Successful Performance Measuring
in the Tool and Die Industry

2018

Wolfgang Boos
Michael Salmen
Tobias Hensen
Max Schippers
Jan Wiese
Thilo Schultes

WBA WERKZEUGBAU AKADEMIE
WZL | RWTH AACHEN UNIVERSITY

WBA Tooling Academy Aachen

The WBA Tooling Academy Aachen develops industry-specific solutions for the sustainable competitiveness of the tool making industry in a network of leading companies. Its activities focus on industrial consulting, further education, industry solutions as well as research and development. Its own demonstration tool shop enables the WBA to test innovative approaches in the laboratory and quickly make them accessible for its partner companies. Key issues are further addressed in the current studies. These provide information about market and competition trends and developments.

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Imprint

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Authors: Prof. Dr. Wolfgang Boos, Dr. Michael Salmen, Dr. Tobias Hensen, Max Schippers, Jan Wiese, Thilo Schultes
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WBA Tooling Academy Aachen
Campus-Boulevard 30
52074 Aachen

www.werkzeugbau-akademie.de

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Spotlight

Shop floor performance significantly defines the efficiency of a tool shop. Due to the high number of employees, applied technologies, and used software systems, value creation is particularly complex. In addition to that, there is a frequent change of priorities in the order scheduling by so-called “rush orders”. These lead to constant planning and scheduling adjustments. A high level of process transparency is required to master the shop floor complexity. In order to measure the shop floor performance, a variety of key performance indicators can help managers and employees with making the right decisions and to holistically address the relevant target key performance indicators, namely “time”, “costs”, and “quality”. The given study gives a summary of relevant key performance indicators in the tool and die industry and presents a cockpit of key performance indicators (KPI cockpit) for performance measurement.

77 %

of employees in the tool and die industry work averagely on the shop floor

22 KPIs

are used by an average tool shop for performance measurement

47 %

of employees do not feel well-informed

88 %

of tool shops plan to apply a system of KPIs or already use them

Amory Ross/Team Alvimedica/Volvo Ocean Race

Initial situation

The discovery of new continents and trade routes attracted a great number of early explorers. With their sailing boats, they discovered unknown seas and were constantly exposed to great risks. Through their bravery during those expeditions, they laid the foundations for modern-day trading routes. The Whitbread Round World Race was first organized in 1973 and was set to remind the world of the historic routes on which the last square riggers transported commercial goods around the world. Nowadays, the race's name has been changed to Volvo Ocean Race and takes place every three years. Split in various stages, during the last race the teams have to cover a total distance of 71,700 km. Due to its long distance, this regatta is considered to be one of the toughest challenges in sailing. By the way, there is no prize money - in this regatta it is all about glory and honor.

The key for successfully completing this regatta is the ability to navigate correctly. Since currents and weather conditions have a huge influence on the ship's speed, the straight route is not always the fastest. A proper navigation requires various measuring devices and data. In consequence of technological progress, the number of technological navigation devices has continuously increased, and seafaring has become more efficient and safer, not only in sailing. For example, one of the most important information in navigation is the knowledge of one's position. The invention of GPS technology has simplified this task dramatically.

Likewise, accurate knowledge of position and performance is of vital importance for manufacturing companies in order to achieve strategic and operational objectives. Tool shops often make use of simple means to measure their own performance. Processes that take part on the shop floor exert an important influence on the company's performance. Shop floor processes, like the mechanical component production, assembly, and try out of tools, generate a huge part of the company's value creation.

An extensive and detailed knowledge of these processes is required in order to create an efficient and effective value creation on the shop floor. For this purpose, data-based key performance indicators at different levels of granularity can be used. When trying to find suitable KPIs for the tool and die industry, an almost infinite number of them appears to be useful. Oftentimes, KPIs suggested by literature are too general and no conclusions can be drawn from them regarding concrete deficits. Similarly, when KPIs have been developed for series production, they allow for only a limited statement about the performance of a single and small batch production. That is why tool shops often find it difficult to choose appropriate key performance indicators suitable for successful performance measuring. Suitable key performance indicators exhibit an optimal cost-benefit ratio regarding the data collection effort and their informative value.

It is necessary to identify the right key performance indicators in order to display the relevant aspects of the value creation – time, costs, and quality – in a correct way and to allow for a performance evaluation. Key performance indicators which evaluate the manufacturing process of a tool are relevant as well as key performance indicators which give information about single processes such as milling.

The study gives an overview of key performance indicators along the entire value chain, which are particularly suited for measuring the shop floor performance of a tool shop. The key performance indicators as well as their necessary data input will be described and suggestions to display these indicators will be given. In addition, a KPI cockpit will be presented. This cockpit summarizes the key performance indicators in a clearly-arranged layout for the display on the shop floor or for the tool shop management.

71,700 km

have to be covered during the Volvo Ocean Race regatta

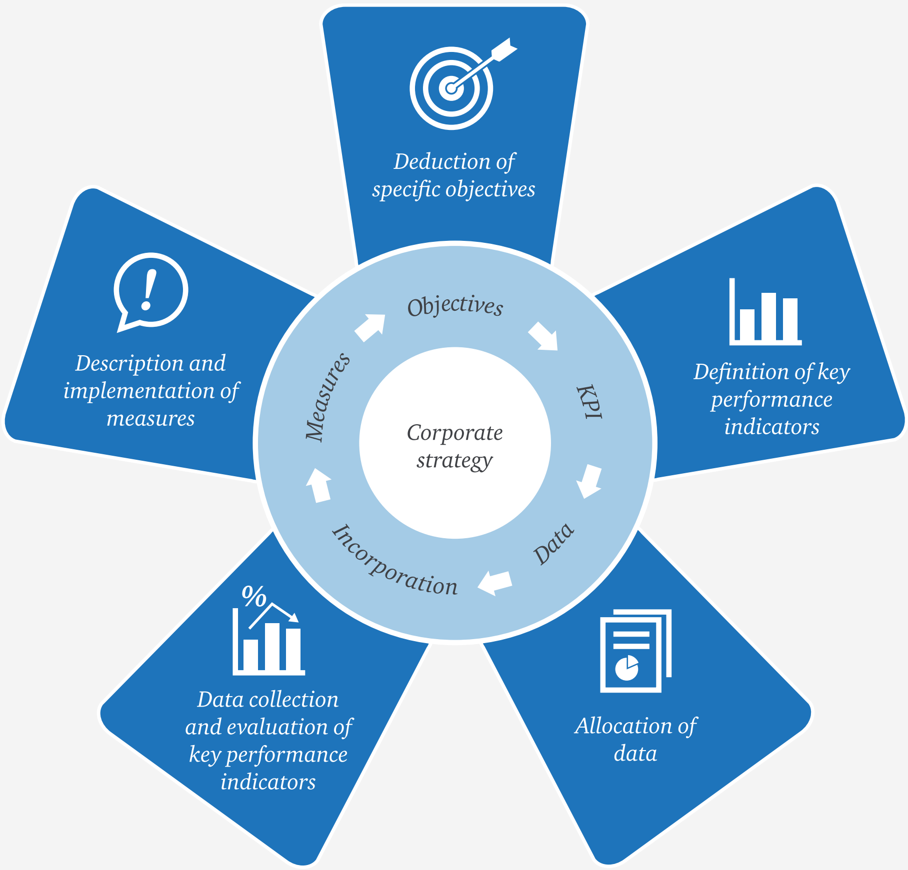
77 %

of employees in the tool and die industry work on the shop floor

Potentials of shop floor performance measuring

For a fast and specific definition of objectives, it is crucial to have a permanent overview on the shop floor performance. Primarily, the most important aspect is not the comprehensive detailing of information, but the compaction of individual pieces of information and their display by means of the KPI cockpit. Before introducing the key performance indicators, objectives have to be derived from the corporate strategy, whose achievement ought to be verified via the key performance indicators. Furthermore, the data to be collected has to be assigned to the key performance indicators. Based on the elicitation of the key performance indicators, measures which serve the achievement of the set objectives are to be derived. All in all, this enables a cycle of systematic performance improvement.

Approach for performance measuring



Every chosen key performance indicator has to be suitable for measuring the achievement of objectives. The determined objectives have to be "SMART". To qualify for performance measuring, key performance indicators need to be specific, measurable over defined periods of time, and relevant for the tool and die industry.

The correct choice of key performance indicator enables the efficient setting of objectives and the subsequent pursuit of achievement. Therefore, it is important to choose the right key performance indicators and to present them according to the target group. In this regard, management and employee demands differ from one another. For the management, it is important to get an overview of the complex processes on the shop floor within a short period of time. This ensures a fast identification of deficits. Additionally, the management requires key performance indicators to support the target-oriented leading of their diverse employees.

The employees, too, need prepared information tailored to their needs. By examining fields of activity within single and small batch production using key performance indicators, the employees are enabled to make decisions, recognize deficits, and give suggestions for improvement. Subsequently, employee motivation and efficiency can be increased. Therefore, key performance indicators have to be chosen appropriately.
An efficient performance measuring requires the periodic and comparable determination of key performance indicators. In order to ensure the comparability of data collection, method and frequency have to be defined for each key performance indicator. Individual key performance indicators are of paramount importance for identifying problems. Hence, it is essential to update these key performance indicators as closely as possible to real time. In contrast, a monthly update would be sufficient e.g. to measure the number of training days. With regard to determining update intervals, the cost-benefit ratio has to be considered. The automated key performance indicator collection offers a huge potential since it reduces expenses and mistakes.

Besides the choice of the right key performance indicators, it is of great importance displaying the key performance indicators in an appropriate and intuitively comprehensible KPI cockpit. Therefore, the key performance indicators have to be prepared in such a way that every employee can immediately figure out the relevant key performance indicators. This is the only way that performance measuring becomes an effective management tool.

47 %

of employees do not feel well-informed

Matt Knighton / Abu Dhabi Ocean Racing / Volvo Ocean Race

Overview of key performance indicators

In order to use a KPI cockpit for the tool and die industry in a targeted manner, the choice of specific key performance indicators, which reflect performance in a proper way, is required. For this, key performance indicators have to be defined. These have to be assessed efficiently based on the existing data and have to enable concise statements on the performance.

Hereafter, a selection of key performance indicators is presented, which is very suitable for setting objectives in the tool and die industry. The compilation of the key performance indicators was realized using values based on experience from the competition "Excellence in Production", in which different tool shops are benchmarked by means of a system of key performance indicators. The selection of key performance indicators also contains best practice examples of different consulting projects carried out by the WBA Tooling Academy Aachen.

The key performance indicators are classified in accordance with the user groups. First, the key performance indicators for tool shop management are introduced. For the management, overall key performance indicators which capture the performance of the entire tool shop are to be recorded. In particular, the key performance indicators must be chosen such that the performance towards the customer is measurable. In this context the adherance to schedules and the claim rate can be chosen. To some extent, it is recommended to measure overall key performance indicators in several areas. However, the balance limit must be defined for each area. For instance, it is recommended to measure the adherence to schedules and other key performance indicators not only in the design but also in the manufacturing department. The reference date for the adherence to schedules should be the respective target date in each department.

Subsequently, some selected key performance indicators are presented for the most important departments in the tool and die industry. The order of the presentation is oriented towards the value chain of the tool and die industry. These key performance indicators provide the employees with insight into the performance of their respective areas.

The key performance indicators will be presented in detail on the following pages. Each key performance indicator description contains specifications regarding their objective and definition. Furthermore, necessary preconditions, the used data collection method and a suggestion regarding their display are specified.

Tool shop management

The tool shop management bears the overall responsibility for the coordination, supervision, and further development of the tool shop. Its main task is the assurance of a tool production appropriate in terms of costs, quality, and on-time delivery. This involves the selection and development of suppliers to build up reliable partners for external value creation.

The tool shop management carries a high responsibility for the company, thus they have to be able to quickly and efficiently inform themselves on the company's performance. The following specific key performance indicators were selected to comply with this purpose.

Classification of order types

Tool shops that process a mixture of order types are faced with their different characteristics. Typically, repair orders are urgent and require a short lead-time. When producing new tools, the focus lays on efficient processing combined with a high degree of machine utilization. In order to optimally align a tool shop with these different requirements, an overview of the shares of the different order types and their changes is an important aid. The classification can be used for the allocation of resources for the value creation. Depending on the priority of the order types, a segmentation of resources by predictable and unpredictable order types can be more efficient.

In order to record the order types, it is important to keep records of the incoming orders and to organize them by kind and scope. As a result, the share of individual order types can be identified.

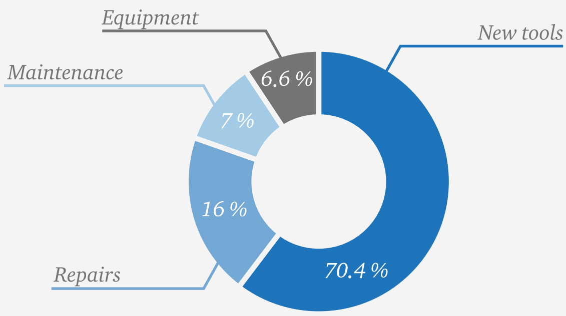
The share of an order type can be described by the ratio of the mentioned values. The duration of a period can be chosen freely. Common durations are monthly, quarterly or yearly elicitations.

70.4 %

is the average distribution of new orders

$$f(x) \quad \textit{Share of order type [\%]} = \frac{\textit{Incoming orders of a department in a period}}{\textit{Total orders in a period}}$$

Distribution of order types [%]
[exemplary layout]



Adherence to schedules

Tool shops are responsible for the tool supply of their customers. The adherence to schedules is perceived as the most important distinguishing feature in the tool and die industry. The challenges with adhering to due dates lie in systematic planning and control of the orders, including the scope of external value creation. Many tool shops face change requests and late orders while the completion date stays the same. Thus, it is reasonable to guarantee due dates in offers only up to a certain deadline. Afterwards, realistic due dates should be communicated to and discussed with the customer.

Adherence to schedules is an important key performance indicator for tool shops that provide insights into reliability and punctuality. Fundamentally, adherence to schedules is a key performance indicator for customers to evaluate the tool shop as a whole. Simultaneously, the control of adherence to schedules of suppliers enables the company to undertake measures aimed at optimizing supply chains. Deviations of the adherence to schedules indicate potentials in value creation. Additionally, it is important to note that the adherence to schedules of orders can be defined as a key performance indicator for different departments. In particular, the assembly supervision regarding adherence to schedules and lead time are essential to meet customer needs. Long waiting and transport times lead to delays which in worst cases cause interruptions of the series production.

Design also has a huge impact on the adherence to schedules. Normally, external orders and internal manufacturing orders may only be commissioned after design has been completed. This means that a lack of adherence to schedules leads to unrecoverable delays already in early project phases. For a continuous improvement of the adherence to schedules it is therefore recommended to monitor deadline compliance for design. For this, setting a milestone “Conclusion Design” for each tool project is indispensable.

26.1 %

of orders on average do not adhere to schedules

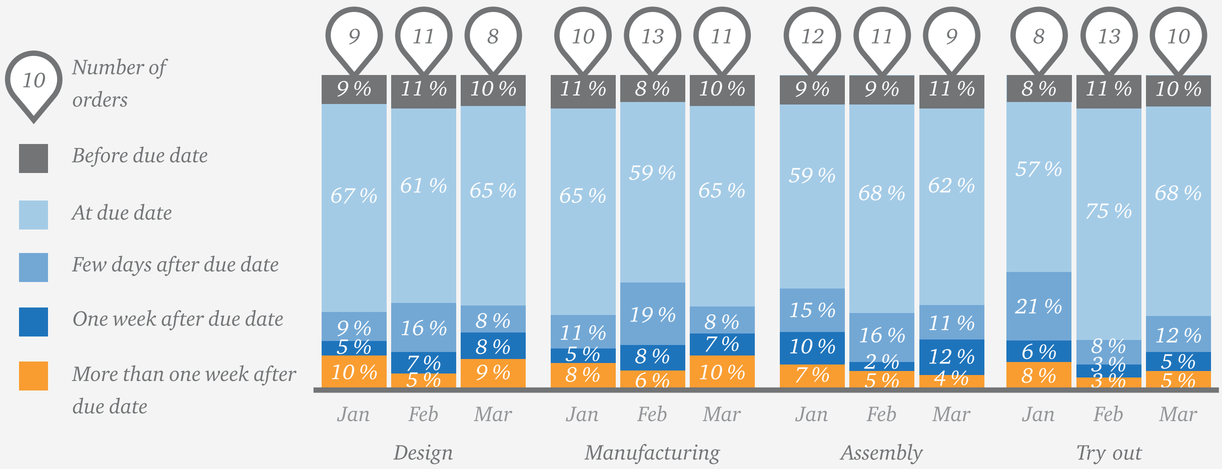
f(x)

$$\textit{Schedule deviation of an order [days]} = \textit{Delivery date}_{target} - \textit{Delivery date}_{actual}$$

In order to measure the adherence to schedules, pre-planned milestones like the delivery of a tool have to be compared to the times actually measured. Furthermore, work and time schedules are required. In addition to the quota of order at due date, the extent of schedule deviation is important to measure as well so that long and short schedule deviations can be distinguished. When a department is behind schedule and thereby following departments also fall behind schedule, this poses a challenge to determining the adherence to schedule. Thus, the scheduled start in the following departments cannot be adhered to which causes schedule deviations that these departments are not responsible for. As the deadline has to be met, it is recommened to hold on to the defined due dates for each department.

A bar chart can help with a clear display of the adherence to schedules in order to spot accumulations of delayed delivery dates and to take measures. Moreover, a periodic presentation of the development of the adherence to schedules lends itself to ensure optimal comparison of this development within a department.

Internal adherence to schedules [%]
[exemplary layout]



Lead time per order and department

Besides the adherence to schedules by single processing procedures, their interaction is a decisive factor for velocity of value creation. According to experience, the waiting times between the various processing steps alone take up to 90 % of lead time. Therefore, lead time is an important indicator for evaluating the value creation process. With the aid of clear controlling principles and responsi-bilities, lead time can be reduced considerably.

A high order backlog, which has already been cleared for processing, has a negative impact on lead time since resources are being utilized to capacity and hence individual orders obstruct each other. Short lead times create room to react quickly to customer inquiries.

Lead time encompasses the period of time necessary for a product from the start of processing until its completion. It can be subdivided into set-up time, processing time, and waiting time. The lead time can be determined in different ways. On the one hand, lead time can be determined by recording and adding all single components of the product development process. On the other hand, lead time can be determined as the difference between receipt of order and time of delivery. For a comparison, the order value has to be considered.

79 days

is the average lead time for injection molding tools with an order value of € 78,500

f(x) $\textit{Lead time [days]} = \sum \textit{Processing time} + \sum \textit{Transport time} + \sum \textit{Waiting time}$

f(x) $\textit{Lead time [days]} = \textit{Time of receipt of order - Time of delivery}$

126 days

is the average lead time for sheet metal tools with an order value of € 162,000

The lead time needs to be measured for every single order. This means, average values can be calculated and put into perspective with other key performance indicators, like the value creation per order. Likewise, lead times and therefore average values as well can be determined for each department. Hence, the distribution of the lead time can be dissected along the entire value chain.

Cost variances of tooling projects

Assessing cost variances of tooling projects offers an opportunity to control calculation and value creation. If this is not performed continuously, but only at the end of the year and not in relation to specific tooling projects, finding causes for cost deviations becomes increasingly difficult. On average, nearly a quarter of all orders experience budget overruns. Therefore, a target-actual cost comparison has to be performed for every single tooling project. It is recommended to perform these comparisons parallel to the project in order to monitor the cost development of single tooling projects. In cases of deviations it can then be examined whether expenditures have been underestimated in calculations or if any problems occurred during the value creation process.

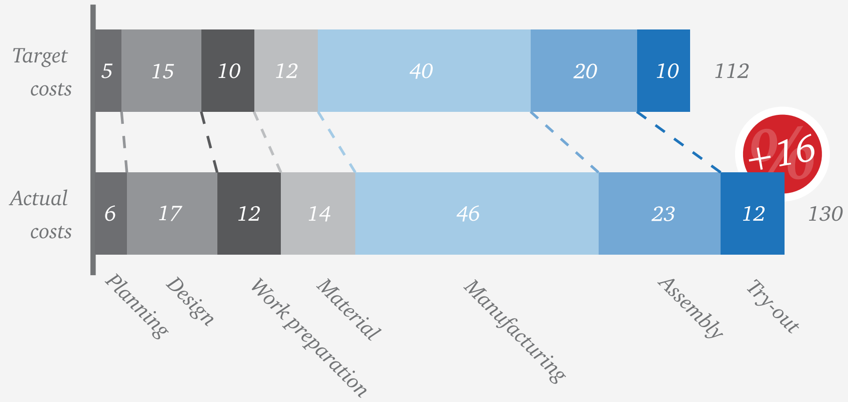
f(x) $\textit{Cost variance [€]} = \textit{Actual costs - Target costs}$

76.8 %

of orders are processed without budget overruns

The cost variance is captured in the form of a balance between reported actual costs and originally calculated costs. The latter consist of the sum of single cost positions such as design costs, external service costs, and material costs, which are usually calculated by multiplying the working hours with the hourly rates. Calculating the single process steps and corresponding target costs is necessary for capturing the cost variance. Hours spent and material used have to be recorded promptly according to the work schedule in order to be able to continuously perform cost comparison.

Cost variance [€ thousand]
[exemplary layout]



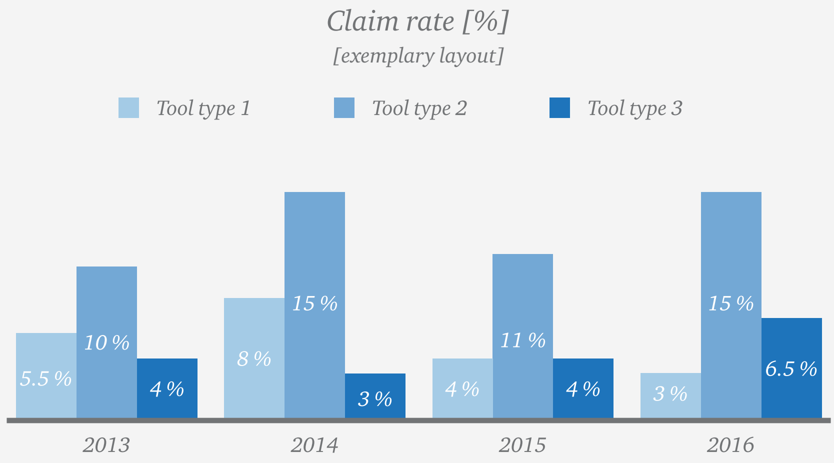
Claim rate and efforts made due to customer issues

Customers expect the delivery of correctly manufactured tools. The customer feedback concerning the quality of the delivered tools has to be recorded and analyzed. The frequency of claims and the effort caused trying to resolve the complaint are appropriate key performance indicators to systematically record customer feedback. Normally, quality issues should have already been fixed during try out. This implicates that even with a low claim rate, the management has to conduct a cause analysis and derive measures for improvement.

The rate of claims per delivery is recommended as a key performance indicator for a successful quality management. It describes the relation between the number of claims and the total number of orders.

f(x)

$$\text{Claim rate [\%]} = \frac{\text{Claimed deliveries in the last year}}{\text{All deliveries in the last year}}$$



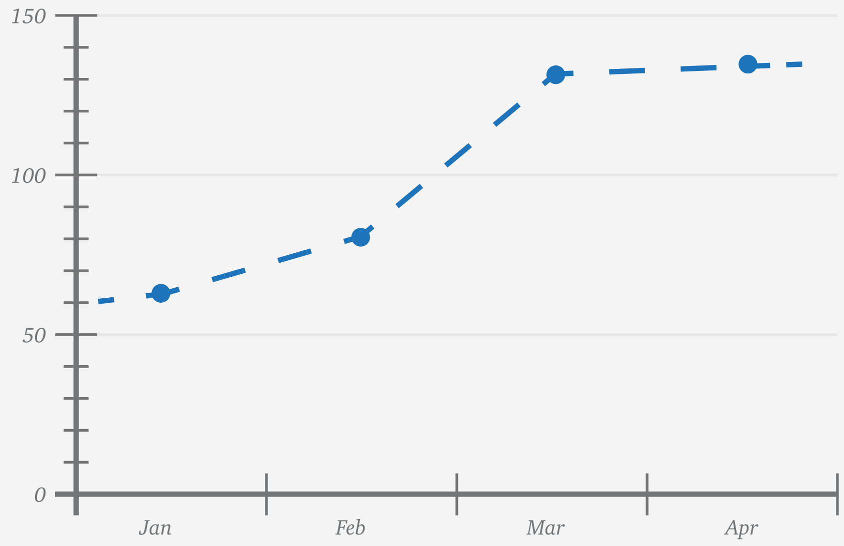
Prerequisite for the calculation of the claim rate is a systematic claim management. Incorrect deliveries must be documented in order to be able to easily determine the number of claimed deliveries in relation to deliveries without claims. In the majority of companies, this occurs automatically by means of an ERP system. For updating the claim rate, a monthly interval is recommended.

Order range

Tool shop management deals with the tasks in order to assess planned resource utilization. Based on this information, management can take decisions on order acceptance and external allocation of scopes of value creation. With the aid of the chronological sequence of the order range within a given calendar year, recurring phases with particularly many as well as particularly few orders can be assessed more precisely.

The key performance indicator order range specifies for how many days the current order backlog still lasts in order to proceed with tool manufacturing. Last year's revenue serves as a comparison value for the velocity of value creation. Accordingly, relevant measures have to be derived, taken, and realized such as promoting sales meetings with customers as well as increasing marketing activities when order range is low.

Order range [days]
[exemplary layout]



When determining the order range, the challenges lie in splitting the value creation of an order according to the single departments involved and taking into consideration value added by external partners. Since orders are being processed sequentially with shares differing from one tooling department to another, over- and underutilization temporarily occur in single departments. At the latest, these should be identified and remediated during rough planning. With highly fluctuating shares of value creation by external partners, it is necessary to calculate order backlog without external value creation participation. In this manner, orders are calculated according to their actual scope for the own department.

In order to calculate the order range, recording the order amount and comparing it to last business year's total revenue is required. For this, a detailed order list with corresponding order values is indispensable. The revenue can be deducted from the company's income statement. For the calculation, it is assumed that tool shop resources have not changed notably compared to last year.

f(x) $$\text{Order range [days]} = \frac{\text{Order backlog}}{\text{Revenue of the past 12 months}} * 360 \text{ days}$$

Overtime rate

Employees are a very important resource in producing companies. When unexpected delays or additional efforts occur in production, overtime is a medium often used for adhering to schedules. Delays result from customer-driven change requests or internal reasons like machine failures. The overtime rate provides inside into employee capacity utilization level. A high overtime rate over a longer period means that employee capacity is exhausted. Overtime is normally remunerated with surcharges, which leads to a disproportionate increase of personnel costs in relation to hours worked.

3.8 %

is the average overtime rate in the tool and die industry

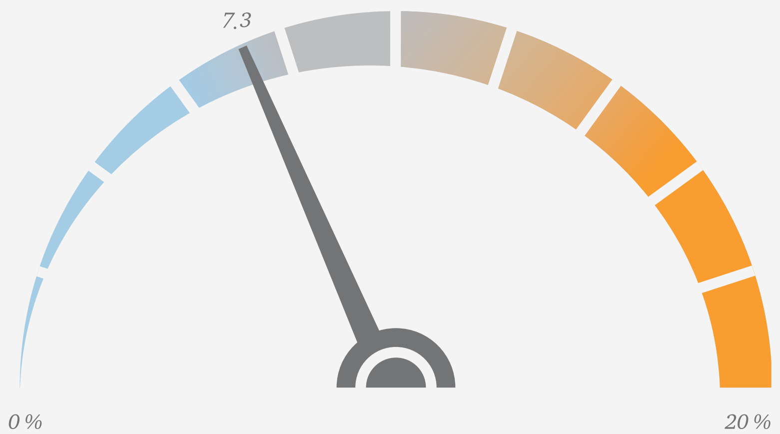
f(x)

$$\text{Overtime rate } [\%] = \frac{\text{Hours worked} - \text{Agreed work hours}}{\text{Agreed work hours}}$$

Overtime rate can be measured in different periods, for example monthly, quarterly or annually. The classification can be carried out on the basis of departments or cost centers. The most important precondition for determining overtime is the systematic recording of working time. In order to counteract overtime hours, countermeasures such as temporary support of affected departments or long-term staff increases can be set in motion. Also, allocating additional shares of value added to external partners is possible.

Overall overtime rate per month [%]

[exemplary layout]



Design

70 %

of total tool costs are determined by design

In tool designing, methods are determined, 3D tool models are created, and tolerances defined. Due to its position at the beginning of the value chain, design has a high importance for successful tool project realization. Even though design oftentimes causes less than 10 % of total costs, it determines more than 70 % of total tool costs. By high complexity and the required creativity in the design process many tool shops renounce performance measuring in the design department. However, based on design's high influence on costs, due dates, and time, performance measuring is highly recommended. Subsequently, three key performance indicators will be presented which help measuring performance in design in a transparent manner.

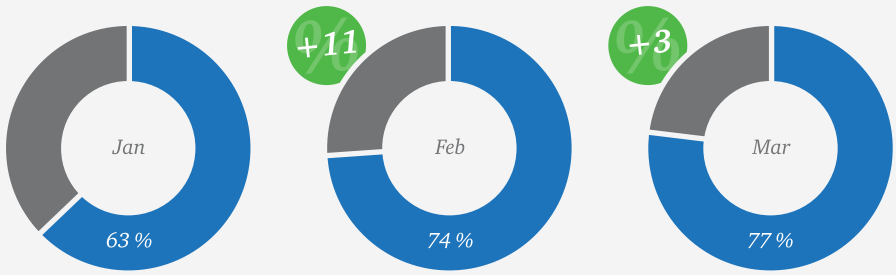
Productive time rate

In many tool shops, less than 50 % of work time in design is used for order-related design work. Often, a large amount of work time is used for planned or unplanned meetings. This often causes long-term timeouts in the tooling projects. "Mental set-up times" often cause mistakes and long lead times. In order to ensure high productivity in design, a well-balanced ratio between order-related and other activities must be guaranteed. For this, measuring the productive time rate is recommended.

$$f(x) \quad \textit{Productive time rate [\%]} = \frac{\textit{Order-related productive working hours in design}}{\textit{Total working hours in design}}$$

By measuring the productive time rate, it becomes clear which share of working time is used for order-related, productive work. It is recommended to identify the productive time rate based on the reported hours for the last month. A low productive time rate can be both a signal for a low utilization rate in design and the consequence of too many meetings or secondary tasks. In the second case it can be analyzed whether the group of participants has been chosen correctly. Optimizing a meeting's group of participants can lead to a considerable increase in design productivity. A target value for the productive time rate has to be set individually for each company since it depends on the company size and culture.

Productive time rate [%]
[exemplary layout]



Number of required modifications classified by causes

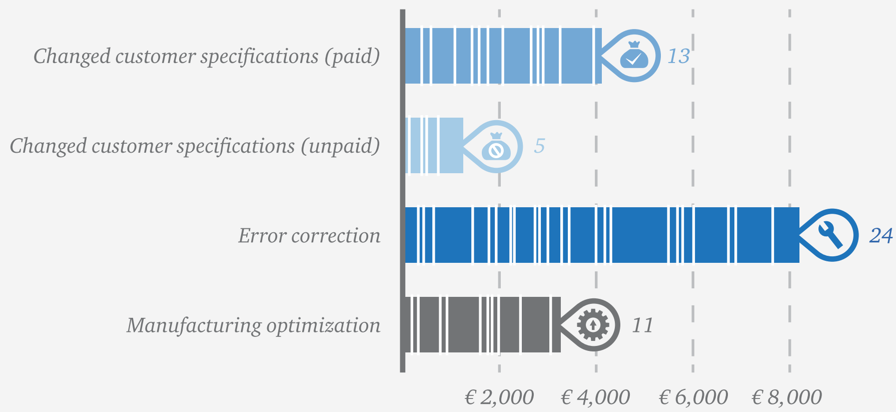
In tooling projects, design changes often lead to significant extra costs and delays in the project flow. Therefore, design changes have a significant impact on tooling procedures. These changes are the result of changed specifications by the customer as well as mistakes. In the case of customers changing specifications, a distinction between paid and unpaid changes has to be made. On average, 18.3 % of all orders in tool shops are externally caused change requests. In addition to these, there are also internally caused changes which should be avoided. The same applies for design changes caused by optimization proposals, encouraged, for example, by the manufacturing department.

By means of a systematic evaluation of the number of required changes, causes for extra costs become transparent. Based on this, a systematic derivation of measures for avoiding errors is rendered possible. This is of vital importance in design, since the design department determines the costs for successive departments in a significant way.

18.3 %

of all orders in the tool and die industry are caused by external change requests

Costs for design changes classified by causes [number and costs]



Share of standardized parts

The use of standardized parts has a substantial influence on tool costs. Furthermore, by using standardized parts the risk of errors in design and manufacturing decreases. Therefore, successful tool shops heavily rely on standardized parts. On average, tool shops have parts commonality of 24.9 % in their tool designs. Norm parts that are usually procured from external suppliers are included in common parts. The design department is responsible for selecting standardized parts. Since using standardized parts in design requires a systematic and disciplined approach, the share of standardized parts is an indicator for design performance.

24.9 %

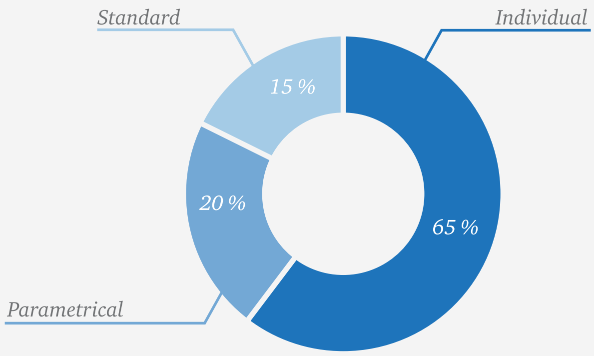
is the average parts commonality in tool design

$$f(x) \quad \textit{Share of standardized parts [\%]} = \frac{\textit{Number of standardized parts}}{\textit{Number of all parts}}$$

In order to measure the performance of the design department, it is recommended to measure the share of standardized parts in relation to all finished tools of the design department on a monthly basis. During operative business, the bill of material can be consulted. Ideally, single tool components can be grouped into one of the possible categories "Individual", "Parametrical", or "Standard", based on their description. Additionally, by measuring the share of standardized parts per tool, it can be checked whether standardization measures have been adhered to. The objective pursued is to continuously increase the share of standardized parts. For this purpose, it is recommended to introduce the mandatory use of standard and catalog parts. Furthermore, the implementation of standard tool modules and components facilitates efficiency improvements along the entire value chain.

Share of designed parts per month

[exemplary layout]



Work preparation

Oftentimes, work preparation undertakes a broad range of tasks in tooling. Essential tasks are NC programming, supplier coordination as well as project planning, machine planning, and personnel planning. Consequently, work preparation predefines the manufacturing process flow to a great extent. A good performance in the work preparation department has a significant influence on manufacturing efficiency. In the context of performance measurement, work preparation should not be viewed in isolation. In particular, key performance indicators have to capture how the work preparation enables a plannable and smooth procedure in manufacturing. With that in mind, subsequently five key performance indicators for performance measurement in work preparation will be introduced.

Adherence to processing time allowances

Efficient machine and personnel planning requires processing times that are calculated or estimated as accurately as possible. Usually, estimating or calculating processing times is carried out by the work preparation department. On average, 8 % of working time is used for this task in work preparation. The level of detail of processing time allowance depends on the company. Usually, processing time allowance is determined for every manufacturing step on an individual parts or module level. Determining processing time allowance on an individual parts level enables a more accurate planning, but results in an increased effort.

8 %

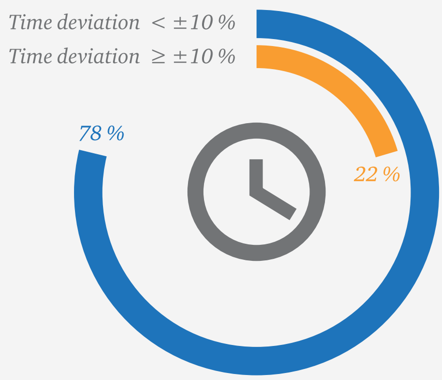
of working hours in work preparation are used for determining processing time allowance

f(x)

$$\textit{Adherence to processing time allowances [\%]} = \frac{\textit{Processing orders with time deviation} < \pm 10\,\%}{\textit{Total number of processing orders}}$$

Adherence to processing time allowances per month [%]

[exemplary layout]



In order to measure the adherence to processing time allowances, it is recommended to define a degree of deviation. If this value is exceeded, processing time allowance has not been complied with. According to experience, a value of 10 % is recommended. Data gathering has to consider both exceeding and shortfall since both cases lead to rescheduling. A weekly measurement period is recommended for this key performance indicator. Thereby, prompt discussions about deviating processing time allowances and hence systematic optimization of time allowances is enabled. In the long term, improved processing time allowances lead to higher planning accuracy and adherence to schedules.

23 %

of working time in work preparation is used for planning activities

Planning time per order volume

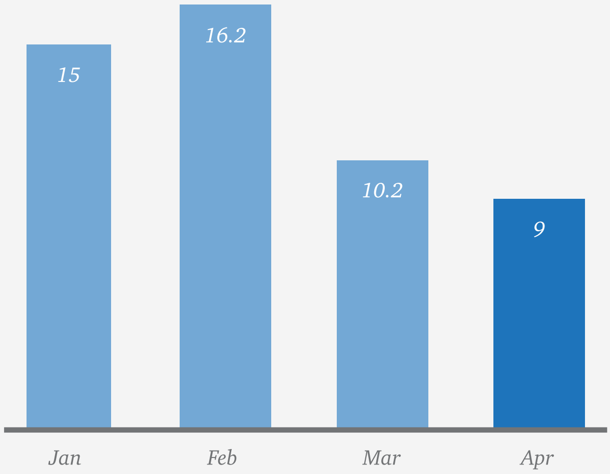
In work preparation, an average of 23 % of working time is used for planning activities. Nevertheless, planning efforts are often captured inaccurately. This leads to a lack of orientation regarding the adequacy of planning efforts. On the one hand, precise and hence often expensive planning enables a smooth manufacturing process. On the other hand, planning causes costs without a direct value creation for the customer. An expressive key performance indicator for planning time efficiency is the planning time per order volume. On average, 12 minutes planning time are spent per one thousand euros of order volume.

Monthly data gathering is recommended for planning time per order volume. This applies both to capturing single orders and to the whole work preparation department. By periodically tracking the key performance indicator, changes of the planning approach or system can be evaluated regarding time efficiency in planning. This allows for long-term planning optimization.

$$f(x) \quad \text{Planning time per order volume} \left[\frac{\text{hours}}{\text{€ thousand}}\right] = \frac{\text{Time effort for planning}}{\text{Order volume}}$$

Planning time per order volume [minutes / € thousand]

[exemplary layout]



Share of programming time

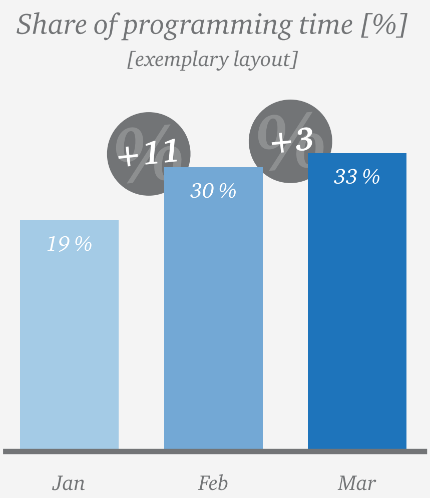
NC programs are the prerequisite for modern and efficient manufacturing. On average, 25 % of working time in work preparation is used for programming. Due to the great importance to value creation, it is necessary that employees in work preparation spend sufficient time programming, despite their broad range of tasks. For this purpose, it is recommended to measure the share of programming time in relation to total working time.

$$f(x) \quad \textit{Share of programming time } [\%] = \frac{\textit{Programming time}}{\textit{Total working time}}$$

A detailed recording of spent capacity in work preparation is a prerequisite for measuring the share of programming time. For this, an easy to use reporting system has to be implemented. The hours have to be assigned to the processed orders. Determining this key performance indicator on a monthly basis is recommended. When using shorter periods, excessive falsification occurs due to special effects. If shares of programming time are permanently low, the reasons have to be identified. Low shares of programming time can potentially be attributed to higher efficiency in programming, capacity underutilization or overutilization of work preparation capacities due to other tasks. In the latter case, early identification and introduction of countermeasures on the basis of key performance indicator measuring is possible.

25 %

of working time in work preparation is used for programming



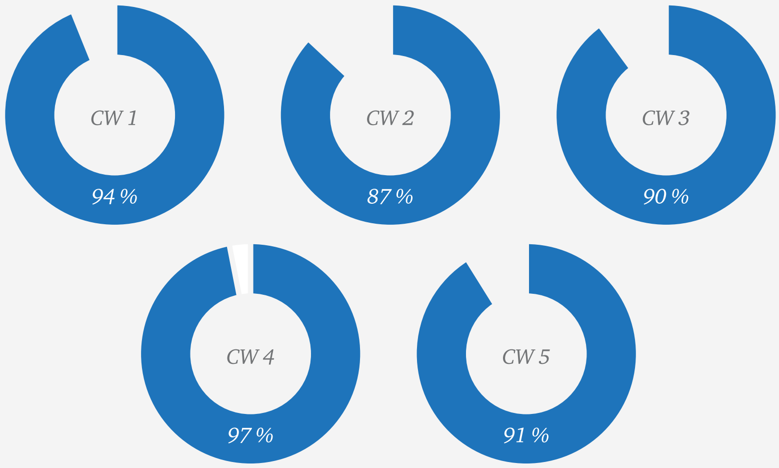
Share of error-free CAM programs

Other than measuring time spent on programming, it is recommended to measure the quality of programming as well. Errors in programming usually lead to incorrectly manufactured parts or collisions within the machine. Thus, programming errors inevitably cause additional costs and oftentimes project delays, too. Hence, it is recommended to measure the quality of programming on the base of the share of error-free CAM programs.

f(x) $$\textit{Share of error-free CAM programs [\%]} = \frac{\textit{Number of error-free CAM programs}}{\textit{Total number of CAM programs}}$$

Determining this key performance indicator manually involves a great deal of effort. However, if the total number of CAM programs used within a week is gathered via CAM or PPS systems, the number of flawed programs can be determined with little effort. The long-term objective is the correctness of all CAM programs.

Share of error-free CAM programs [%]
[exemplary layout]



CW: Calender week

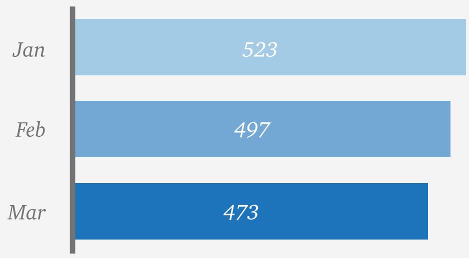
Milling tools in stock

On average, 190 different types of milling tools exist in the stock of German tool shops. Since most of the time several units are stocked for each milling tool, milling tools have a significant impact on cost and capital commitment. Since decisions on buying new milling tools are usually taken by the work preparation department, the key performance indicator milling tools in stock serves as a performance measurement in work preparation. A low stock of milling tools requires tool design standardization. Hence, reducing the milling tool stock requires regular exchange about design standards between work preparation and design.

190

different types of milling tools exist in an average tool shop stock

Milling tools in stock [number]
[exemplary layout]



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Manufacturing

Manufacturing encompasses the mechanical processing of components of the tool as well as components bought in addition. For this, several manufacturing technologies are used. The main technologies include milling, turning, die-sink and wire-cut EDM, and grinding. Along the entire value chain, tool manufacturing's share of costs classified by cost center is highest with average values of 42 % of total costs. With regard to performance measurement, manufacturing normally has a high priority in tool shops. In manufacturing, a large number of key performance indicators can be measured which allow for particulary insightful statements on the technology-based tool shop performance. In this context, key performance indicators for performance measurement in manufacturing are presented subsequently.

42 %

is the average share of manufacturing costs in comparison to total costs

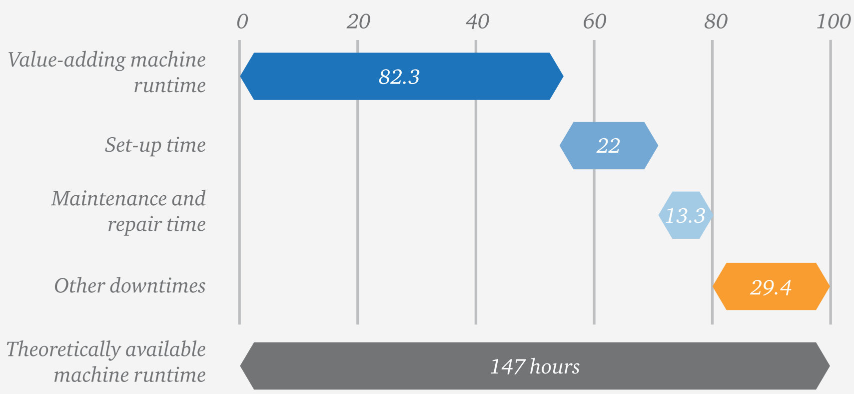
Machine productivity

The objective of measuring machine productivity in manufacturing is to evaluate machinery regarding its performance. By continuously measuring key performance indicators, changes in downtime and set-up time can be exposed and measures for increasing productivity can be taken. The crucial point is to record machine performance by operating mode (e.g. set-up time, maintenance time, operating time) and to consider available machine runtime. Available runtime can be calculated on the basis of the theoretically planned number of weekly shifts for each machine.

f(x)

$$\textit{Machine productivity [\%]} = \frac{\textit{Value-adding machine runtime}}{\textit{Theoretically available machine runtime} - \textit{Downtime}}$$

Machine productivity per month [%]
[exemplary layout]



Machine productivity within a defined period of time can be determined by confronting theoretically available machine runtime-less downtimes and value-adding machine runtime. The value-adding machine runtime is the difference between actual machine runtime and all nonproductive times, composed of maintenance, repair, and set-up times. For milling machines, for example, value-adding machine runtime is defined by spindle rotation and feeding of the milling head. In order to show the development for a specific period, a bar chart on a time scale is appropriate.

Error rate in manufacturing

Errors in the manufacturing industry are generally to be avoided. A preceding step to avoiding errors is error detection and documentation. With regard to error detection, knowing in which process an error has occurred is of vital importance for analyzing why it has occurred and how it can be avoided in the long-term.

In order to come to these conclusions on the basis of gathered data, high precision measuring equipment as well as systematic documentation are required. Measuring stations and opportunities for documentation have to be placed along the entire manufacturing chain in order to enable the concretizing of error cause and time.

Serving as a key performance indicator for systematic error management in manufacturing, the number of errors in manufacturing is an important base for error avoidance. Hereby, errors can be assigned early on.

f(x)

$$\textit{Error rate [\%]} = \frac{\textit{Number of defectively manufactured parts}}{\textit{Number of all manufactured parts}}$$

Manless machine runtime

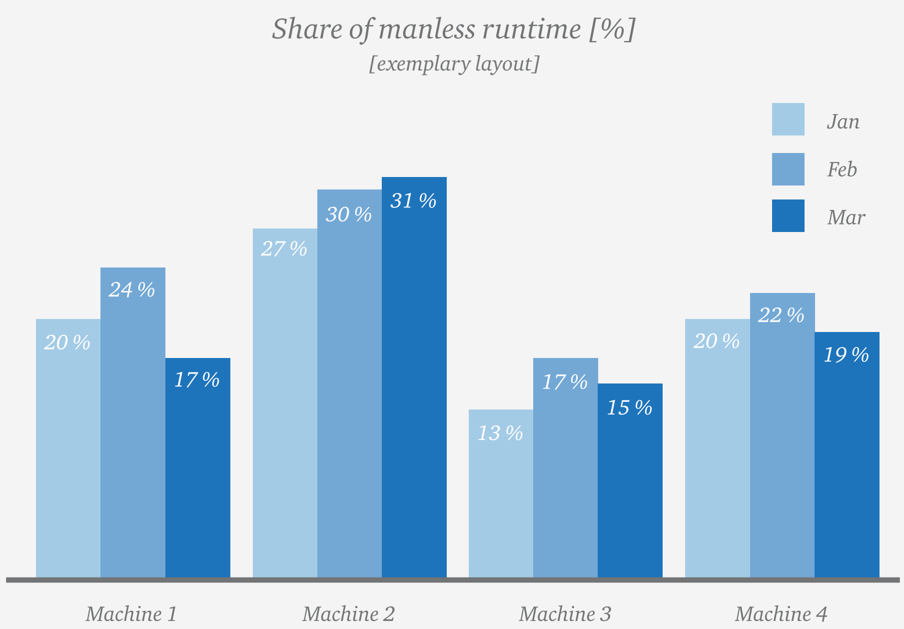
1.5

milling machines on average are operated by one employee

Shorter clamping and set-up times, longer machine runtimes, high precision, and exact reproducibility are among the most important benefits of automation in manufacturing. In particular, single and small batch production in the tool and die industry poses big challenges for automation in manufacturing. Machines have to be enabled for manless processing of different sizes, weights, and geometries. In the last years, the number of machines per user has increased continuously. In milling, it currently amounts to 1.5 machines per user. In order to illustrate this degree of automation, the key performance indicator share of manless runtime can be determined. This key performance indicator specifies the share of machine runtime without manual intervention in a previously defined period. Manless machine runtime can be determined by the difference between total recorded machine hours (runtime from MDE) and employee working hours.

$$f(x) \quad \textit{Share of manless runtime [\%]} = \frac{\sum \textit{Manless machine runtime}}{\sum \textit{Total machine runtime}}$$

A bar chart is the best option for transparently displaying manless machine runtime for each machine in manufacturing. With the aid of this representation, manless machine runtime of different machines in manufacturing can be compared based on technology. On the basis of this comparison, key competences regarding the degree of automation can be presented.



Number of unplanned machine failures

Systematically avoiding machine failures in manufacturing is the objective of any producing company. In times of Industry 4.0, versatile sensors are being used to solve this problem by trying to detect machine failures before they happen ("predictive maintenance") and to prevent them early on, at an appropriate time. Nevertheless, unexpected machine failures still happen and cause serious consequences. Due to resource constraints, this often leads to problems with adhering to delivery dates.

Unexpected machine failures are systematically recorded and, if possible, assigned to their respective causes using the key performance indicator number of unexpected machine failures. With the aid of this, it is subsequently possible to identify improvement potentials in machinery and intensify maintenance activities after performing a thorough key performance indicator analysis.

Since the number of unexpected machine failures is a key performance indicator for which a simple number is summed up incrementally, there is no special method for determining this key performance indicator. In addition, the ratio of breakdown duration to machine runtime can be taken into consideration.

A bar chart can be used for displaying the number of machine failures in manufacturing transparently. With the aid of this representation, it is possible to compare the failures of single machines in manufacturing based on technology.

f(x)

$$\textit{Share of machine failures [\%]} = \frac{\sum \textit{Time per unplanned machine failure}}{\textit{Total machine runtime}}$$

Number of suggestions for improvement

63 %

of submitted suggestions for improvement are implemented on average

Incorporating employee's suggestions for improvements does not only increase productivity and innovation, but also improves the working atmosphere, which in turn has positive effects on business key performance indicators. In order to determine the development of employee participation, the key performance indicator number of suggestions for improvement is used. The aim of this key performance indicator lies in making a statement on the acceptance of and response to the corporate suggestion system. Since manufacturing has the highest staff share in tooling, capturing this key performance indicator in manufacturing is particularly important. Based on the number of suggestions for improvement, the general suggestion system can be measured in manufacturing and possible potentials for optimization can be identified. In order to calculate this key performance indicator, it is necessary to know the number of submitted suggestions for improvement as well as the total number of employees in the specific period. For a more detailed analysis it is recommended to distinguish between submitted and implemented suggestions for improvement. On average, 63 % of submitted suggestions for improvement are implemented in successful tool shops.

The rate of suggestions for improvement is calculated by dividing the number of submitted suggestions for improvement by the total number of employees.

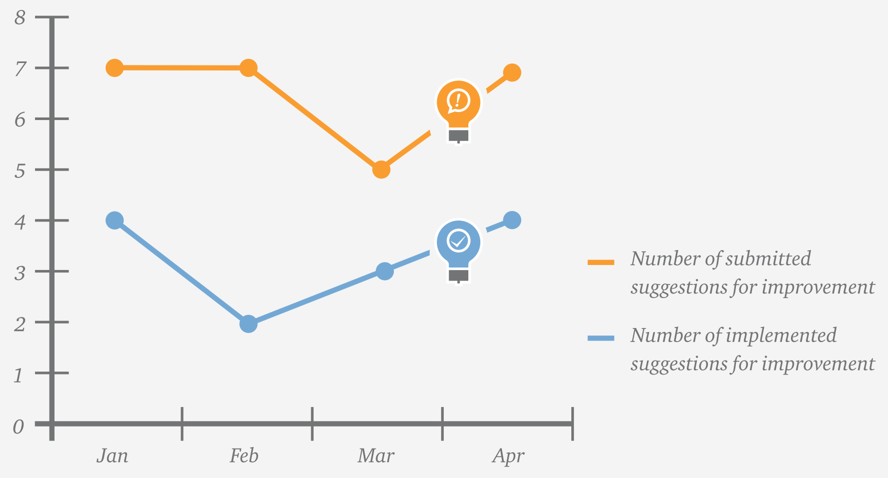
Precondition for measuring the number of suggestions for improvement is a systematic suggestion system in which suggestions are documented and analyzed with regard to feasibility. The key performance indicator cannot only be determined across all departments but also department-specific.

In order to capture development over time, it is recommended to use a line chart on a time scale. For the department-specific ratio of suggestions for improvement actually implemented suggestions are taken into account and are presented as an absolute value.

$$f(x) \quad \text{Suggestions for improvement per employee} \left[\frac{\text{number}}{\text{employee}}\right] = \frac{\text{Number of submitted suggestions}}{\text{Total number of employees}}$$

Suggestions for improvement [number]

[exemplary layout]



Assembly

Assembly includes all processes for the joining of internally manufactured and purchased tool components and component groups for the completion of the tool itself. After the assembly, the tool's functionality is tested and optimized in the try out. A step-by-step assembly instruction does often not exist due to diversity of tools. Instead, the assembly operators determine a possible assembly order based on assembly drawings and 3D models. Subsequently, key performance indicators for assembly performance measurement will be examined more closely.

Adherence to delivery dates by tool components for assembly

A smooth tool assembly flow requires all needed tool components to be delivered fully machined in assembly. Delayed delivery of a few central tool components can lead to interruptions in the assembly process already. These interruptions lead to inefficiencies regarding personnel deployment and to longer assembly times. Capturing delivery delays of tool components in assembly allows for conclusions about the adherence to schedules and the optimization potential of preceding processes. The aim is to determine the reason for the delay. Furthermore, the gathered information can be used in order to better plan date interaction between manufacturing and series production. The better these departments are coordinated, the more the total lead time of tools can be reduced.

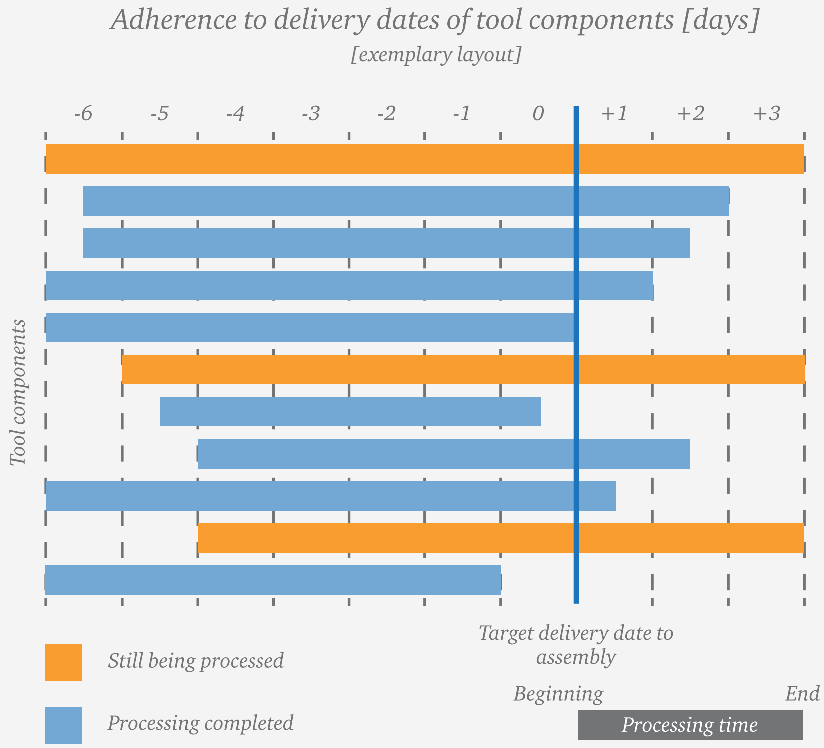
A systematic documentation and capturing of deadlines in a time and work schedule is the prerequisite for measuring and evaluating delivery delays of tool components in assembly. At all times, these plans have to be up-to-date. For this purpose, tracking the single tool components by means of a planning system is suitable. Based on planned and actual delivery dates, the difference can be calculated in days. Hence, orders delivered prior to the agreed date receive a positive number.

Systematically measuring delivery date deviations enables the identification of frequent deviation causes. Examples for these causes include delayed or defective preliminary work or uncertainties during value creation. Identifying such deviation causes enables the development of an error database as well as questioning causes and elaborating possible solutions. In this way, occurrence of delivery date deviations can be reduced and shop floor efficiency can be increased in the long-term.

10 %

of external tool component deliveries are unpunctual

$$f(x)\quad \textit{Delivery date deviations [days]} = \textit{Delivery date}_{planned} - \textit{Delivery date}_{actual}$$



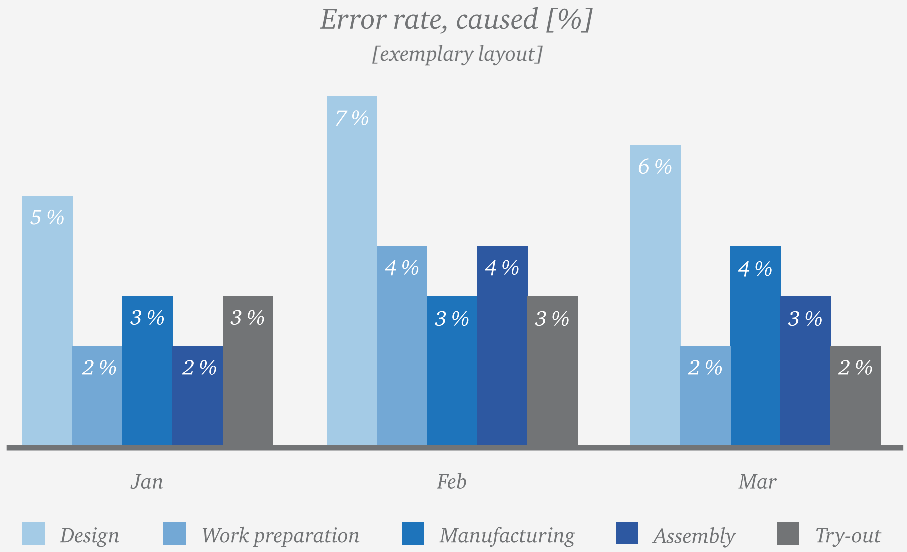
Error rate

Error rate determination in assembly is essential for identifying errors along the entire tool manufacturing process and for defining the correct measures. In this context, it is required to distinguish between random and systematic errors and to analyze the impact on following process steps.

In order to substantiate these complex conclusions, precise measuring equipment is required as well as documenting identified errors for each tool component. Concretizing the error cause and point of origin are important for meaningful error descriptions. Furthermore, the total number of tool components, which pass through the same process steps, must be documented. The error rate represents a relative key performance indicator that allows statements about the absolute number of defective parts in relation to the total number of produced parts in a process step. The error rate can refer both to the process step in which the error has occurred and to the process step in which the error has been detected. This way, error-prone process steps can be identified as well as process steps which are meticulous regarding error identification.

$$f(x) \quad \text{Error rate, caused [\%]} = \frac{\text{Number of defectively produced parts}}{\text{Number of all manufactured parts}}$$

$$f(x) \quad \text{Error rate, identified [\%]} = \frac{\text{Number of identified defective parts}}{\text{Number of all examined parts}}$$



1,697 h

on average are performed per employee per year in assembly

Adherence to time allowances in assembly

Adherence to time allowances for assembly processes is an important contribution to short lead times made by the assembly. By adhering to time allowances, additional delays are avoided. This is of great importance especially at the end of the value chain, since subsequently only try out is performed and delays are difficult to compensate. However, in case of large deviations between time allowances and actually needed assembly times, time allowances should be revised. Since sometimes the assembly process requires reworking or fitting of tool components, causes for deviations and the accuracy of time allowances must always be examined simultaneously.

Data gathering for the adherence to time allowances in assembly requires a work plan with time allowances for assembly steps of parts or component groups. With this, all deviations from processing times are measured and compared to time allowances.

$$f(x) \quad \text{Adherence to time allowances, assembly [\%]} = \frac{\text{Number of correct assembly steps with a time deviation of } < \pm 10\,\%}{\text{Number of all assembly steps}}$$

Try out

At the end of the value chain, tool production finishes with testing the tools in try out. Using an iterative process step, the tool's quality requirements are checked and necessary changes are documented. Subsequently, these changes are carried out by the corresponding departments and the tool is tested again until it can be released to the customer for series production. Regarding the performance measurement it is very important to identify the influence of both preceding process steps and the impact on series production. In particular, try out must be examined with regard to reliability and speed. With that in mind, four key performance indicators for performance measurement in try out will be presented.

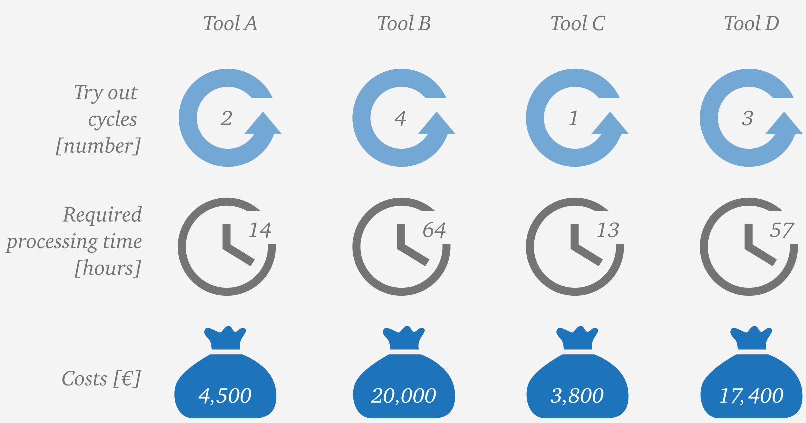
Number of try out cycles

The number of try out cycles is an indicator for a tool's quality after its production. Tools that reach readiness for series production within few try out cycles usually exhibit shorter lead times and lower costs. Hence, transparency regarding the number of try out cycles is of great importance.

In addition to the number of cycles, however, the duration of each cycle is relevant for measuring a possible delay caused by try out. Another important factor is the determination of incurred costs caused by the try out cycle itself, but also costs for necessary changes. Costs, which incur during try out cycles, result from labor utilization, material usage as well as the utilization of relevant production machines. By indicating the number of try out cycles, it can be seen quickly and easily how successfully the try out process of a tool has been performed. In order to show the number of try out cycles transparently and order-specific, a bar chart can be used. With the aid of this diagram, the number of try out cycles can be compared across several orders.

f(x) *Number of try out cycles per tool* $= \sum$ *Try out cycles*

Analysis of the try out cycles
[exemplary layout]



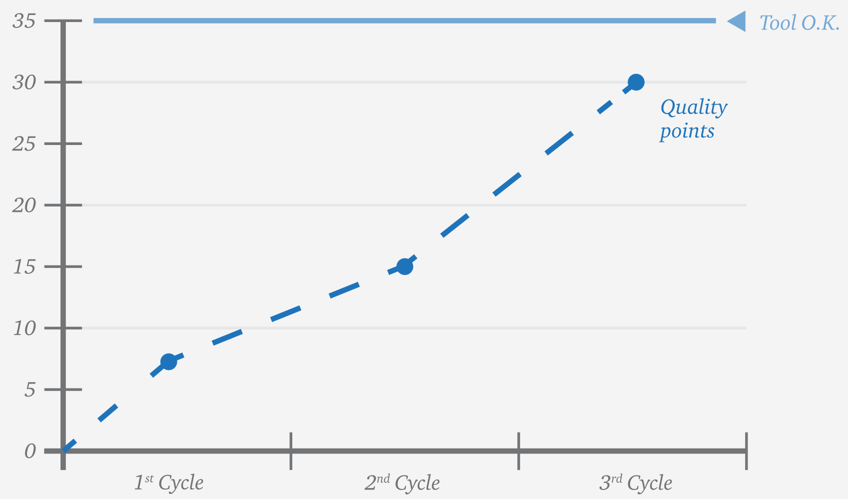
Tool quality in try out cycles

Delivering error-free tools via the tool shop is critical for series production. Especially in try out, at the end of the tool shop's value chain, exact measurements and quality checks must be carried out in order to avoid quality defects for customers. Thus, fundamental quality criteria should be recorded in a uniform manner after each try out cycle for tools in try out. Following this, improvement of quality criteria along the try out cycles can be comprehended and tools with problems difficult to remediate can be identified. Quality criteria include the share of dimensionally stable produced plastic and metal parts from a sample or the tool's productivity. Depending on individual requirements of the tools, other quality criteria can be consulted such as the surface finish of the produced parts.

$$f(x) \quad \textit{Share of dimensionally stable parts per cycle [\%]} = \frac{\textit{Number of dimensionally stable parts}}{\textit{Number of produced parts}}$$

Tool quality [points]

[exemplary layout]



The different quality criteria can also be converted using a consistent point scale and can then be added up. Following this, the different quality criteria that all have to be fulfilled at the end of try out can be combined to a score, comparable across all tools. Typical quality criteria of a so-called list of characteristics include, for example, surface quality, dimensional accuracy or production speeds. Consistent criteria definition and subsequent addition of awarded points per criterion allows for establishing a tool-independent quality standard.

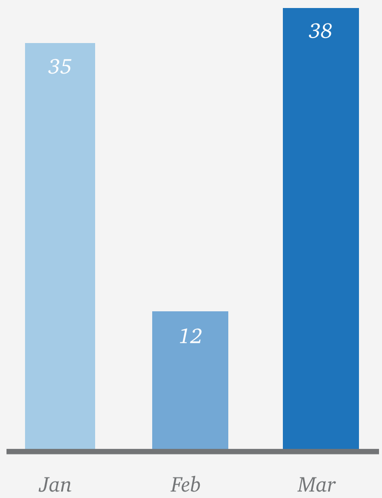
Utilization time of production machines

An efficient start-up of a tool in series production depends significantly on the preliminary works in the try out process. In particular, it is important to perform the try out on series production machines that are as similar as possible. Oftentimes, these are not available in a tool shop. Hence, try out can only be performed on machines in series production. In order to interrupt series production as little as possible, utilization time for the try out process needs to be kept as short as possible. This can be achieved by systematic preparation and follow-up of the try out.

In order to measure the utilization time of the production machines in try out, adding the runtime of the respective series production plants is sufficient.

f(x) *Utilization time of production machines [hours]* = *∑ Runtime of production machine for try out cycles*

Utilization time of production machine [hours]
[exemplary layout]



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Number of documented lessons learned

Not only in manufacturing but also in try out there is a continuous improvement process. Based on documented lessons learned, it is possible to prove how identified defects were recorded and communicated also to preceding processes. In particular, inter-divisional communication along the entire value chain poses a challenge.

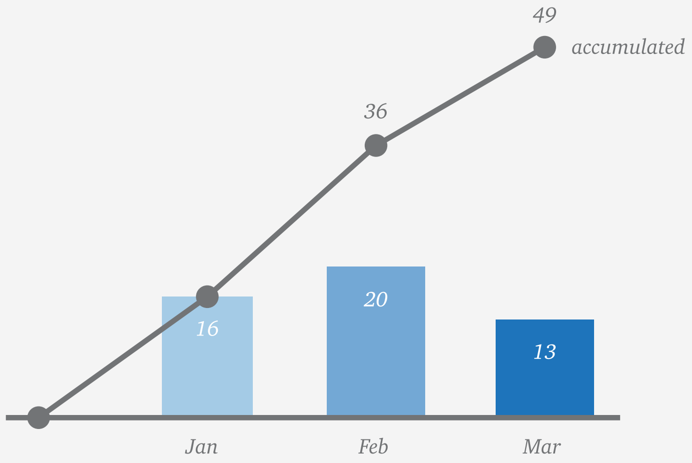
In order to determine the number of documented lessons learned, perceived defects have to be documented systematically and saved for structured transfer and editing. Apart from mere error description, the error cause has to be identified and lessons learned have to be derived in another step.

Subsequently, the number of documented lessons learned can be aggregated to a sum. It is recommended to provide lessons learned with key words in order to be able to identify them in the future. Besides the tool type and the error cause, it is also possible to use information on materials or series production plants.

f(x) *Number of documented lessons learned* $= \sum$ *Documented lessons learned*

Documented lessons learned [number]

[exemplary layout]



KPI cockpit

Objective and definition

The previously presented key performance indicators enable the display of relevant information regarding current shop floor performance. In order to use this information effectively, however, displaying these key performance indicators in a manner that suits the target groups is of particular importance. The task and goal of a KPI cockpit is to display key performance indicators to all individuals on the shop floor as well as to enable the exposure of weaknesses and potentials. Moreover, such a KPI cockpit can increase employee motivation due to increased availability of information. It also serves as a place for discussions between management and employees on improving order steering on the shop floor.

22

key performance indicators are used on average in a tool shop

Preconditions

Successful utilization of a KPI cockpit requires the identification of relevant target groups in order to subsequently prepare information for each of them. Order-specific key perfomance indicators, like deviation of delivery dates or cost deviations, have to be accessible to both management and all the employees involved in the value creation process. Process step-specific key performance indicators are of particular interest to employees involved in the process. Superordinate key performance indicators are primarily important to management. However, they have a positive impact on employee motivation by better providing employees with information.

Besides target group-specific display, information topicality is another relevant part of the implementation. For this, information availability as close as possible to real time has to be striven for. In order to avoid disproportionate effort, recommendations on individual update frequencies of the single key performance indicators have been described in the previous chapters.

Another aspect for securing acceptance by employees is the clarity of displayed information. The KPI cockpit has to be designed in such a way that information can be comprehended and interpreted quickly. The ability to see how to influence key performance indicators needs to be evident to the viewer instantly. This means that the introduced display possibilities of the key performance indicators have to be arranged in a structured manner, easy to read, and in a compact form on a panel or similar. Both for key performance indicator evaluation and display, a high degree of digitalization is recommended. Besides the form of display, the place of display also has to be selected for the different target groups in order to secure the acceptance and use of the KPI cockpit. This means placing every KPI cockpit where it can best be perceived and discussed by its target group.

Possibilities for displaying

For displaying superordinate and order-specific key performance indicators, the shop floor board has proven to be an effective tool. The shop floor board is set up at a central place of the shop floor and serves management and employees for discussing current shop floor performance as well as for deriving optimization measures. As a result of its position and periodic meetings in front of the board, it is secured that shown key performance indicators are perceived and reflected upon by all employees of the shop floor.

For department-specific key performance indicators it is recommended to display the information directly at the point of data generation. For example, data regarding the milling process is displayed in close proximity to the milling machine. This leads to the fact that employees in charge of operating have direct access to all relevant information and therefore have the opportunity to detect weaknesses. It is important that this information is discussed regularly between management and employees, e.g., in front of the shop floor board.

Possibilities for the digital networking

A disadvantage of the KPI cockpit presented so far is the required effort for continuously updating information. Usually, this information has to be evaluated manually, printed, and then made available to the employees on a regular basis. Progressing digital networking on the shop floor offers numerous potentials for reducing this effort and further improving weaknesses detection. Currently, four tablets are used on average in a tool shop. The preconditions for this are the clarity and digital availability of data, already recorded in an ERP system in most tool shops, as well as screens and tablets for displaying information on the shop floor. If these preconditions are fulfilled, the continuous effort required by a KPI cockpit can be reduced significantly by automatically evaluating and displaying the key performance indicators.

Another advantage of a digital KPI cockpit is the easiness of adapting the display and content to individual preferences as well as the opportunity for interacting with the user. This includes giving feedback concerning submitted suggestions for improvement or access to further information on key performance indicators. Thus, cockpit acceptance by employees and participation in the continuous improvement process can be further increased.

In addition to displaying the KPI cockpit, screens and tablets at the same time are preconditions for further digital networking solutions such as digital assembly steering, prioritization support, or error documentation. Hence, they provide an impetus for further optimization measurements based on Industry 4.0 applications.

4

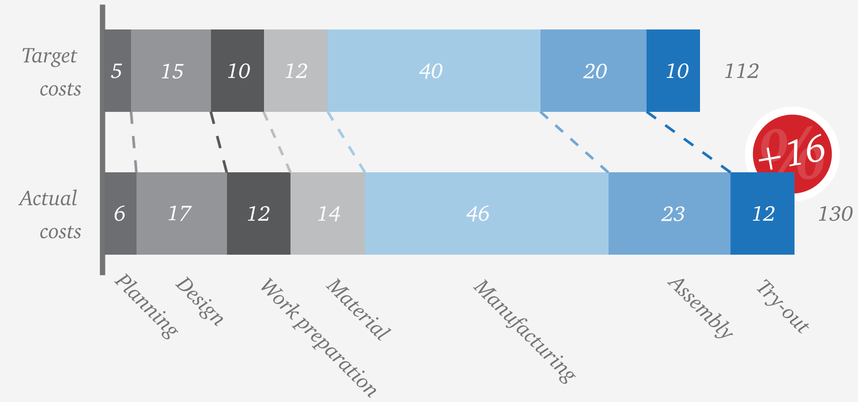
tablets are used on average in tool shops

KPI cockpit

Exemplary screen layout for a digital KPI cockpit

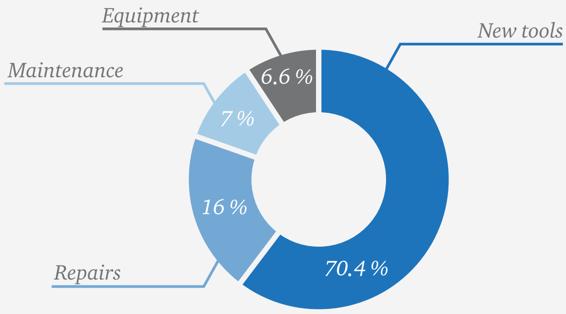
Cost deviation [€ thousand]

[exemplary layout]



Distribution of order types [%]

[exemplary layout]

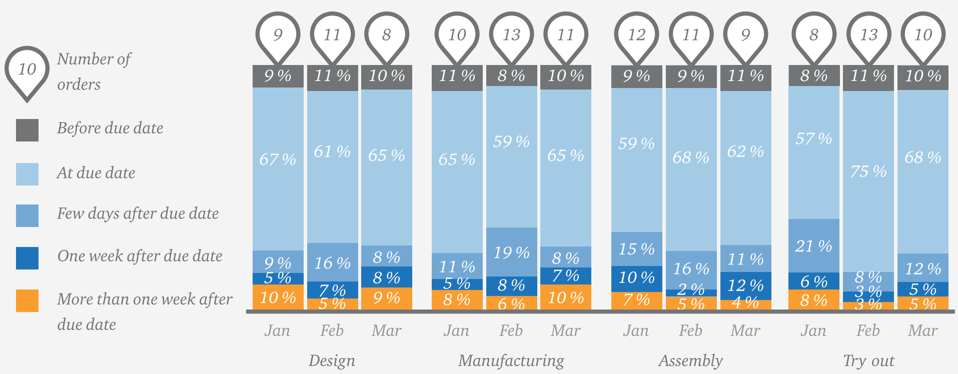


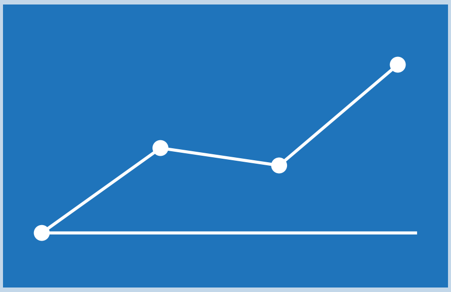
Tool shop management

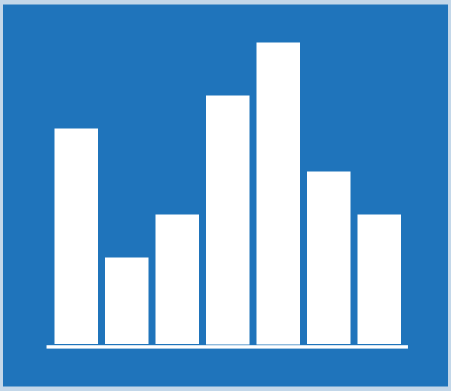
- Design
- Work preparation
- Manufacturing
- Assembly
- Try out

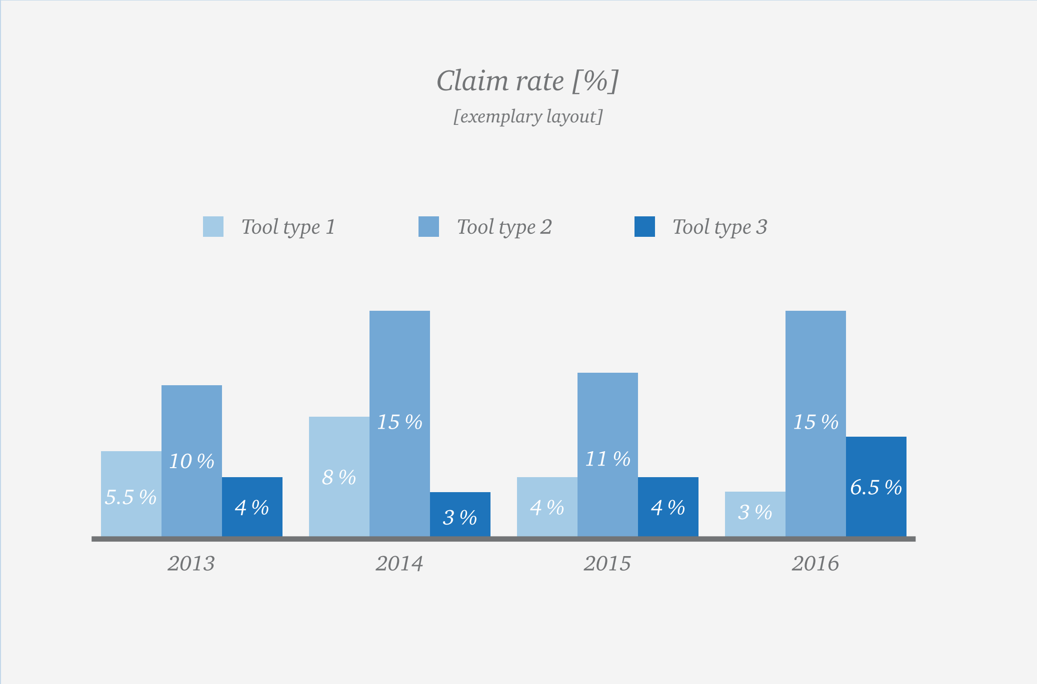
Internal adherence to schedules [%]

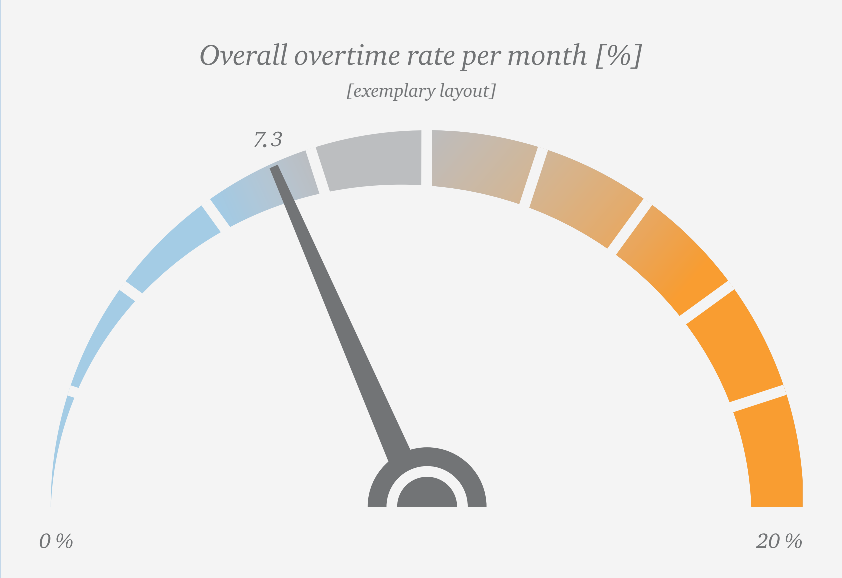
[exemplary layout]

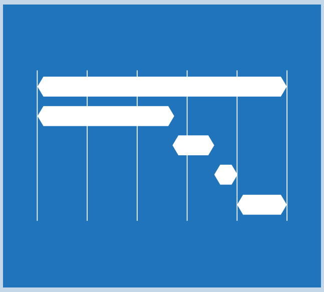


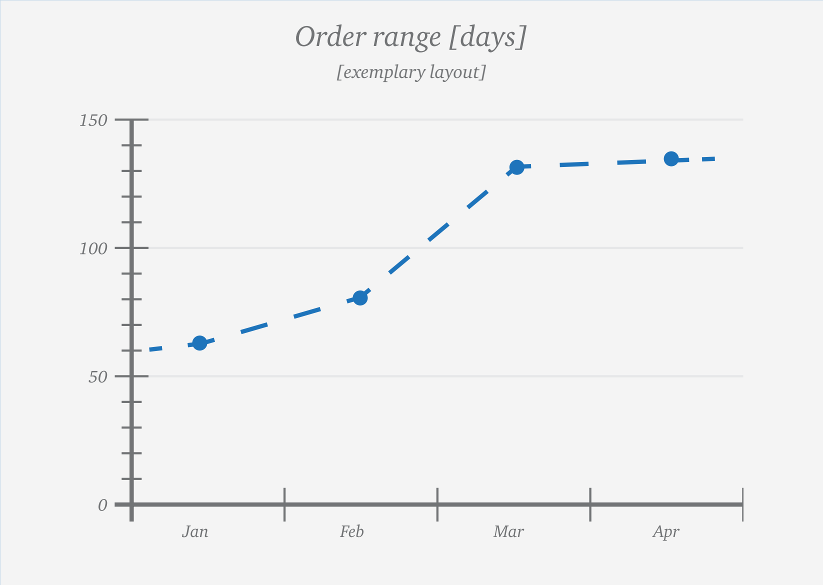





Claim rate [%]
[exemplary layout]
Tool type 1
Tool type 2
Tool type 3
5.5 %
10 %
4 %
8 %
15 %
3 %
4 %
11 %
4 %
3 %
15 %
6.5 %
2013
2014
2015
2016


Overall overtime rate per month [%]
[exemplary layout]
7.3
0 %
20 %

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Ainhoa Sanchez/Volvo Ocean Race

Summary and outlook

Only the team that knows its exact position and that sets the right course can win the tough competition that is the Volvo Ocean Race. The situation in tooling is quite similar. Tool shops have to master the three target key performance indicators time, costs, and quality as good as possible in order to be competitive. In particular, however, interactions between these three indicators make tool production a complex task. Optimizing one of the three target key performance indicators, while simultaneously performance of the other two, poses a big challenge for tool shops.

Transparent display of information regarding the three indicators represents the first step of meeting this challenge. Especially on the shop floor, a wealth of information is generated and has to be prepared and displayed suiting the requirements. For this, compression of relevant key performance indicators for measuring shop floor performance by means of a KPI cockpit is recommended. This KPI cockpit enables management to detect deficits early on, to take measures quickly and to lead employees in a target-oriented way.

Ideally, a KPI cockpit for the shop floor prepares the relevant information of single departments in such a way that the employees of the department have direct access to information on their performance. When selecting the key performance indicators, it needs to be taken into account that the employees of the respective department have the possibility to influence the displayed key performance indicators. The aim is to display the processes on the shop floor transparently in order to identify optimization potentials and to turn off existing weaknesses early on.

This study gives an overview of relevant key performance indicators for measuring performance along the value chain in the tool and die industry. In this context, definitions of several key performance indicators are provided, preconditions are defined, and the methods of data collection are described. Moreover, suggestions for an intuitive and clear display of the key performance indicators are made and a display concept for a shop floor KPI cockpit is presented.

Key recommendations for action

- Defining key performance indicators relevant to the own shop floor along the value chain of the tool and die industry
- Creating the preconditions for automated recording of data relevant to the key performance indicators
- Designing a suitable, intuitively understandable, and adaptable KPI cockpit for measuring shop floor performance

Authors

Prof. Dr. Wolfgang Boos
Director WBA Aachener Werkzeugbau Akademie GmbH

Dr. Michael Salmen
Head of Department Business Development
Laboratory for Machine Tools and Production Engineering (WZL)

Dr. Tobias Hensen
Former Group Leader Department Business Development
Laboratory for Machine Tools and Production Engineering (WZL)

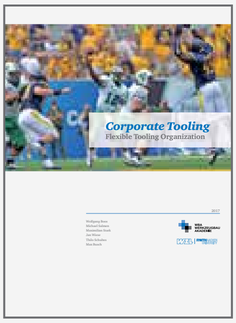
Max Schippers
Former Research Associate Department Business Development
Laboratory for Machine Tools and Production Engineering (WZL)

Jan Wiese
Research Associate Department Business Development
Laboratory for Machine Tools and Production Engineering (WZL)

Thilo Schultes
Research Associate Department Business Development
Laboratory for Machine Tools and Production Engineering (WZL)

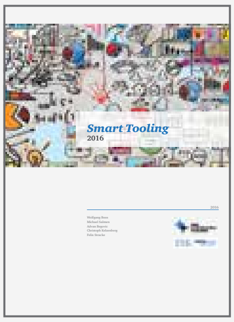
Our Studies – Strategic Development

Corporate Tooling – Agile Tool Development
2017

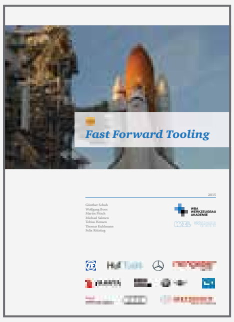


Corporate Tooling – Flexible Tooling Organization
2017

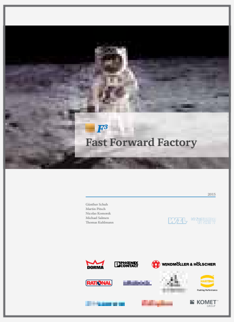
Corporate Tooling – Intelligent Tool Manufacturing
2017



Smart Tooling
2016



Fast Forward Tooling
2015

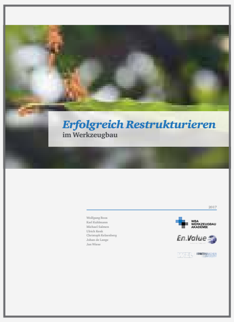


F3 Fast Forward Factory
2015

Our Studies – Successful…

Successful Milling
2018

Successful Automatizing
2017



Successful Reconstructing
2017

Successful Performance Measuring
2017

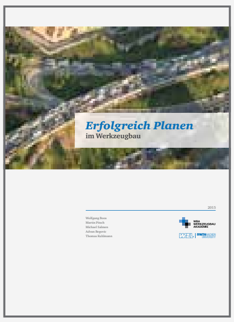
Successful Applying Manufacturing Technologies
2017

Successful Financing
2016

Successful Implementing Digital Networking
2016

Successful Motivating Employees
2016

Successful Calculation
2015



Successful Planning and Scheduling
2015

Our Studies – Tooling in…

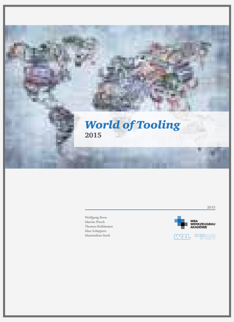
World of Tooling
2018

Tooling in Germany
2018

Tooling in China
2016

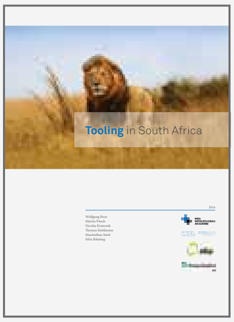
Tooling in Turkey
2016

Tooling in Germany
2016



World of Tooling
2015

Tooling in China
2015



Tooling in South Africa
2014

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WBA Tooling Academy Aachen
Campus-Boulevard 30
52074 Aachen

www.werkzeugbau-akademie.de

Laboratory for Machine Tools and Production Engineering (WZL)
of RWTH Aachen University
Campus-Boulevard 30
52074 Aachen

www.wzl.rwth-aachen.de

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