Industrie 4.0 meets Lean

Guideline to increase added value holistically

in cooperation with

FKM Forschung im VDMA

TU DARMSTADT

VDMA Forum Industrie 4.0

Editorial

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Through continuous improvement and further development of their own products and capabilities, mechanical engineering companies remain successful in the long term. In the age of digitalization, especially Industrie 4.0 plays a key role in this. The aim is to integrate new information and Internet technologies step by step into one's own processes.

The mechanical engineering industry is already a successful supplier of such technologies in many cases. But it is also a user of Industrie 4.0 itself. Integrating internal processes should be economical and beneficial, especially for small and medium-sized companies. Irrespective of the size of the company, Industrie 4.0 generally does not encounter perfectly optimized processes, nor a blank page with all degrees of freedom for new technologies. Instead, it must be possible to integrate the existing technologies in the best possible way.

For some years now, many companies have adapted the ideas and methods of Lean Management. People, technology and organization are considered holistically in order to continuously improve and increase the benefit for companies and their customers. These basic and proven approaches continue to apply in a digitized world. However, well-known lean elements must be rethought and approaches to digitalization must be tested for their contribution to value creation. The companies' target image remains the same: High added value, high quality, transparent processes and motivated employees.

Industrie 4.0 opens up new opportunities for improvements in production by linking it to Lean Management. Above all, however, it is able to leverage potential at the interfaces to sales, engineering, purchasing and logistics. In this way, companies can lift themselves to a new level of productivity with their own resources. The VDMA guideline "Industrie 4.0 Meets Lean" is doing pioneering work. It sees itself as an aid to designing processes effectively and efficiently through classic lean ideas and digital integration and thus to remaining competitive in Europe as a production location.

With this guideline, the VDMA is realising a further implementation module for practical use and extending its successful VDMA guideline series. Special thanks go to Prof. Dr.-Ing. Joachim Metternich from the Institute for Production Management, Technology and Machine Tools (PTW) at the TU Darmstadt for the scientific preparation of the guideline. We would also like to thank all VDMA members of the working group" Industrie 4.0 trifft Lean" for their commitment and their direction-giving impulses.

We wish you interesting and inspiring reading.

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Industrie 4.0 meets Lean Management

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Lean production is the leading concept of companies in mechanical engineering to reduce waste in processes, increase productivity, and continuously improve working procedures. A consistent focus on value-adding activities, a value stream oriented way of thinking, as well as the integration of employees and suppliers in improvement activities have proven to be extremely successful.

The future project Industrie 4.0 envisions a factory in which operating resources network themselves, every product knows its path, even finding its way through the factory, employees are relieved of routines, and optimal decisions are possible. With regards to their goals, both approaches are similar in that Lean Production pursues goals in the dimensions of time, quality, costs, safety and motivation. Furthermore, Industrie 4.0 additionally accentuates the dimension of the individualization of products and services as well as their offerings within the scope of new business models.

As similar as the goals are, the approaches are somewhat different. In the past, Lean Production was the measure of all things, but now many companies in industry are wondering where "Lean" is to go from here in the age of Industrie 4.0. Many are even asking themselves whether they should skip the adaption of a Lean roduction system and erect a "smart factory" from the beginning. Those doing business face the challenge of utilizing the potential of the digitalization and simultaneously circumventing the pitfalls of a too strongly technology-driven approach. Here, this guideline should generate clarity and provide orientation.

In mastering the future project Industrie 4.0, a timely contemplation on the basics of previous work helps. With this in mind, this guideline briefly discusses the mindset behind the methods and procedures of lean systems. With this understanding and with relation to the challenges of mechanical engineering, subsequently digital paths to the development of lean are demonstrated.

We thank for the open collaboration with the VDMA work group, "Industrie 4.0 meets Lean", from which many valuable suggestions were incorporated into the guideline.

With this guideline, we hope to be able to provide you with at least a few recommendations for your further improvement work.

Sincerely,

Prof. Dr.-Ing. Joachim Metternich | Tobias Meudt | Lukas Hartmann

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Management summary

Lean Production was developed throughout the course of many years by TOYOTA and continuously expanded into a holistic management system. Within the scope of lean production, depending on the context and pursued improvement, certain methods are used in order to eliminate waste. Doing so often the basis of values and behaviors is neglected like leading on-site, respect, team work, and the development of exceptional employees. These values and behaviors make "Lean" a management approach that can be transferred to all company processes. This guideline now involves itself with the exciting question of how the Lean approach can be systematically connected with the new opportunities from digitalization and Industrie 4.0.

This guideline shows how the Lean approach can be systematically connected with the new opportunities of digitalization and Industrie 4.0.

First, the principles, basics, as well as the interplay of the most important elements of traditional lean production are presented. The next section includes a comparison of lean and Industrie 4.0. Here it is shown that there are similarities in their targets but differences in their approaches. As fundamental knowledge, it should be retained that the cycle of stabilization, standardization, the recognition of deviations, and employee-driven problem solving are at the center of a lean system. A digitalization that is consistent with lean should support every step of this cycle but must not break it up.

The guideline also emphasizes the depiction of the current limits of the Lean approach and the opportunity for enhancing and expanding Lean, especially in the project business of machine and system engineering. It shows that the targeted application of digital solutions allows for an expansion of standard work, makes the recognition of deviations easier, and can accelerate problem solving.

So that Lean in combination with digitalization can reach their full potential, in the guideline, the term 'waste' will be expanded upon, as wastes don't only occur in value creation, but also in handling information itself.

In addition, the information that is accrued during the value-adding process is attributed its own value, be it for problem solving, the improvement of the product flow, or an expansion of the service offering. Furthermore, the guideline extends the focus of the treatment of production to the entire order-processing, as large proportions of time are lost in upstream and downstream processes. These thoughts are incorporated into an expansion of the familiar Value Stream Design (VSD) method first presented to a wider public by Mike Rother. The VSD 4.0 is introduced in the guideline and clarified with the help of a practical example. An impressive reduction of work hours and throughput time as well as of wastes in handling information can be the result.

Subsequently, four applications from companies are mentioned, which demonstrate their own successful combination of lean and Industrie 4.0.

The presented guideline is a result of a close cooperation between the VDMA work group "Industrie 4.0 meets Lean" (to which 30 companies belong) with the Institute of Production Management, Technology and Machine Tools (PTW) from TU Darmstadt.

Starting point and objective

Starting point

Industrie 4.0 currently dominates the discussion about the development of production. Self-organization and self-optimized systems are being discussed as well as products that find their own way through production. Also, the protagonists of Industrie 4.0 are demanding a swift introduction of digital technologies as well as a rapid adaption of business models to not disappear from the market as a company. In contrast, critics say that Industrie 4.0 is bypassing people in its development. It is therefore in the interest of the authors to provide a guideline for practical application that shows where both approaches complement one another or where they contradict one another.

Especially SMEs have oriented themselves significantly on Lean Production in the last years. They now ask themselves which opportunities, demands, as well as changes for their production system may result from digitalization and Industrie 4.0 and how they should position themselves for the future. Currently there is no single holistic approach for this. However, there are promising examples that develop lean production in certain areas to new horizons. These are worth discussing within context and with certain objectives (e.g. speed or customer individuality).

Information was considered within the context of the Value Stream Design method, above all, in the light of production control. This perspective must be extended with regard to progressive digitalization and integrated into value stream planning. On the one hand, wastes in dealing with data and information are to be recorded systematically and finally eliminated. On the other hand, the information itself is valuable. It can be used to continuously improve processes (e.g. through component traceability combined with problem solving processes) or to increase customer benefits (e.g. through condition monitoring to trigger maintenance processes). This new view towards information must be represented in an extended Value Stream Design method.

The desire of customers for tailor-made problem solving leads to ever more individualized machines and systems. Wherever a customer desire exceeds the planned solution scope, however, increased amounts of special constructions and thereby an increase in the ratio of project work to overall business is the result. This has an impact on the entire product development process, from system design to purchasing, all the way to final assembly and maintenance. To keep the complexity of this process manageable, the logistical process chain including production must be able to handle individualization without losses in efficiency.

Objective

The guideline aims to demonstrate how by digitalization an increase in product diversity, down to the individual workstations, can become manageable with regard to such important standard work. The actual potential, however, lies in the reduction of the throughput time of individualized orders through a horizontal integration of data from the customer request all the way to delivery or maintenance. Such approaches already affect the business model.

For whom is the guideline relevant?

The guideline is intended for companies who would like to further develop their Lean Production system through digital technologies and are thereby searching for their first orientation and substantive inspiration.

What is not discussed within the scope of the guideline?

The topics that are not or only marginally discussed are change management, lean product development, process automatization, and complexity management.

Lean and Industrie 4.0 – two approaches, one goal

Lean Production – An attempt at a definition

The pioneer in the development and application of lean production is the Japanese automobile manufacturer Toyota. At first glance a variety of methods and principles are amalgamated under the umbrella of the Toyota Production System (TPS). Looking closer they comprise a holistic approach to the orientation of all activities towards the generation of customer value and the elimination of non-value-adding activities.

Lean is a strategic approach to improve operational excellence in the dimensions time, quality, productivity and flexibility. It is based on consistent values to engage people by leading from the shop floor, respect for people, teamwork and the development of exceptional associates and partners.

Whether in production or in adjoining areas like development or purchasing, the following applies: The fundamental mode of action of Lean lies in closely connected processes in which problems cannot hide and in employees who causatively solve these problems.

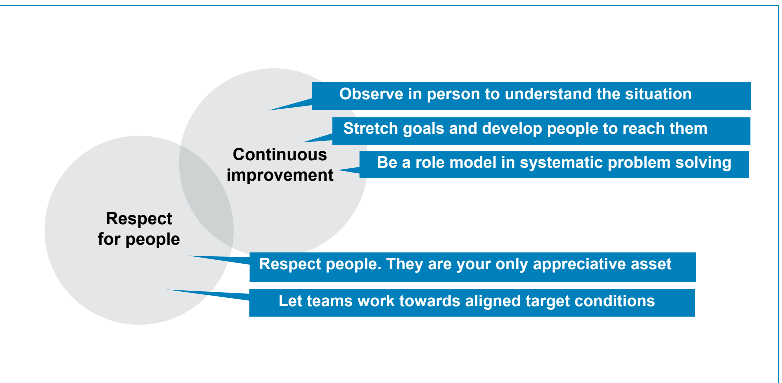


Fig. 1: Values and leadership behaviors in an example from Toyota [1]

Meaning of standards

Standards with regards to Lean Production determine the current best methods for fulfilling a work task. The following applies: The right process delivers the right results.

Standards are usually the result of a process analysis and the subsequent elimination of instability and non-value-adding activities. The improved process or procedure is documented and rehearsed for as long as it takes to deliver stable results. It is differentiated between general work standards (e.g. about safety in production), process standards (e.g. technical parameters), standard procedures (e.g. procedure of daily team meetings or material replenishment), and standard work. Standard work contains guidelines for

- the time it takes for the fulfillment of a work task
- the sequence of work steps, and
- the permitted inventory of materials at a workstation. [2]

Standards build the baseline for continuous improvement, as they comprise the basis to justify the current process performance and, thus, they enable the identification of deviations.

Lean is a holistic approach, not a methods toolbox

Many companies begin their journey with Lean in production, often with their first 5S campaigns or the development of KANBAN cycles for material controlling. If the correct methods are applied to the recognized waste, success will possibly set in. Often, however, disillusionment follows this project-driven approach, as these improvements are not sustainable. Among others, the reasons for this are:

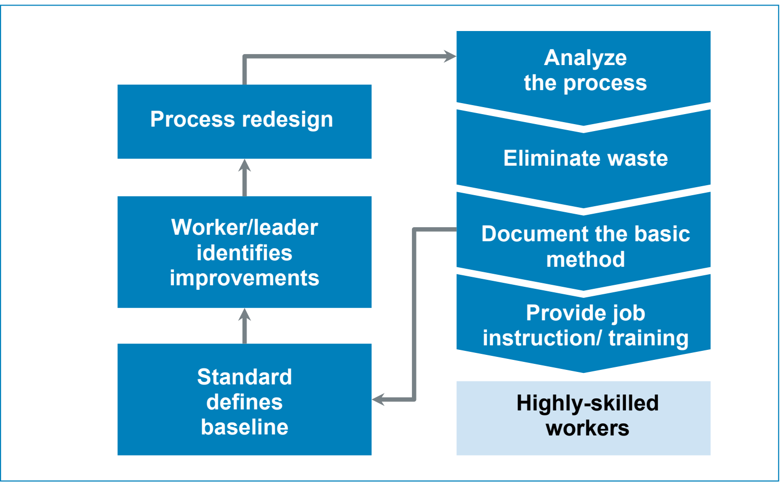


Fig. 2: Introducing, exemplifying and continously developing standards [2]

- The isolated method application does not take place within the context of other methods (e.g. the 5S is introduced production-wide instead of focusing within the scope of the running setup time project).
- There is no value stream vision that synchronizes the improvement projects among one another in a targeted way (e.g. a setup time reduction project is carried out at machine X without reducing subsequent lot sizes and throughput times).
- A culture is missing that secures the improvements (e.g. if management doesn't understand the necessity of standardizing and stabilizing new processes by detecting deviations).

The successful anchoring of Lean Production requires a system concept, a change in attitudes and awareness, and a long-term approach that extends beyond short-term savings targets.

The interplay of Lean elements in the Toyota Production System

Using the example of the TPS, the ideal interplay of lean elements is explained.

A The basis of TPS are organizationally and technologically stable or managed processes (e.g. in material provision or machining), that are subsequently standardized.

B The standardization of processes facilitates the secure (possibly takt-bound) interplay of processes and is the prerequisite for moving workstations closer together. The better processes work together, the lower the buffer stocks can be defined, the smaller is the space required, and the better are the material flows.

C The transfer of ever smaller batch sizes all the way to individual pieces facilitates the detection of defects, a quick escalation (Japanese: Jidoka), as well as the subsequent fault isolation.

D Visual management facilitates the recognition of deviations from standards (e.g. quality or process performance target).

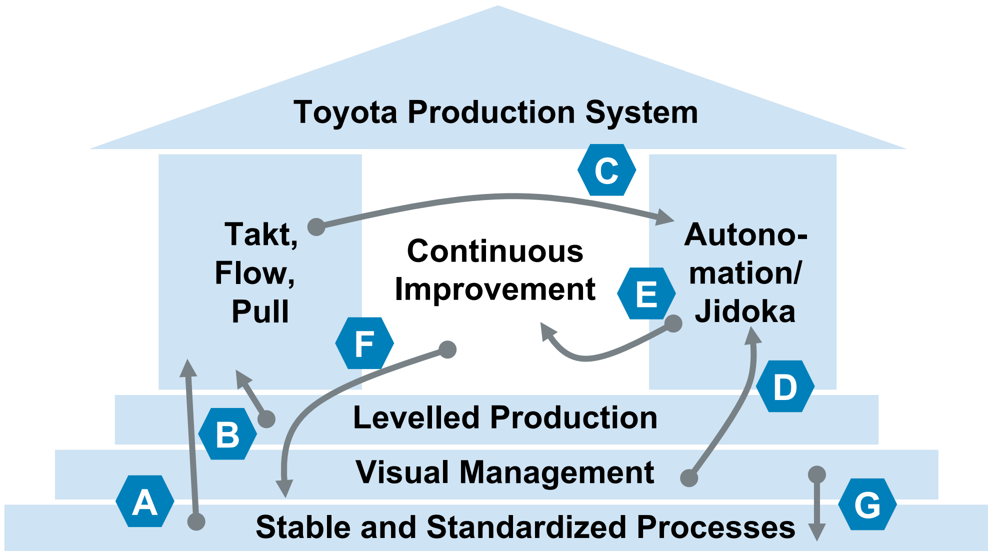


Fig. 3:
The Toyota Production System [2]

E Recognized target/actual deviations ideally trigger problem solving or improvement processes (cf. Plan Do Check Act, PDCA), which begin with the question of the true cause. Here, deviations can be recognized in comparison to an existing standard or even with respect to new, more demanding target conditions.

F Finally, improvements lead to a higher level of stability or more efficient processes as well as employees with increased problem solving skills.

Impact directions of digitalization and Industrie 4.0

Generally, digitalization can be characterized by two basic impact directions.

- First, by means of the digitalization of one's own internal processes for efficiency enhancement (Field A in Fig. 4). If the improvement of time, quality, and costs were the dominant topics of the past, flexibility and individuality are becoming increasingly more important.
- Second, through the generation of an additional customer benefit through the digitalization of the product or service offering (Field B in Fig. 4).

The digitalization and interconnectivity of the products provide machine manufacturers with the opportunity to keep interacting with the customer beyond the time of sale. The product becomes the basis of continual customer communication. This can result in new data-based services and possible business models. Here it is pivotal that an additional benefit results, which is perceivable by the customer (e.g. through quicker delivery in ≤ x days or increased technical machine availability at x %, etc.) and for which the customer is willing to pay. In a completely digital business model architecture, a digital process integration of the customer with digitally supported value-added service and a digital payment model are merged (Field C in Fig. 4).

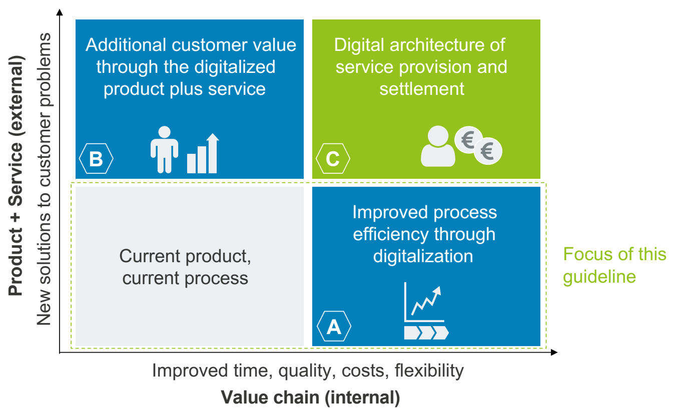


Fig. 4: Impact directions of digitalization [5]

Industrie 4.0

Industrie 4.0 stands for the superordinate idea of taking value creation to a new level through the merger of information and communications technology with production technology. This means knowing and networking products, operating resources, production processes, and organizational procedures. The networking should take place here both vertically from the sensor to the cloud and horizontally via customer-supplier relationships in value creation networks. The person takes center stage who orchestrates the digitally supported processes and is supported by digital tools in his or her decision-making. Employee motivation should be encouraged through tools. Intelligent products possess both information with regards to their own manufacturing process and the ability to collect and communicate data during the production and utilization phase.

The overall objective of Industrie 4.0 is to save costs by higher productivity and, at the same time, to achieve direct benefits for customers and for one's own company through better quality and new business models. Procedures should become more efficient and customers should profit from higher reliability of delivery as well as more individualized products. For the planning and implementation of Industrie 4.0, there is no template or methods toolbox. Each company needs to define and follow its own path.

Synergies and contradictions

Lean Production and Industrie 4.0 are essentially in pursuit of similar goals. Lean Production aims for improvements in the dimensions of time, quality, costs, safety, and motivation. Furthermore, Industrie 4.0 accentuates the

	Lean		Industrie 4.0
Approach	Holistic (person + technology + organization)	↔	Technology as driver
Philosophy	Respect, problem solving, employee development	↔	Feasibility, (self-)optimization
Foundation	Stability and standardization	+	Integration, adaptive
Control principle	Flow, FiFo and Pull	+	Dynamic, situation-dependent
Information acquisition	Current location, current material (“Go and See”)	+	Situation-dependent, data processing in real time
Improvement	Reactive in day-to-day business through employees	+	Self-optimization, prediction

↔ contradiction + supplementation

Fig. 5: Synergies and contradictions of Lean and Industrie 4.0 [5]

dimension of the individualization of products and services as well as their offerings within the scope of new business models.

As similar as the goals are, the approaches are quite different. With Industrie 4.0, the pursuit of simple, stable, and standardized processes is abandoned in support of more complex, self-controlling systems. [3] With that the standard, as the important basis in Lean Production for the recognition of deviations, is dropped. Instead of continuous, employee-driven improvement, systems based on big-data and algorithms should optimize themselves. [4] Systematic problem solving by people is potentially replaced by the search for correlation in data instead of the search for the root cause in the real-life process. Flow lines with takt and sequence are dissolved. Thereby important components of standard work are missing as a basis of the recognition of deviations. The line stop (Japanese: Jidoka), as possibly the most important pillar of Lean Production, is in danger. In the case of deviations, intelligent algorithms search for alternative production paths through decoupled systems and thereby cushion the impact of interruptions in the production flow. In this way the important pressure in a Lean Production system, to immediately recognize and analyze a deviation and come up quickly with a solution to the problem, is dropped. This short account provides plenty in terms of a potential for conflict in the interplay of both approaches. The risk of an ideal-typical implementation of Industrie 4.0 lies in the penetration of the “lean” improvement cycle from the recognition of deviations, the causative solution of problems, and the continuous development of processes and employees. [5]

If this topic is treated deliberately, digitalization and Industrie 4.0 offer a new, larger solution space for the development of Lean. The foundation for this is the opportunity for an exchange of information between random end points of the value stream in shortest time. Great potential is possible in the following areas, among others:

- The product, as an information carrier, generates data and actively controls its production process.
- The configuration of (standard) work instructions and workspaces takes place through the product.
- Condition monitoring leads to faster, more reactive problem solving, e.g. through the linking and processing of product and process data.
- Prediction allows for proactive problem solving if deviations are recognized before impacts on the production process occur.
- Companies are able to standardize large and customer-individualized workloads at less efforts, e.g. when the product provides the configuration and provision of its own standard work documents during the production process.

Lean 4.0 – reaching the next level of excellence through digitalization

The ideal in Lean Production is characterized by 0 errors, 100% value creation and 0% waste, one piece flow, and employee orientation. In the age of digitalization and Industrie 4.0, there is no reason to change something with this ideal. There are, however, new opportunities for bringing an existing Lean Production system closer to these goals step-by-step by integrating the potential of digitalization into the familiar Lean methods without giving up the underlying mindset (cf. Fig. 6).

If you consider the development of Lean in companies, different development horizons can be identified (cf. Fig. 7):

1. Lean – first walking attempts

Many companies make their first lean walking attempts with topics like 5S, quick setups, KANBAN and group work. If this "Lean toolbox" is used within the scope of individual improvement projects without the system mindset, Lean will not unfold its full effect and the results won't be sustainable.

2. Value stream perspective

With the goal of letting products flow and reducing throughput times, Value Stream Management helps to develope the vision of a lean value stream Taking this up, Lean projects serve the implementation of this vision and are placed in a general context. Initially stabilized and then standardized processes are geared towards the customer takt. Significant improvements in quality, productivity, and inventory are often the result. This approach is driven from the top-down, however.

3. Employee perspective

In order to secure an achieved condition and continue to improve, deviations from standards (such as time constraints, process parameters, etc.) must be reliably recognized by employees and management and have to trigger new PDCA cycles. Many companies are currently introducing such an improvement approach with "Shop Floor Management". It is supported by leadership that clearly specifies an improvement direction (but not the solution) and supports its

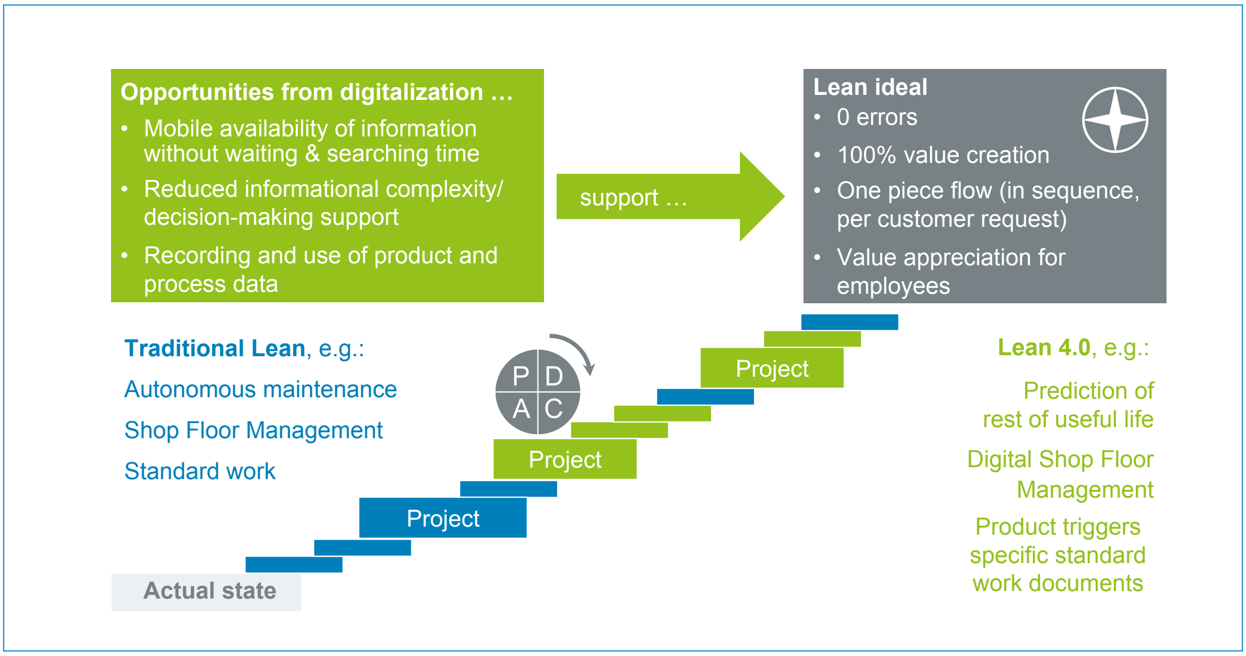


Figure 6: Integration of digitalization in traditional PDCA improvement processes

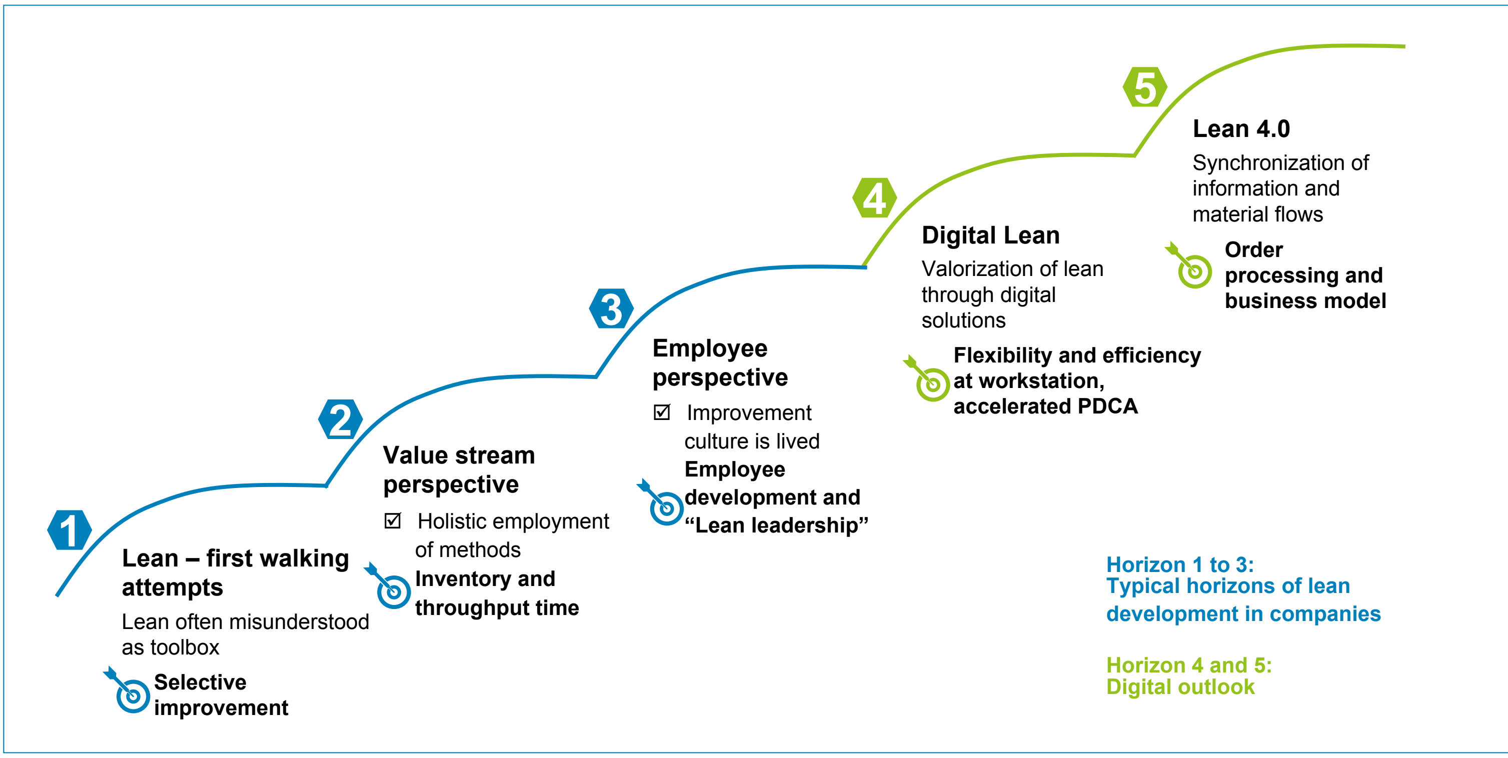


Fig. 7: Typical horizons of lean development in companies (horizon 1 to 3) and digital outlook (horizon 4 and 5)

employees in daily improvement routines. This demanding leadership approach leads to continuous process improvement along with the simultaneous development of employees and their problem solving skills.

4. Digital Lean

Only after a sufficient degree of Lean maturity has been reached and the respective culture has been anchored, the digital upgrading of established solutions should be started. A focused digitalization must take place within the context of the overall value stream goals. Questions can be, for example: Which workstations or machines are especially critical to quality? At which workstations does a flexible and simultaneous mistake-proof design play a role? Which problems were not able to be solved to satisfaction up to this point? Before a new technology is introduced, it must also be asked how stable it is, which new process risks it brings along, and whether it can be integrated into Lean procedures without additional waste. In this way, for example, a problem analysis solely on a data basis or on a screen contradicts the underlying Lean improvement principle of directly and personally grasping the situation at the location of occurrence (Japanese: Genchi Genbutsu).

5. Lean 4.0

The digital upgrading improves a lean system within the previous value stream thinking. In order to achieve the next horizon in terms of faster and more flexible order processing, a cross-departmental synchronization of information and material flows is necessary ("Lean 4.0"). The starting point is therefore the customer's request and its integration into the supplier's IT systems. One question, for example, can be how individualized customer requirements can be implemented in terms of standard work at every workstation without additional planning effort (e.g. during work preparation). Here, at the latest, Lean abandons production and becomes a company-wide management approach.

Digital development paths using the Toyota House as an example

Lean production often appears as an approach that comes from the large-scale production of automobiles and from time to time reaches its limits in the project business of machine and system engineering. A high percentage of customer individuality, a low repetition frequency of activities, and extensive work contents impede the standardization of procedures and thereby prevent the basis for a sustainable introduction of lean. Especially the aspect of overcoming these limits through digital opportunities will play a role in the following chapter. For each element of the TPS the underlying mindset will be briefly introduced and where the practical implementation often reaches its limits will be shown. Subsequently, the opportunities for overcoming these limits within the context of digitalization and Industrie 4.0 will be presented.

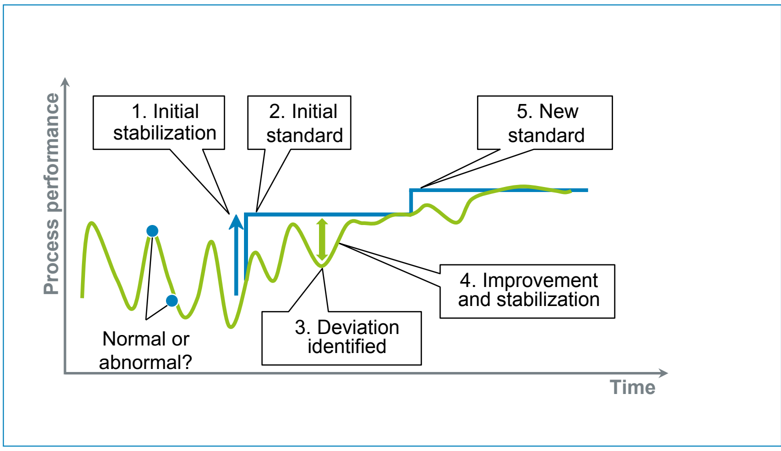
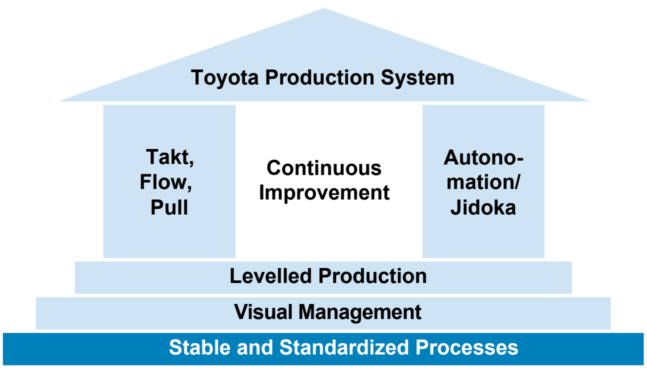


Fig. 8: Connection between stabilization, standardization and improvement

Stable and Standardized Processes

The stabilization and subsequent standardization of processes is the foundation for continuous improvement processes. The recognition of deviations is only possible through standards with a continuous target/actual comparison. Stability and standardization are furthermore the prerequisite for running further TPS elements, such as flow production or the triggering of PDCA cycles. Therefore, stability and standardization build the foundation of the TPS.



Limits of Stable and Standardized Processes

Customer-specific individual products cause a high processing effort from sales to adjustment development, purchasing, and work preparation all the way to production and service. The creation of standard work instructions for individualized products and their components is time-consuming and error-prone. The processing and cycle times vary both in production and in all other areas. Frequently changing processing tasks mean that it is almost impossible to set times for workplaces and systems. But without standard specifications, deviations and underlying problems can hardly be recognized.

Opportunities through digitalization and Industrie 4.0

Opportunity 1:
Extend standard work in customer-individualized production

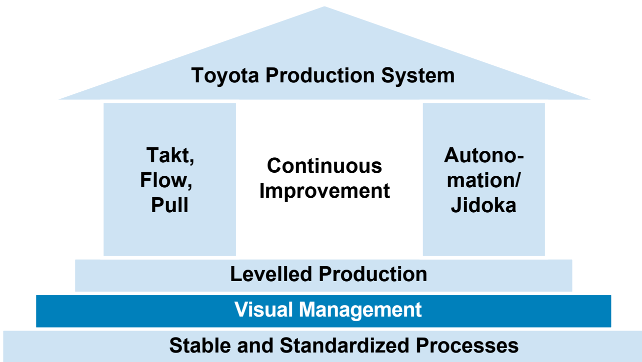
Analogous to the structure of the product program, related work and process standards can be modularized and digitalized. Subsequently, the work documents are adaptively configured for each of the products to be produced and digitally made available to the operator on-site. In this way, quantity and time per unit can also be specified for non-series production. These adaptive work standards, in turn, are the basis for managing deviations as a foundation of continuous improvement processes.

Opportunity 2:
Reducing effort in production preparation, avoiding mistakes during execution
The modularization and digitalization of work instructions means increased initial effort, but subsequently reduces work preparation effort for individual orders. Digital worker assistance systems provide the current information and thereby avoid improper processing caused by outdated paper documents. This way, paper will continue to be increasingly replaced in production by networked, electronic media. At the same time, assistance systems (e.g. pick-by technologies in commissioning) can avoid or recognize wrongful acting. Thereby, quality can be improved, order throughput time be reduced and flexibility be increased.

Opportunity 3:
Increasing the reliability of machines
Many companies measure the efficiency of their machinery and equipment and record the reasons for loss. Regardless, unplanned breakdowns still occur. The targeted equipping of existing systems with networked sensors can help to detect critical conditions (contamination, filling levels, wear and tear) at an early stage and to plan the maintenance or replacement of components in good time (e.g. during the next planned maintenance shift). The next predictive level of maintenance can be reached with machine learning. Through the linking of a machine's condition data with labeled event data (dimensions, surface areas, tool breakage, etc.), connections can be found and future events predicted.

Visual Management

The visual representation of process conditions and performance as well as standard procedures and work documents provides employees and management with the opportunity to recognize deviations immediately and without additional aids and activities. A good visualization makes standards simple and easy to understand through optical elements without additional tools so that no deviation keeps consealed. The identification of deviations is in turn a trigger for continuous improvement processes.



Limits of Visual Management

Manual recording, continuous updating and subsequent visualization of key figures is time consuming and error-prone. The performance of a process is often only recorded at the end of a shift or a week. This wastes valuable response time for managers and employees.

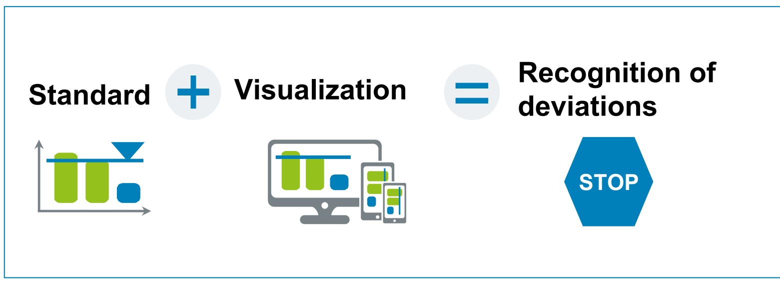


Fig. 9: Recognizing deviations through standards and visualization

Opportunities through digitalization and Industrie 4.0

Opportunity 1:
Early detection of deviations – Employee perspective

Important information about one's own process can currently be made available to the employee directly at his or her workstation or anywhere else. In the simplest case, this is the current target/actual performance comparison (e.g. for number of units/productive time and scrap/rework time). This way, the employee can react or escalate in a timely manner. By expanding information to a simple trend analysis all the way to the prediction of deviation (realized through machine learning), the employee can engage proactively before negative effects on the process occur. Already today, for example, the failure of tools can be predicted. Depiction can take place, depending on the user, on-site via monitor, smartphone, or directly on a smart wearable (watch, glasses, etc.). This way, information can be made available directly to the respective employee.

Opportunity 2:
Early detection of deviations – Management perspective

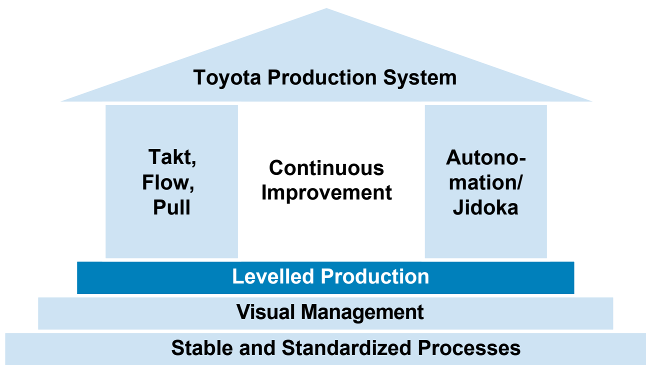
Through the digital and direct provision of actual values, trends, and prognoses, management is provided with the opportunity to intervene more quickly. The daily meetings on the shop floor can be supported by the current values of important workstations, machines and systems, which are sent via radio technology directly to a device. Escalation cascades are pushed beyond the limits of manufacturing execution systems (MES) or enterprise resource planning systems (ERP) and management can provide support early on, reallocate resources, or situationally find solutions.

Opportunity 3:
Solving problems more quickly with digital shop floor management

In daily shop floor meetings, above all, it is about recognizing target/actual deviations and describing these for the subsequent problem solving as comprehensively as possible. Figures, measurement results, and process data provide help and enrich the structured problem definition. Their digital measurement can bring about a temporal relief. The far greater benefit of digitalization lies in the possibility of detecting relations between deviations (e.g. product defects) and the associated process data (such as temperatures, power consumption, feed forces, etc.).
In this way, the point at which the error occurs can be narrowed down more quickly and more reliably. Utilizing documented digital PDCA cyclesenables a networked search for similar events and thereby successful solutions.

Levelled Production

The direct transfer of fluctuatingdemand to production leads also to a fluctuating capacity utilization. This results in provision of additional capacity, unused capacity, as well as continuous plan changes, also in supply. The stronger the fluctuation of capacity, the harder it is to adhere given standards and processes, with the corresponding consequences for quality as well as managing deviations. Therefore, through levelling and smoothing, the planning of production is decoupled from the market demand to a certain extent. This takes place, on the one hand, with a view to the overall capacity of production, in which orders are planned only until the attainment of maximum capacity. On the other hand, orders are scheduled with a smoothing pattern ("mix") so that individual stations are not overloaded while others are simultaneously underloaded.



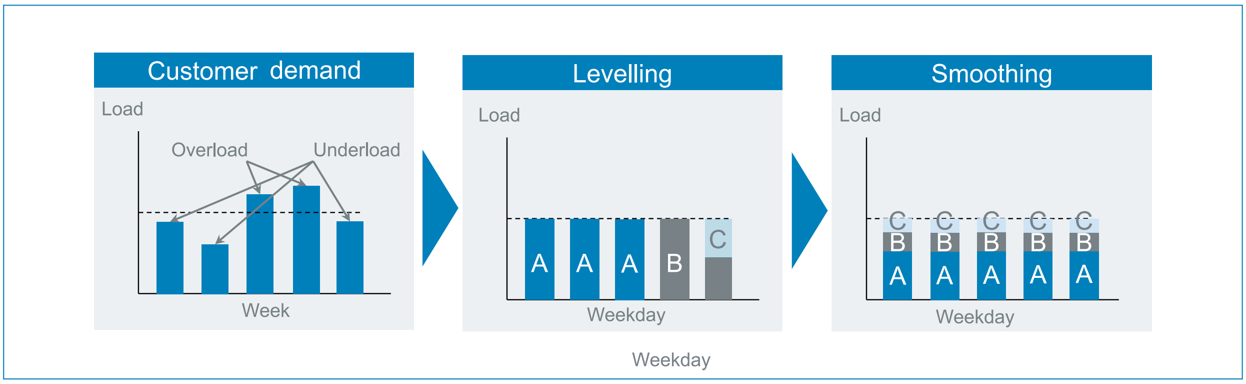


Fig. 10: Mode of action for the levelling and smoothing of customer demand

Limits of Levelled Production

Levelling and smoothing fluctuating demand for customer-individualized products is a challenging task. This is mainly due to the very different character of products and the associated fluctuating load of individual workstations or production areas. In this environment, master data, order data, resource data or project data are barely maintained or not available. Furthermore, available resources are unknown when decisions on the quantities and deadlines are made. Cooperation between sales, customization development and work scheduling is not synchronized, which is why customers are promised orders that cannot be realized within the specified time frame.

Opportunities through digitalization and Industrie 4.0

Opportunity 1: Making better decisions in sales

For the even planning of orders, it is already necessary in sales to estimate a new project's capacity requirements in individual areas or at different locations and to synchronize it with the available capacity. The basis for this is on the one hand the division of the available capacity into so-called capacity buckets On the other hand, maintaining bills of material and standard times in the ERP system is needed. While this is a standard function of current ERP systems, the great opportunity lies in making the capacity available for sales via a mobile frontend. Within a time frame (e.g. one week), only a certain amount of orders is confirmed until the associated capacity bucket has been exhausted. This way, customers can be promised more realistic delivery dates and throughput times decrease, as the inventory of already begun orders is avoided by less rescheduling.

Opportunity 2: Better utilization with simpler planning

For certain product properties, a solution space can be defined that can be mapped by production without major planning and set-up effort. Configurators enable the sales department or even the end customer to find their individual solution based on rules. If the affected production system is prepared for all parameter combinations without major set-up effort, customers can book the next free deadline for their orders themselves. There is no need for the creation of engineering drawings, the writing of offers, as well as activities in work preparation.

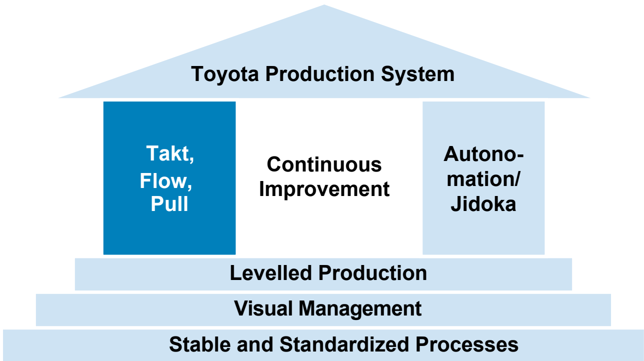
Opportunity 3: Self-organized pull planning

In defined segments of production (e.g. final assembly), free workstations can pull the next suitable order from a reserve of released and prepared orders. This is supported by automated guided vehicle systems (AGV) which transport the preliminary product and the required material to the next free station. The goal is an efficient and even use of available capacities.

Takt, Flow, Pull

The customer takt is the average time that passes between the shipment of individual products of a product group. The closer and more stable process steps can follow the customer takt, the more closely they can be connected, the less unproductive waiting times occur and the better the material flows.

"Pull" means that material movements or orders are only authorized or started by a demand of internal or external customers. Within the scope of flow and pull, the customer takt synchronizes the activities of all parties involved in the value stream so that they intertwine with as little waste as possible.



Limits of Takt, Flow, Pull

If products are very different with regards to their work content and bills of material and if their demand fluctuates strongly, then determining a customer takt is very demanding or even impossible. The stronger the fluctuation of the work content within a product group, the more demanding it will be to economically organize flow lines with takt. Also, big machines and systems can only be moved between stations with great effort, which is why they are often constructed at the location. At the level of the production material, pull control according to the supermarket principle can only be economically implemented for materials that have a regular consumption and a not too high value.

Opportunities through digitalization and Industrie 4.0

Opportunity 1:
Reducing cycle times through an improved flow of information

In project business, a value stream analysis should take place from the first contact with the customer all the way to the maintenance of a product. Thereby, special focus should be on idle times and waiting times due to missing information (authorizations, documents, programs, etc.). Here, the following rule applies: No order may wait due to missing information. The necessary extension of the value stream focus to production-related areas (work preparation, order planning, logistics) provides valuable new insights. Subsequently, unused information is to be eliminated and the measurement, transfer, and provision of necessary information is to be improved through digitalization.

Opportunity 2:
Aligning material logistics with demand

Inventory at workstations and lines can be reduced if transport orders for material are only triggered by a pull signal from the line itself (e.g. via MES). Here, the release of productions orders is to be treated separately from the authorization of the transport orders. For large assembly works the request for retrieval of the material can take place in this way in accordance with the assembly progress through appropriate terminals at the assembly site. A better levelling of the workload in logistical areas is the result.

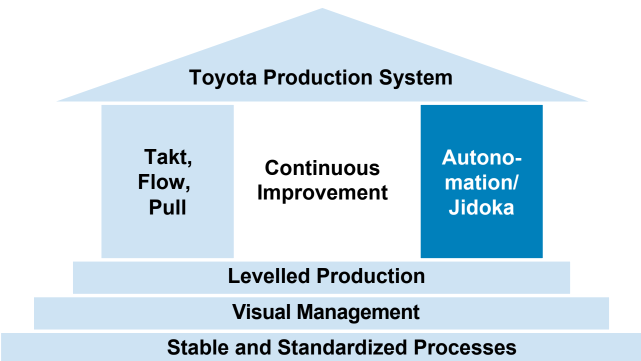
Logistical elements like supermarkets or FIFO (First-In-First-Out) lanes can be made more flexible through digital support.For example, by dynamically adapting inventory to demand and supply patterns. eKanban helps reduce inventory by a faster transmission of information. Milk run systems (e.g. routes) can be dynamically adapted to the current demand. The drivers of a milk run train are to be shown all necessary information in order to guarantee the shortest routes and to avoid mistakes. Automated guided vehicle systems also find application here.

Opportunity 3:
Utilizing assembly lines in a better way
By adapting the workstations, a larger spectrum of different products can be economically assembled at the same stations. Here, the ability of products to identify themselves at workstations (so-called active traceability) proves helpful. It is conceivable that a product configures its own work instructions, triggers the picking of its individual materials, or ensures that the workstation is digitally supplied (the product controls the process) with the suitable process data (e.g. torque, NC program codes, test programs, etc.).

Opportunity 4:
Recognizing bottlenecks early on
Through the networked representation of the information from critical reporting points and a tracing of materials along a supply chain, bottlenecks can be recognized early on and countermeasures can be taken before serious disturbances occur.

Autonomation / Jidoka

Autonomation / Jidoka pursues the goal of developing processes that allow only to produce good parts. This should be achieved through mistake-proof devices (Japanese: Poka Yoke) as well as through a workstation design that guarantees zero defects (so called "built-in quality"). In case of problems occurring they should be reliably recognized by machines or employees, which usually triggers a defined escalation process that can lead all the way to the stop-



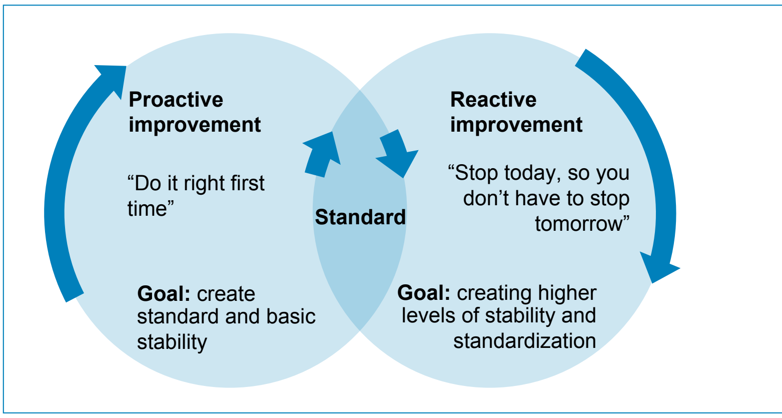


Fig. 11: Goals of proactive and reactive improvement

page of production (reactive improvement cycle). It is important to ensure a short feedback loop to the location of an error, so that containment can start quickly and a problem analysis can be carried out with fresh and reliable information. This is the prerequisite for short-term protection of the customer and a sustainable problem solution.

Limits of Autonomation / Jidoka

If small quantities of different products are produced at the same workstation, often a 100% avoidance of error through devices cannot be achieved with acceptable effort. Without a clear specification of process parameters, work steps and expected work progress, the recognition of deviations is hindered. Escalation cascades (who reacts until when?) do not work safely, if they are defined at all. If a problem is nevertheless identified, measures are first taken against the effect of a problem. A systematic, causal problem solution is often omitted, so that a problem can reoccur. However, if a systematic approach is taken, problem analysis is often sloppy because associated process information is missing or can only be obtained with a great deal of effort. This leads to inadequate measures or prolongs the problem-solving process.

Opportunities through digitalization and Industrie 4.0

Opportunity 1:
Increasing safeguard against improper mishandling (production)
Where hardware solutions are too inflexible to handle variety, improper handling and mistakes during execution can be prevented through software-based solutions. Products that identify themselves when registering for a process (e.g.

at a screw or test station) can initiate the configuration of devices, tools, and work instructions specific to them. Digital worker assistance systems show work documents and steps via a monitor or data glasses. The movements of a person can be followed through ultrasound or camera systems and compared with the expected procedure in order to intervene in the event of deviations. In this way, mistake-proofing processes can finally be achieved by a software-supported, adaptive Poka Yoke.

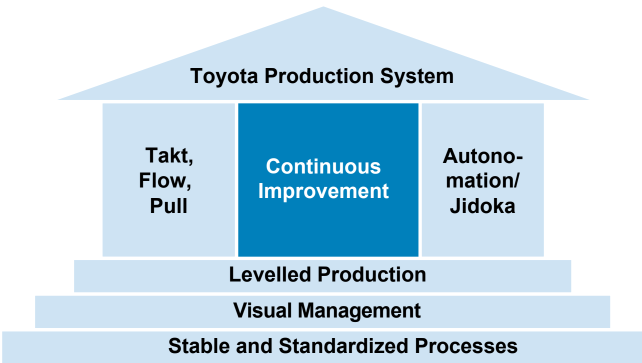
Opportunity 2:
Avoiding improper handling in information flow
In areas that are upstream or downstream of production (e.g. development, work preparation, or shipping), IT system discontinuities are to be avoided that can lead to the error-prone transmission of data and waiting times. Generally, in these areas all activities with mainly repetitive character are to be critically scrutinized.

Opportunity 3:
Solving problems more effectively
Through component identification and back-tracking, product and process information can be comprehensively interwoven. Defective products can be better narrowed down. Also, the location of the emergence of an error can be found faster and problems can be described more fully.

Opportunity 4:
From reacting to preventing defects
The linking of process data with deviations allows for the training of systems. In this way, conditions in the future can be forecasted based on current process data. The residual lifespan of tools or components for instance,can be determined. In several cases, problems can be proactively recognized and solved without defects emerging. This results in a reduced rate of rejects and rework.

Continuous Improvement Process (CIP)

The reduction of non-value-adding activities forms the core of a lean system. Improvement activities are either reactively initiated through deviations from target conditions or proactively created through the provision of newer, more demanding goals. The underlying approach of improvement follows the PDCA cycle. Deviations from standards or gaps to targets initiate the PDCA cycle anew every day. Employees solve the underlying problems and ideally thereby improve both their processes and their own problem solving skills.



Limits of Continuous Improvement Process
Occurring problems may have already been solved elsewhere in the same or a similar form. Often the team lacks knowledge of these solutions which could shorten the problem solving process.

If the problem complexity is underestimated and an appropriate problem analysis remains undone, then the cause-effect-chain will not be traced back to the root cause. In consequence the defined measures very likely won't address the root cause. Such a process can only effectively solve "simple" problems.

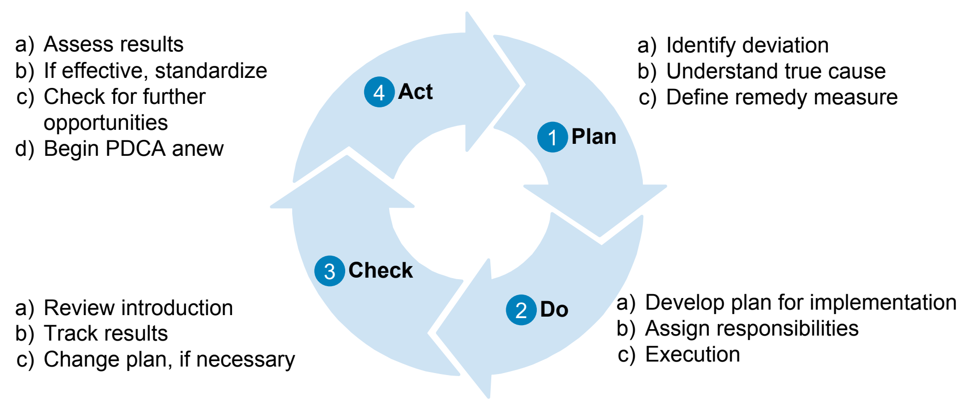


Fig. 12: The PDCA cycle

The more complex problems are, the more spread out the activities of the PDCA cycle across multiple employees and departments. This complicates the pursuit of deadlines and results on the action plan and the probability increases that the PDCA cycle is only undergone incompletely. Typically, a measure is only partially implemented (Plan & Do), the necessary success monitoring on-site remains undone (Check), and the improvement approach “peters out” with time.

Opportunities through digitalization and Industrie 4.0

Opportunity 1:
Transparency in the tracking of improvement measures

Software-based action plans help to more easily track the progress of individual measures and to increase transparency through the allocation of tasks amongst employees and between different departments. At the same time, they help to ensure the complete execution of a PDCA cycle.

Opportunity 2:
Improving knowledge management

The digital documentation of successful problem solutions and their implementation can take place through databases (e.g. in the form of a Wiki system). The opportunity for a networked search for these activities can prevent the same problem or similar problems from being solved twice.

Opportunity 3:
Better recognizing complex connections

The process data that belongs to a deviation or a defect can be automatically integrated into a systematic problem analysis and clearly depicted. In this way, the team receives a better foundation for the subsequent search for the cause.

The stated opportunities can, for example, be realized through digital Shop Floor Management.

The path to a lean, digital value stream

The customer-individualized project business is formative for many companies in mechanical engineering. An exemplary analysis of the throughput times of orders of a manufacturer of customer-individualized machine components shows that the largest proportion of time goes towards development and parts procurement, followed by customer contact during project clarification and in the context of delivery and commissioning. The product only spends a small portion of time (4% in the example) in production. It can be assumed that a similar time distribution can be observed in many companies in the industry.

Today, the Value Stream Method, as suggested by Mike Rother and John Shook, is the standard in many companies that want to improve their product flow, reduce inventory, and decrease throughput times. [6] The method's focus is mostly on the parts and product flow from supplier to customer. Information flows are essentially regarded from the perspective of production control and its improvement.

The extended Value Stream Method

If the objective, however, is to satisfy individualized customer requests quickly, flexibly, and, at the same time, efficiently, only considering production, material flows, and the associated control information falls short. For this reason, in the following, the focus of the traditional Value Stream Method will be extended to all areas involved in order processing, including the customer. Furthermore, the information within the scope of this method will be considered from three new perspectives:

- Waste in handling information
- Use of information for process improvement
- Use of information to increase customer value

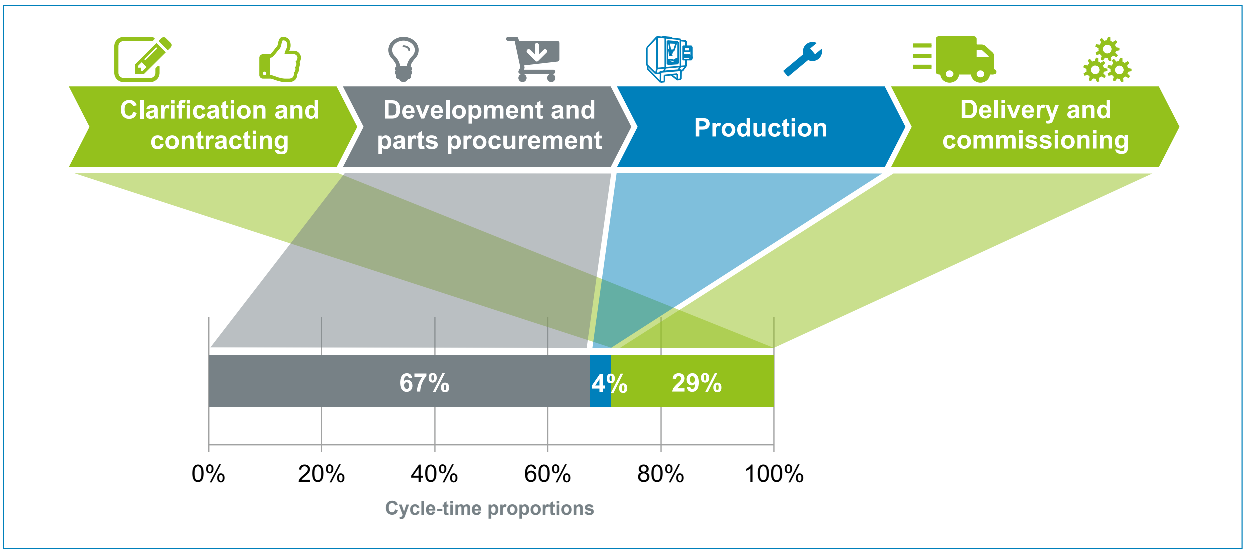


Fig. 13: Assessment of the throughput time proportions from the initial customer contact to the commissioning of a system (example taken from a company in plant engineering)

A look at waste in handling information

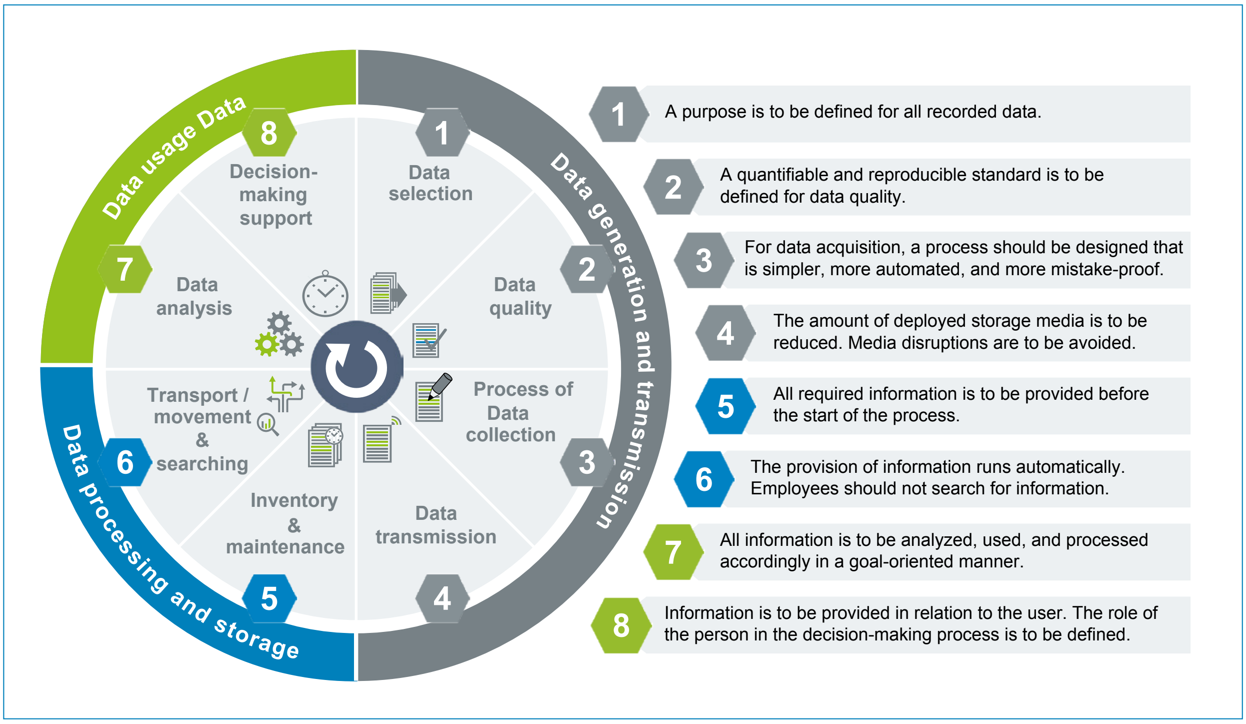


Fig. 14: Eight types of waste in information logistics and guiding principles to prevent individual waste in information logistics [7]

Lean activities typically aim for eliminating transport, inventory, movement, waiting time, overproduction, over-fulfilling processes, and defects. [2,6] These traditional types of waste provide support in the analysis of material flows and production itself, but they cannot be transferred directly to information flows. In order to holistically recognize wastes and potential in handling information, a new perspective is necessary. Following material logistics, the term information logistics is therefore introduced. For this, the goal is formulated to provide information at the right time, at the right place, in the right amount, and of the proper quality and ultimately to be used in a target-oriented manner. This should take place with as little waste as possible. [7]

Within the scope of a Value Stream Analysis 4.0, eight types of waste in information logistics are introduced that emerge along the lifecycle of information and can be assigned to defined phases. A cycle consists of three phases:

- Data generation and transmission
- Data processing and storage
- Data usage

The individual types of waste in information logistics are clarified in the following by guiding questions.

Phase of data generation and data transmission

The goal during data generation and transmission is to make the desired data available in the proper quality. Wastes can occur in the:

Data selection

- Has a purpose been designated?
- Is clearly defined what the data will be used for?

Data quality

- Do the frequency and level of detail of the collection fit with the intended use?
- Has the data been collected and transmitted in a standardized manner?

Data collection

- Is the collection of data appropriate with regard to the costs and benefit?
- Is the regular collection of data automated?

Data transmission

- Does an interface-free communication of data take place?
- Is the data stored centrally?

Phase of data processing and storage

Data and the resulting information should be processed continuously and without waiting time in order to be available for decisions or activities. Wastes can be:

Waiting times and inventory

- Can an order not be processed because information is missing?
- Is data and information available at exactly the right time?

Transport, movement and searching

- Can employees find the required information without searching effort?
- Is the presentation medium suitable?

Data usage

The data compacted into information is to be used purposefully, either for order processing, for the improvement of processes, or to increase to product's value. product value The following wastes can arise:

Data analysis

- Is the recorded data analyzed with appropriate methods?
- Are these analyses used?

Decision-making support

- Is the data verifiably used for decisions or improvement activities?
- Is the information processed in accordance with its use?

Value Stream Method 4.0

Through the Value Stream Method 4.0, all product and information flows of a value stream are analyzed and designed. It comprises the Value Stream Analysis 4.0 (VSA 4.0) and the alue Stream Design 4.0 (VSD 4.0). The approach extends across departments from the first customer contact all the way to the shipment of the product. The goal of the method is to develop all processes of a value stream in such a way that customer requests can be satisfied quickly, flexibly and thereby efficiently. The emphasis here is on the simultaneous consideration and synchronization of product and information flows.

Approach in three steps – an overview

Step A – Define added value

The starting point of the Value Stream Method 4.0 lies in obtaining a basic understanding of what generates customer value. This refines one's awareness during the search for wastes.

Step B – Analyze the current state

Within the scope of the traditional VSA, process data, inventory, and control information are recorded and so-called "Kaizen flashes" (improvement opportunities) are delineated. The scope of the VSA 4.0 is extended to the entire order-processing, begins with the first customer contact, and goes all the way until product usage. A detailed observation of the information flow follows during the order cycle. It targets wastes that emerge during the handling, transport and usage of data and information (so-called wastes in information logistics).

Step C – Determine the future state

Only a fundamentally stable and, with regard to material flow, lean value stream should be digitally supported or digitally valorized. Therefore, the traditional VSD, with its design rules, continues to remain the first step to the digital target condition. The resulting value stream vision is improved through the targeted use of digitalization solutions in order to stabilize or expand the flow, or to eliminate process steps. The VSD 4.0 focuses on the integration of product flows and the necessary information flows as well as on elaborating a consistent implementation in IT systems.

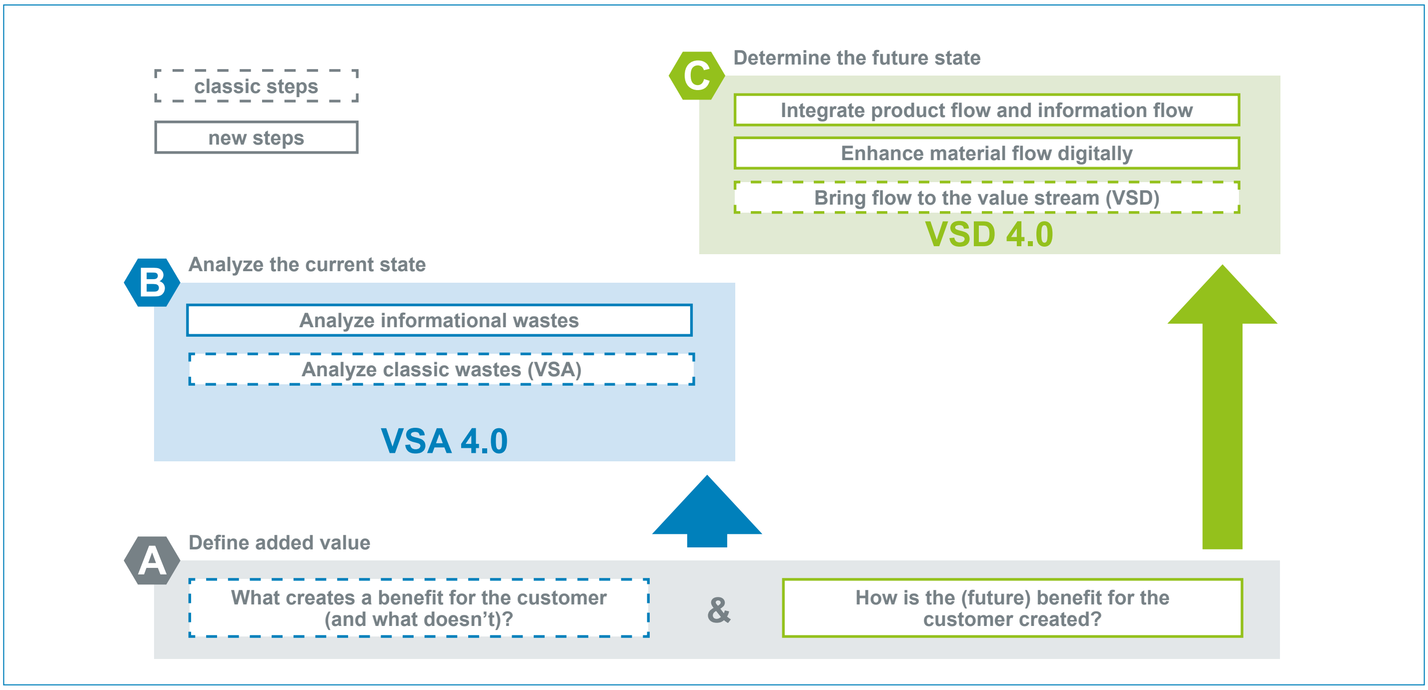


Fig. 15: Approach of the Value Stream Method 4.0

Execution of the Value Stream Analysis 4.0

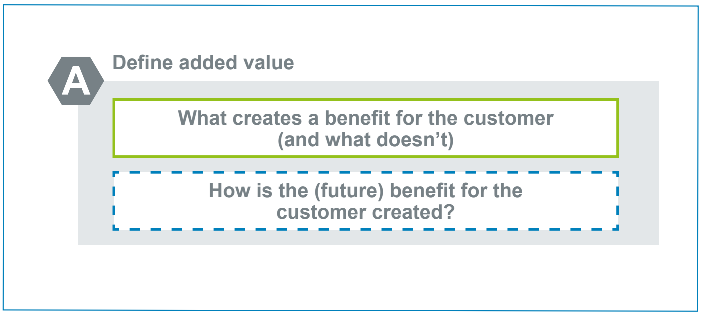


Fig. 15a: Customer value as the starting point of a value stream analysis and design

Starting the project & defining added value

Before the start of the project, the product or product family is determined, which is going to be analyzed. A product family is a group of products that occupies the same or similar resources in production and order processing. The VSA 4.0 is carried out for the entire order processing process. Therefore, the project team must also be assembled cross-departmentally. Employees from marketing, sales and adjustment development should especially be integrated.

At the beginning it should be clarified which product characteristics are especially important for customers and how they are created today (Fig. 15a). This helps refine one's awareness for non-value-adding activities in the VSA. At the same time it is to define, what the value stream has to accomplish in the future in order to establish a striving competitive advantage (e.g. "…we deliver faster than…", "…free product configuration…") and to realize the planned business model. Then a clear target should be set by management which KPIs should be improved for the selected product group (e.g. reduce order throughput time to X days, reduce First Time Failure Rate to Y ppm, etc.) to achieve the desired competitive advantage. This makes it easier for the project team to prioritize improvement opportunities. In this way, improvement ideas can already be thought up by the team during the analysis phase to shape the future state vision.

Analyze the current state – Value Stream Analysis 4.0

The traditional VSA initially creates an overarching understanding of the value stream for all involved. The result is a value stream representation with visualized areas of potential, the Kaizen flashes. [8,6] The familiar process boxes from the VSA are first extended upon in the VSA 4.0 in such a way that the collected information sources can be represented in extended notation. The type of data collection is characterized by the collection interval and its type of recording. At the same time, the respective current value is determined and inscribed in the process box. This notation should be used as uniformly as possible across all processes (Fig. 16).

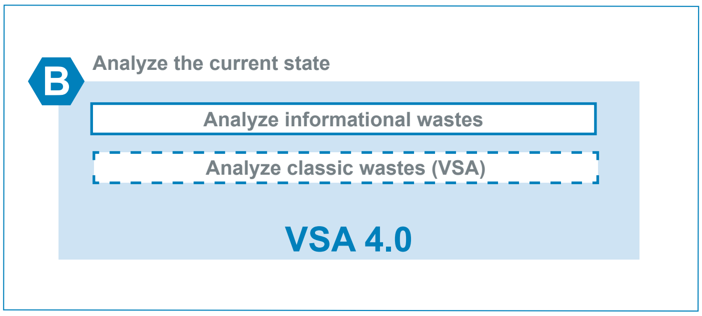


Fig. 15b: Extended focus on wastes in handling information

Unrstanding and incorporating storage media for information

To make the handling of data and information transparent, horizontal lines for each used storage medium are now delineated on the value stream map below the process boxes. [9,10] Examples of storage media are paper, ERP systems, MES or MS Excel®, as well as the employees themselves. Next step is the analysis and representation of the information flows from the sources to the storage media. Therefore, information sources are affiliated with the associated storage media through vertical lines and nodal points.

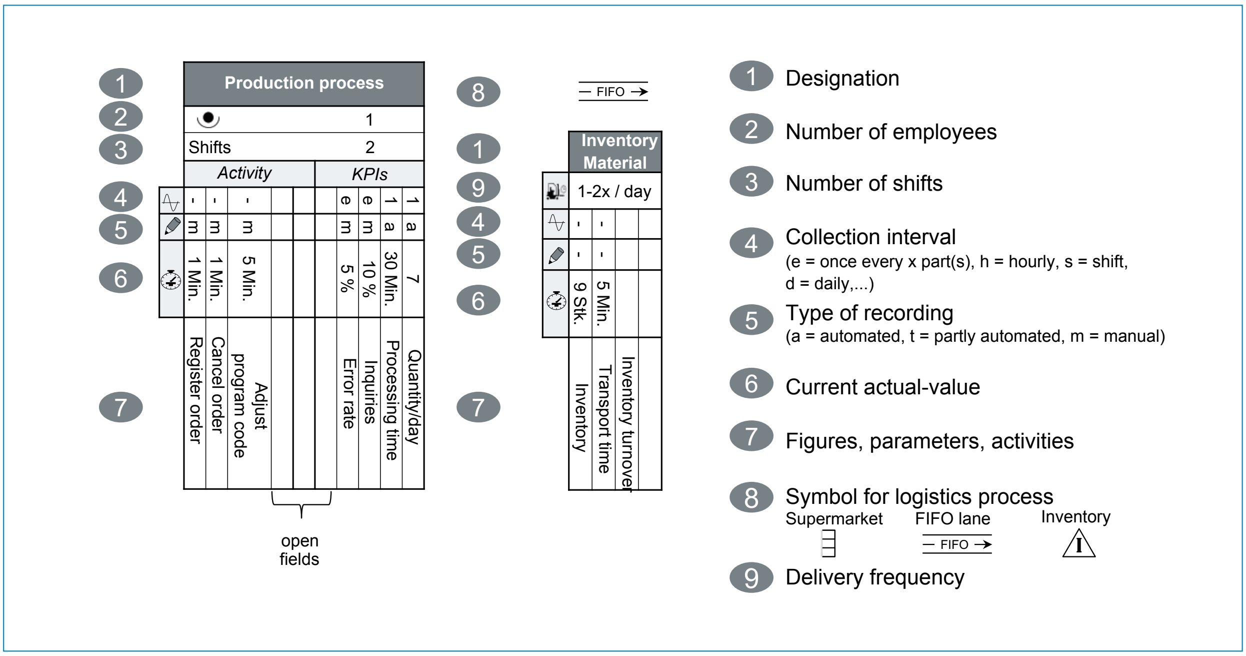


Fig. 16: Notation of production and logistics processes in accordance with VSA 4.0 (exemplary data in the fields) [10]

Analyzing the use of information

Subsequently, there is a review of which applications the collected information is used for, e.g. in quality management, for order control, or for shop floor management. For every type of usage, just like for storage media, horizontal lines are inscribed. Information sources, in turn, are subsequently affiliated with the applications through vertical (in this case, dashed) lines and points. Here it already becomes evident as to which collected information will not be used or will be used differently than intended.

Recording wastes in information logistics

In this step, the already introduced wastes in information logistics are recorded for all processes and inscribed as Kaizen flashes. Furthermore, the observed level of waste in dealing with information can be quantified by means of figures. As an example, here three figures are specified: [9]

- Data availability: It answers the question what percentage of necessary information/figures is actually being recorded.
- Data usage: It shows what percentage of the recorded information sources is actually subsequently used.
- Digitalization rate: It discloses what percentage of the recorded information sources is digitally recorded.

These figures can be calculated for a single workstation, a line or the entire order throughput.

Example application of VSA 4.0

The example shows a portion of the value stream of a special machine manufacturer, which extends from customer contact all the way to production (Fig. 17). Though products are individually adjusted in size and material depending on the customer's application the order-specific information processing (customer clarification, adaptation of drawing, CNC programming) is basically the same for every customer project. The programming time for an order amounts to approx. 30 minutes and ultimately represents an implementation of the customer's desired product parameters in a CNC code.

The following wastes arise from the traditional value stream analysis:

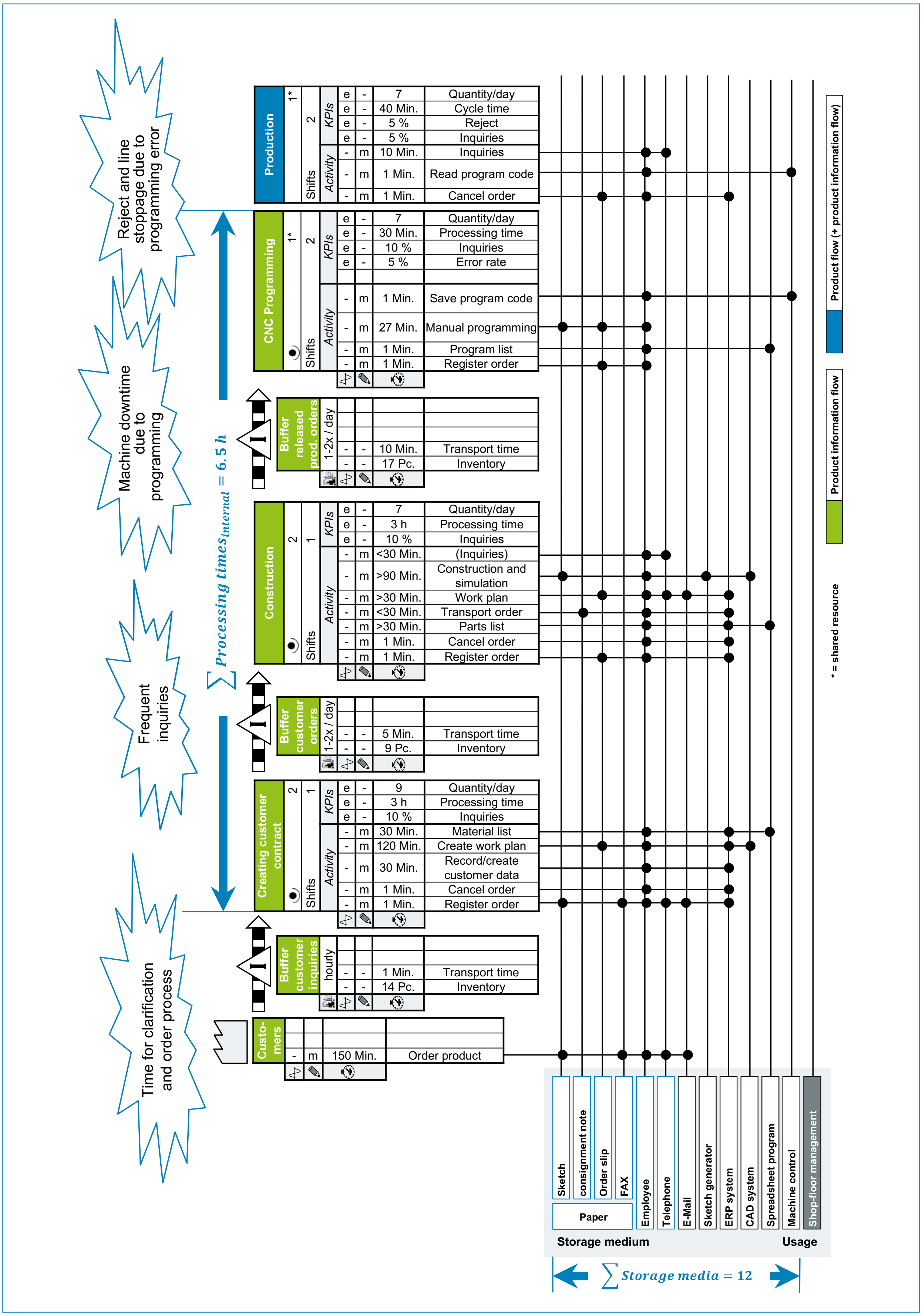


Fig 17: VSA 4.0 Example – before

- Frequent questions from construction to sales
- Machine downtime during programming
- Rejects due to programming errors
-

The application of VSA 4.0 provides further insights:

- To exchange data and information, twelve different storage media are necessary (number of horizontal lines).
- The high number of nodal points on the vertical lines of the data exchange indicates that process steps use several storage media for the same information.

Additional wastes arise from this, e.g.:

- Employees must transmit information from different systems and with different formats by hand.
- Media disruptions hinder the smooth flow of information and extend the processing time.

The figures confirm the findings and demonstrate additional potential for improvement:

- The data availability of the key performance indicators desired by management, such as processing time, quantity, etc. is 0 % for all processes.
- None of the recorded information is being used in order to push forward an improvement of the value stream (undermost horizontal line). The data usage figure is therefore 0 %.
- The digitalization rate in the value stream is 0 %, since paper is the storage medium used in different forms for every exchange of information.

Quick order processing through the synchronization of information flows

The traditional VSD aims to reduce the throughput time of a product by eliminating non-value-adding activities. Information is considered mainly from the process control perspective. This doesn't sufficiently take into account the comprehensive, new opportunities for the use of information through digitalization and networking. Companies in mechanical engineering must consider further information flows beside the information for process control in order to be able to supply customers quickly and flexibly, improve processes, and increase the customer value through information-based services. Four information flows can be recognized that must mesh together in synchronization (Fig. 18):

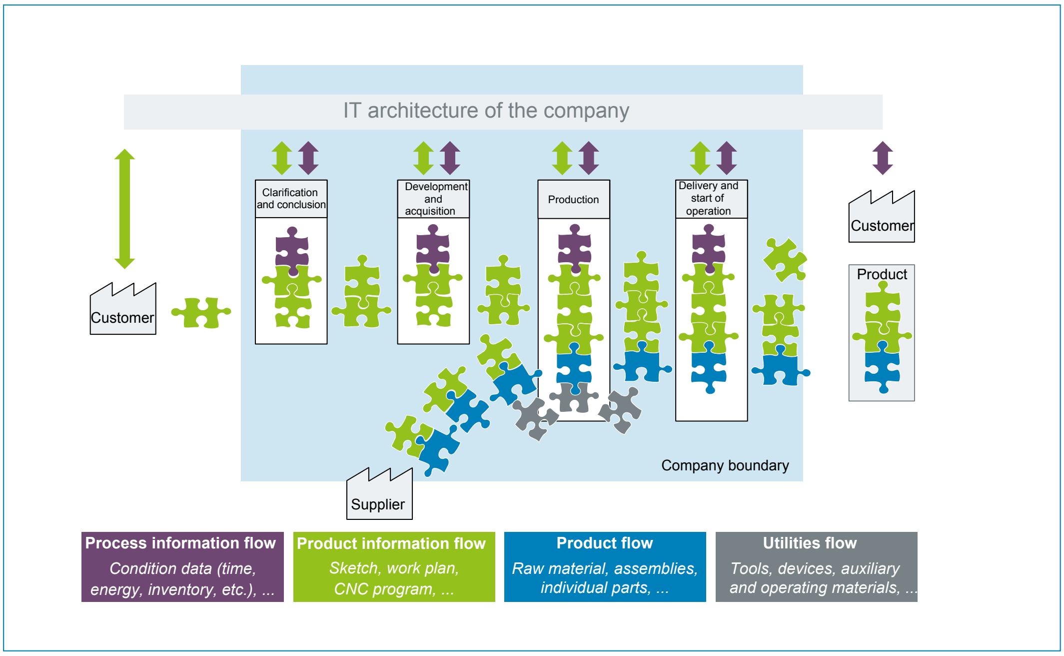


Fig. 18: The integration and synchronization of all information flows creates flow in value stream 4.0

The **product flow** represents the physical flow of material. In production, this coincides with the product information flow (see below), partly from the flow of suppliers.

The **utilities flow** controls the provision and transport of necessary operating and auxiliary materials for the execution of an order.

The **process information flow** comprises information about the condition of production and all supporting processes (like processing time, force, temperature, pressure, etc.).

The **product information flow** comprises all information about the product. It begins with the customer but leads through development (e.g. drafting of drawing) and work preparation (e.g. programs, work plans) all the way to logistics, production and to the customer.

If one of the four information flows comes to a halt or is not synchronized with the other flows, delays can result due to waiting times. In order to avoid this, a synchronization of these information flows should be ensured. This is especially demanding in production, as all four flows encounter one another here. At a workstation, the work and testing instructions must be available at the same time as the physical product, the tools, fixtures and measurement devices, and the necessary process parameters configured. In addition, the customer is to be linked to the in-house information flows in order to accelerate order clarification, adaptation development and work preparation, but also to receive product information from the usage phase.

Determining the target condition – Value Stream Design 4.0

VSD 4.0 serves the designing of the target condition for the future order-processing process including the associated information flows. In the first step, the approach comprises the traditional VSD, which aims to bring products into flow in order to achieve short throughput times. In the second step, there is a check of which stations can be further stabilized and designed to contain less waste through digitalization in order to improve or expand the product flow.

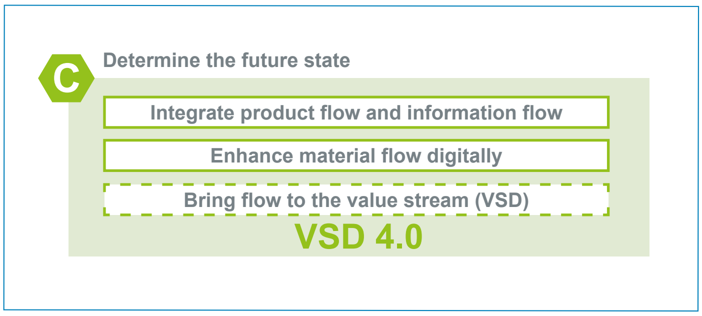


Fig. 15c: From the traditional VSD to VSD 4.0

Finally, in a third step, the product and information flows are integrated and synchronized (Fig. 15c). The basic rule is that initially it should be striven for a robust flow based on process stability instead of digitalizing complex and inherently instable processes.

Execution of traditional VSD

Through VSD, a value stream vision is developed that preferably satisfies the previously formulated targets regarding throughput time, quality, productivity, etc. The approach was established following Rother [6], who describes value stream guidelines. The use of these guidelines results in workstations and processes being capable to fulfill a given work content within the scope of customer takt time allowance. Subsequently, adjoining processes can be linked with one another to create the largest flow areas possible. Within those “islands of flow” a product or order can be further processed without waiting times. If processes cannot be directly linked (e.g. due to setup times or different cycle times), they need to be decoupled through pull systems (FIFO systems or supermarkets). The authorization of new orders preferably takes place in one place, the so-called pacemaker process.

Digitally improving product flow

If a value stream vision has been developed in this way, implementation projects are defined that develop the current value stream step-by-step towards this vision. Typically, these projects first address traditional wastes. Fundamental projects are the introduction of standard work and the stabilization of quality. Subsequently, projects follow that bring about the improvement

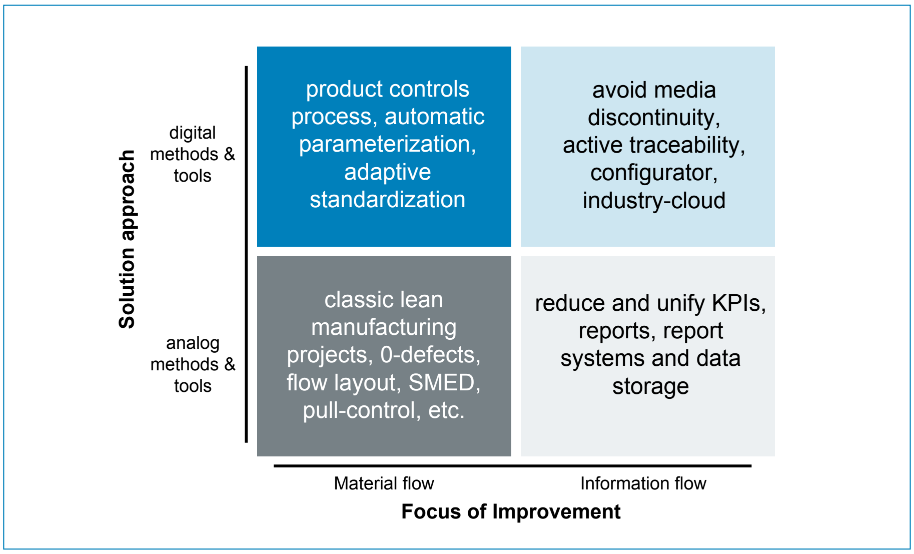


Fig. 19: Solution space for material and information flow

of the material flow, e.g. the line balancing of flow lines, the development of flow layouts, or the organization of a pull-material supply.

Subsequently, digital improvement opportunities through the following questions can be checked systematically:

- Which traditional wastes can be better eliminated through digital measures? Example: The use of flexible pick-by technologies if material trays are too inflexible for zero-defect commissioning.
- Which wastes in information logistics can be eliminated by a better organization? Example: Figures and their recording are unified for all machines in a group and used in the morning meeting for the target/actual comparison.
- Which wastes in information logistics should be eliminated through digital measures? Example: The data for machine availability is recorded directly to the machine control instead of a manual transmission to MES.

Finally, there should be a check of which performance characteristics of the formulated busines model can be supported by the digitalization of the order processing. Example questions could be:

- How can the flow be further improved by automating manual planning steps that are repeated for every order?
- At which point do configurators help in automatically translating customer requests into process parameters?
- How can the product automatically parameterize work stations in order to further decrease setup times and support standard work?
- Where does it make sense to assign process data to the product and make them available to the customer?

Integrating the product and process information flow

In the last step of VSD 4.0 the information defined, which is needed (product, process, and resource information) at the stations of the new value stream to implement the vision of order processing without waiting times. To start processes at a station without delay, all required information must be available at the beginning of the order. With this goal, the information needs of all processes are assessed and recorded as ”activities” in the process boxes. The same applies to the support processes like work preparation, intralogistics and maintenance.

Linking of information sources and storage media

Based on the definition of future informational needs, suitable storage media are defined in cooperation with production-oriented IT and inscribed in the value stream map with the respective horizontal lines. Through vertical lines and the placement of points, a clear and standardized assignment of information sources to storage media takes place. For example, in this step it can be determined that, in the future, all quantity reports are automatically collected in MES. To show this, a vertical line from the data point “quantity” is drawn to the line of the storage medium MES and connected with a point.

In this final step, all activities that use available information are attached by dashed lines. For example, it is determined that the output quantity of every station available in MES is discussed daily in the course of shop floor management in order to recognize deviations and initiate improvements. From data point “quantity”, a dashed line is therefore drawn to the horizontal line of shop floor management and also connected with a point.

Example application of VSD 4.0

For the already exemplarily observed value stream of the special machine manufacturer, the objective of value stream design is to significantly reduce the cycle-time whilst offering simultaneously high flexibility in the configuration for sales and customers. This is essentially achieved through

- consistent digitalization of information sharing from the customer all the way to the machines
- a drastic reduction in manual process steps and the associated processing time (from 6.5 h to 15 min)
- a reduction of storage media (from 12 to 7) and media disruptions

The new process in detail

On the customer side, an online configurator was implemented that depicts the solution spaces possible in production in the dimensions categories, materials, and measurements. In this way, it is possible for the customer to configure and order the product without further communication with sales or development. The product data generated through the configurator is automatically transmitted to a parameterizable CNC code generator. The new CNC program arrives directly at the machine through the Distributed Numerical Control (DNC).

Until now, the order authorization took place through a push principle. The foreman planed the sequence of the orders according to demand and his own judgement (Go-and-see planning). In the course of VSD 4.0, strict FIFO pull processing now takes place (Fig. 20).

In order to stabilize and further improve the new processes, the figures delivery performance and capacity utilization are discussed in future daily shop floor meetings. In the event of deviations the PDCA cycle is started.

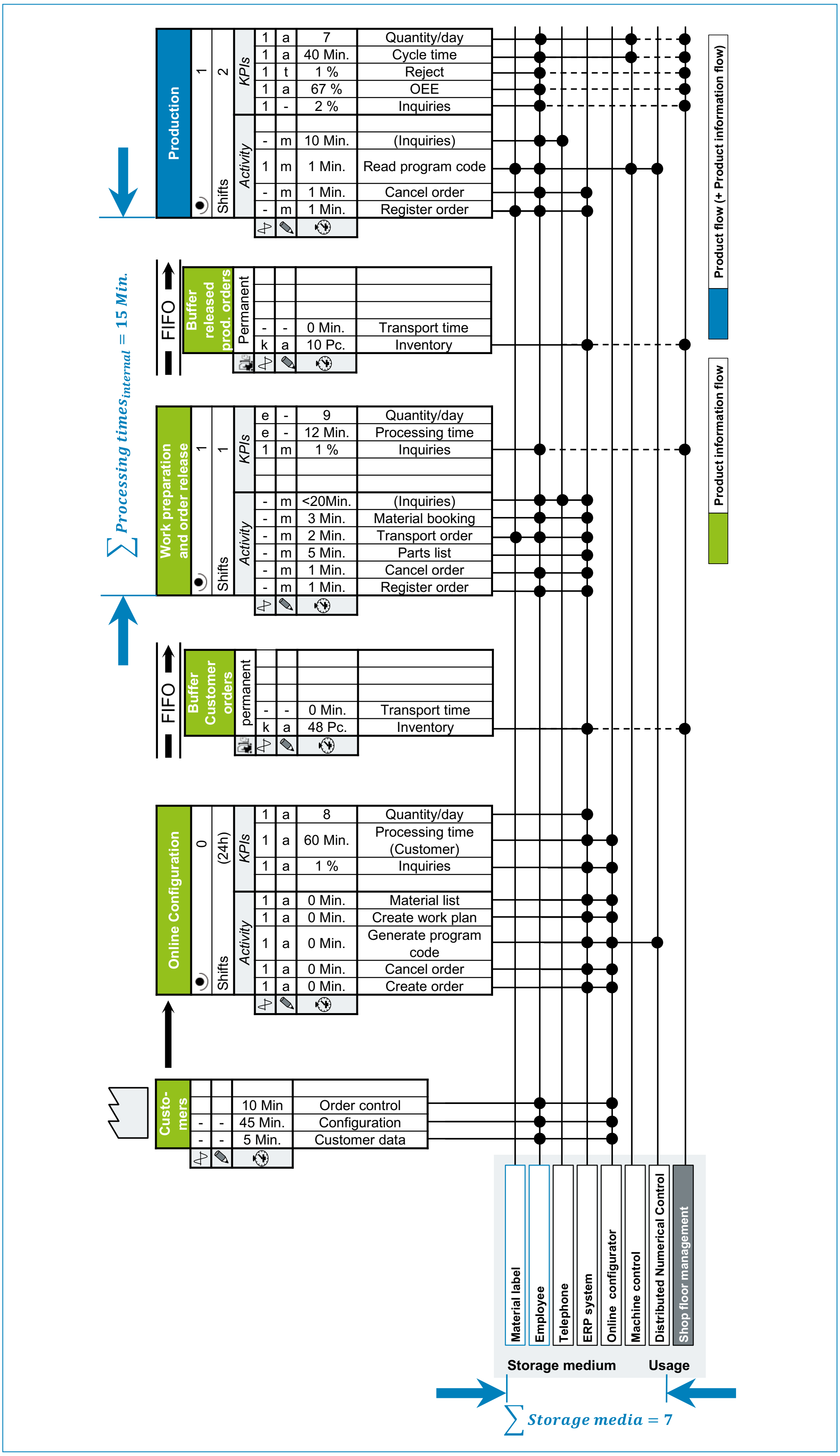


Fig. 20: VSD 4.0 Example – after: Drastic reduction of processing times and storage media

Best practice examples from industry

Continuous information flow up to the tooling machine

Carsten Schaede und Stefan Munsch, MUNSCH Chemie-Pumpen GmbH, Ransbach-Baumbach

In the production of customer-specific products, the stability of the manufacturing and assembly processes is the basis for achieving short throughput and delivery times. The minimization of possible sources of error, which can lead to rejects and rework, is of great importance. One source of error in the manufacture of customer-specific products is often manual CNC programming on the machine tool. In the case of Munsch Chemiepumpen GmbH, the CNC programming of customer-specific drilling patterns of the pump base plates was analysed: The manual transfer of the bore positions from the drawing to the CNC program on the machine tool was one of the causes of instability in the production process. A programming error quickly brought the assembly line to a standstill because the pump, motor and accessories could not be mounted on the base plate as configured.

Connection of configuration data and machine tool

In a project of the Munsch Chemiepumpen GmbH in cooperation with the Mittelstand 4.0-Kompetenzzentrum Darmstadt a software was developed which creates the individual CNC program directly from the configuration data. For the more than 500,000 possible combinations of pump base plate size and material as well as the configurable bore positions, the corresponding CNC program is now generated after completion of the product configuration and made available on the machine tool. This is made possible by the fact that the company has been using a product configurator with a comprehensive configuration set of rules for over a decade in order to document the configuration possibilities and restrictions of the high product variety in a standardized way. Based on this standardization of product variance, it was also possible to standardize the multi-variant manufacturing process and to automate the corresponding program creation.

Photo: Munsch Chemiepumpen

The standardization and subsequent digitization of the CNC program generation eliminated transmission errors.

Benefit

The transmission errors resulting from the media break could be eliminated by the standardization and subsequent digitalization of the CNC program generation. The pump base plates produced now always match the product configuration exactly. Assembly downtimes due to incorrect drilling patterns are a thing of the past. Since the error-free CNC program is available as soon as the configuration is completed, the time-consuming transfer of drawing data to the CNC program and machine control is no longer necessary. Overall, the throughput time for the pump base plate could be reduced from several days to one shift.

True to the motto “Those who standardize product variance can produce batch size 1 as in series”, the solution for CNC program creation from Munsch Chemiepumpen GmbH shows how the lean principle of standardization through digitalization can also be successfully applied in customer-specific production.

Best practice examples from industry

Communicating – quickly and visually

Norbert Dunker, technotrans SE, Sassenberg

technotrans SE produces amongst others cooling systems for batteries, charging stations and charging cables in the growing field of e-mobility. Fast and uncomplicated communication processes between different areas such as production, product development, design and logistics are elementary.

A simple idea

On existing PC terminals in production, a program was to inform the various company departments about communication requirements. Technotrans SE planned to use the traffic light principle to visualize the level of urgency. The concept included a red signal for high urgency and a yellow signal for a less urgent communication requirement. The expected response times were 15 minutes for red and
45 minutes for yellow. The green status was intended to reset the other two states and indicate that everything was alright at the workplace.

Photo: technotrans

A communication concept based on the traffic light principle facilitates work in the production line.

Three forms of visualization complete the urgency display:

- A pop-up window should appear on the PC of an employee or a defined group of several employees to address the required company department directly. If a person selects the pop-up window, he or she accepts the request. The pop-up disappears on all other computers.
- The current traffic light colours per workstation had to be displayed in a schematic production layout on a centrally visible large monitor. This would also inform other employees beyond the direct contact.
- In order to signal the current status on site, a multicoloured LED light was planned above the respective production line. This gives the responsible team leader a quick overview. Colleagues from other areas are guided by the signals directly to the right place.

The potential of your own employees

In its search for a cost-effective way of implementing this communication concept, technotrans SE came across previously unknown potential of its employees: it became apparent that several of them were privately using the Raspberry Pi, a mini-computer costing around 35 Euros, for various applications. For an IT employee with particularly pronounced knowledge, the passionate hobby thus turned into a successful project at the workplace.

The necessary hardware was created by the trainees of the training courses “Mechatronics” and “Technical System Planner for Electrotechnical Systems”. The experience gained by the employees in other areas helped them to successfully install hardware and software. The willingness of the technotrans employees to use their previously unknown skills to the benefit of the company led to the rapid implementation of a robust solution tailored to individual needs – at low investment costs.

Best practice examples from industry

Mobile maintenance with tablets

Marius Christian, Festo Didactic SE, Denkendorf

Limits of conventional maintenance

Short reaction times and fast troubleshooting are of central importance for the work of maintenance personnel. In the past, long walking distances, cumbersome gathering of information from documents and time-consuming searching for spare parts were part of the agenda. Thus, despite a functioning TPM (Total Productive Maintenance) system, there was always waste in the maintenance activities.

Combining maintenance and digitalization

In a joint maintenance and IT project, an app was developed for Technologiefabrik Scharnhausen that greatly simplifies and streamlines maintenance processes. Each maintenance technician is now equipped with a tablet and the corresponding app and is thus directly connected to the central maintenance system.

Maintenance personnel are regularly informed about current malfunctions and their corresponding priority and can accept orders directly outside their office - all information about the location, the type of malfunction and the operator's comments are displayed directly on the tablet. This saves long distances to a local computer and internal coordination.

The mobile recording of time and status feedback and fault rectification measures are just as possible as the display of documentation and photos for individual machines. With the help of the camera, faults and weak points can be documented directly on site. It is also possible to check whether and where the required spare parts are stored. If it is necessary to order spare parts, this is done directly via tablet. The spare parts lists and repair instructions for all machines and systems can be called up on the move. If there are any queries or problems need to be solved, the tablets can also be used to contact the machine manufacturers directly.

Photo: Festo

A tablet with associated app informs the maintenance staff about current malfunctions and their corresponding priority.

Benefit

With the mobile solution, an average time saving of about 10 minutes per maintenance process can be achieved. With approx. 19,000 fault messages and 2,000 planned maintenance orders, this leads to a saving of 3,500 man and machine hours per year. The maintenance staff themselves are impressed by the mobile solution because it makes their daily work easier and they can focus fully on their actual task: maintaining and optimizing the systems.

The direct digital recording of feedback data also reduces data interfaces and improves overall data quality. Ultimately, this also enables simpler data evaluation of typical maintenance key indicators such as MTBF (Mean Time Between Failure) and MTTR (Mean Time To Repair).

Best practice examples from industry

Lean culture in digital change

Matthias Schorr, Festool GmbH, Neidlingen

Since the mid-90s, the Festool GmbH production plant in Neidlingen with its 450 employees has been on a learning journey through the Lean world. Over the years, the company has developed a Lean culture that has gone hand in hand with the pursuit of continuous improvement.

Transformation in small steps

While in the past years the shop floor management consisted of whiteboards and paper, the assembly division is currently working with a strong focus on providing all relevant information in digital form. This leads to questions that need to be answered with a permanent solution and thus with standardization: Which information is really relevant? Who needs the information for fast utilization and in what format? How are all digitally available information connected? How do employees deal with this? How do employees manage the balancing act between transparency and sensory overload?

In order to approach the long-term goal of digital production, Festool is proceeding in small steps: In the first step, all relevant processes are digitally recorded in detail and the flow of information analyzed. This is done by the direct process operators themselves. Building on this, all analog media (whiteboards, paper, etc.) are replaced by digital information carriers. Until mid-2017, the morning meeting ("pull round") was still held on the whiteboard. Now this takes place in an interaction of Microsoft Excel, SAP and production data acquisition. This has reduced the duration of the meeting to one third of the time previously required and at the same time offers the permanent availability of all relevant information for the participants. Even in the long term, everyone can access this information, for example for evaluations and statistics.

In the second step, the rapid initial solution of the various digitalizations is then replaced by standardized software.

The third step is to create the appropriate platform using a suitable MES in order to take full advantage of the fast and linked information. The result is a fast response time, an increase in productivity by reducing information transport times and the integration of all employees. Although the three steps are mutually dependent and build on each other, Festool started all three steps simultaneously and in parallel. This was necessary due to the different implementation periods.

Objective

The aim is to use the digital opportunities that fit the (Lean) corporate culture, to weigh them up, test them and standardize them. This is meant to also enable an economic production system in the future, which creates value for the customers and thus makes the company and the location sustainably successful.

Photo: Festool

"With this digital overview, we can see the current states of the assembly islands in real time," says Matthias Schorr of Festool.

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