO,j} \) capacity needed for changeover time

Finally the units produced and the number of variants (the production program) can be levered and an estimation of costs in a scenario of production program changes can help the user value existing or future production structures.

6. Summary and Conclusion

With the presented approach, scenarios for production program changes in existing or future production structures regarding their impacts on the level and the allocation of the costs along the value stream can be depicted.

If it is possible to picture interrelationships between product variants, production volume (units produced) and costs in 3 dimensions, the related velocities and critical production programs can be identified. If probabilities and corresponding cash flows are deposited, the results can be used for investment appraisals or discounted cash flow methods. Finally, this approach will allow an in depth comparison of different production structures.

The proposed approach will be the basis of a calculation tool that is developed. Currently the system specifications and the conceptual design of the calculation tool are in progress. For an extensive testing phase and in order to secure the viability of the approach an experimental setup of the solution is envisaged.

References


