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Controlling Production with KPIs

Knowledge is power – how to increase productivity with KPIs

Businesses need reliable key performance indicators from production as a control tool to manufacture efficiently. The real skill is to convert large amounts of data (big data) into meaningful information (smart data).

Capacity utilization, OEE, scrap ratio and worker efficiency — these are all KPIs used to evaluate efficiencies in production. But what are the right KPIs? What happens if a KPI does not achieve the target set? And above all: Are the data sources for calculating KPIs reliable? These are the questions that one must answer in the age of Industry 4.0.

Manager and staff require reliable information in form of KPIs and evaluations to make decisions and introduce suitable measures. You can only intervene in processes if you have up-to-date information and know what really happens in production. Naturally, each decision-making level requires their specific KPIs and evaluations.

In line with requirements

It is paramount to select the right KPIs in order to supply appropriate information to the different target audiences. Operators in production will not be interested in business data but in information on the personal performance or scrap quantities because these are the values they can influence. Management on the other hand requires higher-level KPIs providing information on the current productivity and, further down the line, the company's competitiveness. KPIs are thus a useful instrument to break down business targets to departments, operating areas and target groups creating a control loop in this way that can be applied by every company division.

Motivation: Control Loop of Production

Cause and effect

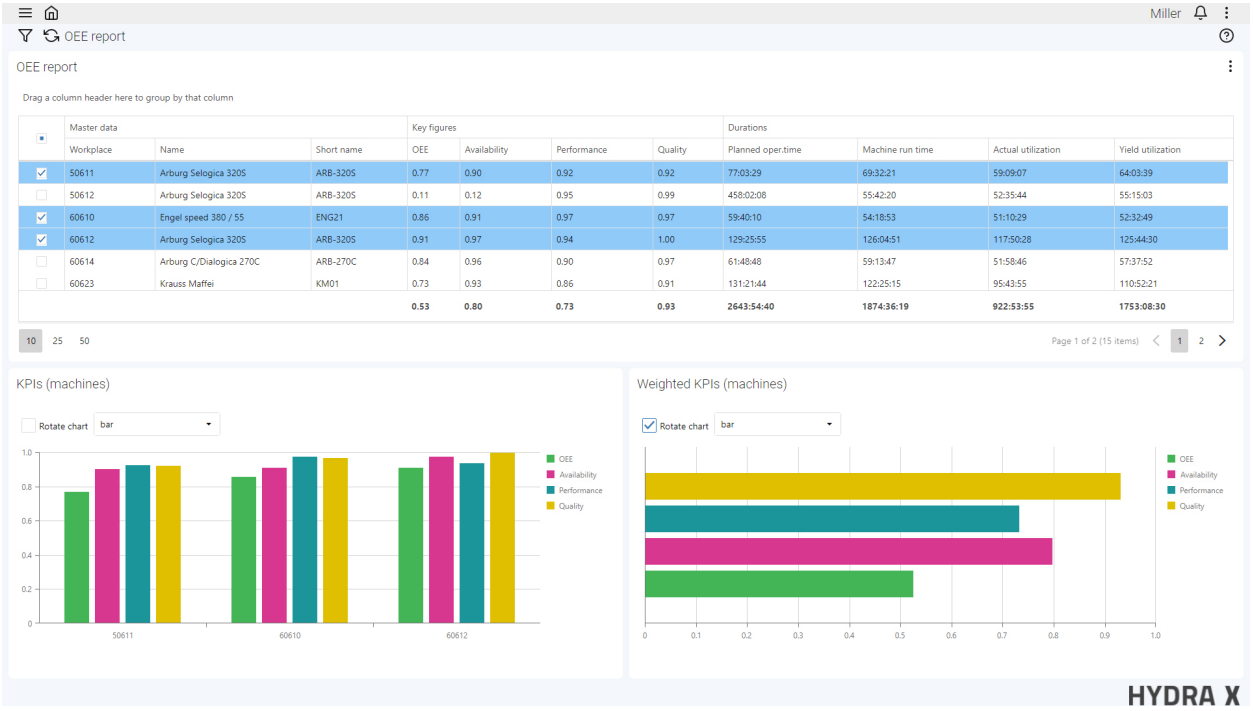
Mere KPIs are not sufficient to make decisions with a long-term effect. They must be suitably presented, especially their correlation.

Let's say a production manager detects a decline in the OEE (Overall Equipment Effectiveness). This decline may have different reasons. If the manager wants to find out what caused the decline, a closer look at the OEE calculation is necessary. This is how the OEE is calculated:

A declining OEE can therefore have three reasons: declining availability (increase of machine downtimes and as a result less production time than planned), declining quality (more scrap) or lower performance (longer cycle times on average). Manufacturing IT shows these complex relationships in charts totaling the numbers and displaying details on the different factors. The responsible person obtains an instant overview of the causes that have actually led to the current situation and can react accordingly.

OEE = AVAILABILITY * QUALITY * PERFORMANCE

The OEE key performance indicator can be used to control whether the targets are achieved, and also to compare machines, departments or different sites with each other. Of course, you can only compare data that is calculated the same way so it is essential that OEE calculation uses identical data.



Important criteria for KPIs

To achieve consistent communication across all company levels, the used KPIs must be based on a common data basis. Data (such as production quantities) collected with modern manufacturing IT is aggregated to be finally displayed as KPIs to their audience. In this way, operators can directly view the quantities produced and their supervisor obtains the OEE calculated from these quantities and other related data.

KPIs also include a time aspect. Some KPIs show a current status while others refer to a defined period of time. KPIs providing information about a defined period of time are only meaningful once the interval has elapsed (KPI about availability, for example), whereas real-time KPIs can be evaluated at any time (quality KPI, for example).

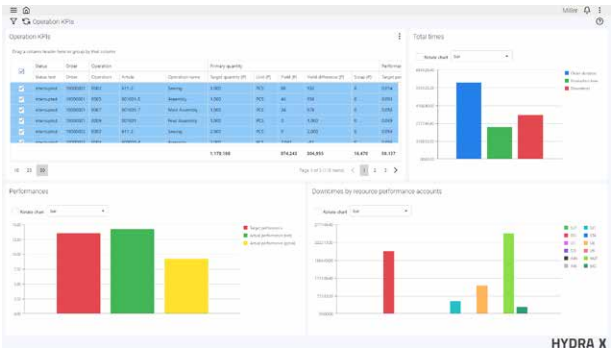
Important criteria of a KPI:

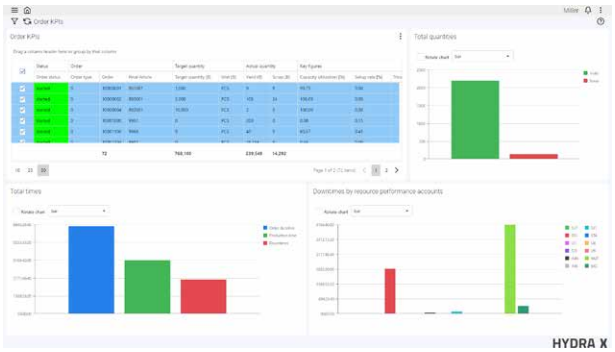
- **Currentness**
- **Transparency and comprehensibility**
- **Consistency**
- **Unambiguity**
- **Comparability**

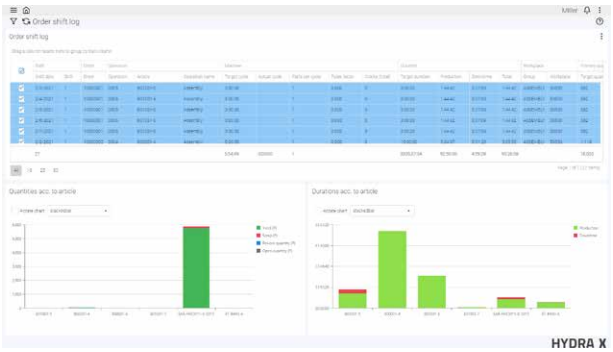
KPIs for management and controlling

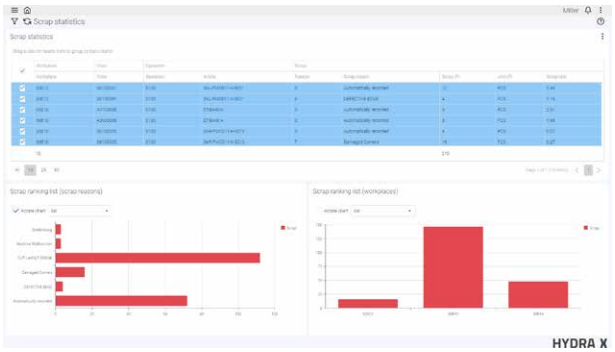
In order to carry out a weak point analysis for management and controlling, the user requires long-term KPI evaluations based on aggregated and accumulated data. For this reason, the MES Cockpit from MPDV displays not only the raw KPIs, but also the defined target values to show the KPI trend and also the target compliance.

The graphical display of KPIs provides a better overview. In the MES solution HYDRA, such evaluations can be as follows:









Relevant KPIs

Experiences gained from multiple optimization projects show that a selection of only a few KPIs proves to be successful. These include:

- Capacity utilization
- Setup ratio
- Performance
- Allocation efficiency
- Worker efficiency
- Scrap ratio
- Output ratio
- Overall Equipment Effectiveness (OEE) including performance, quality and availability

These KPIs are clearly defined in the VDMA standard sheet 66412 (ISO 22400-1) and fulfill the criteria of standardization and comparability.

KPIs for the production management

Supervisors and production managers need an overview of KPIs in their responsibility area. They can access current figures and also figures of a medium-term period in the past. It is therefore possible to evaluate KPIs of the current production and also past trends of previous shifts. During shift handover, the supervisor could inform about increasing scrap rates. In the shift that follows, the input material and the setting parameters of the machine might then be checked.

With regard to the KPI trend, a maintenance engineer could also initiate a maintenance or inspection measures for specific machines.

Company KPIs – functions, effects and benefits

The success of a company is tied up with a rise in number of staff or in turnover and profit compared to the previous fiscal year. A share is considered promising as long as its price is rising. These are indicators which make the success of a company comprehensible to general public converting it into a tangible number.

A standardized and scientific definition for these KPIs does not exist. The VDMA uses the following definition in its sheet 66412-1 / ISO 22400-1 (KPIs in Manufacturing Execution Systems):

„Key Performance Indicators (KPIs) are business indicators which can be used to measure the progress or degree of achievement in terms of targets or critical success factors within an organization. Important issues and structures in the company require a business KPI for

1. **decisions (problem identification, presentation, gaining information)**
2. **control (target/actual comparisons)**
3. **documentation/coordination (control of behavior).“**

In short, a KPI presents company targets in a simple format. The objectives become tangible for employees, so they can contribute to their achievement and share the success of the company.

KPIs were and still are a vital instrument to promote a company's success!

Objectives of KPIs

The following objectives of KPIs can be derived from the definition:

- KPIs simplify complex issues and structures in a company.
- They are presented as a figure on a metric scale and are easy to compare.
- They are informative.

The below matrix illustrates the functions of KPIs:

Comparisons	Targets
▪ compare efficiency of companies or sites ▪ outline local advantages ▪ compare departments	▪ set realistic objectives ▪ trace objectives ▪ evaluate business activities
Controlling	**Monitoring**
▪ detect deviations ▪ identify strengths and weaknesses ▪ identify need for action	▪ visualize impact of processes ▪ illustrate success and failures

Different types of KPIs

KPIs can be displayed in different ways. They can be absolute or relative values and refer to different times.

Absolute versus relative KPIs

- Absolute numbers present a measured value (e.g. turnover, number of staff, etc).
- Relative numbers present comparative values. They are calculated comparing two values (e. g. (good/total quantity)*100=output in %).

Absolute KPIs show a trend over a given period of time. A single value has no significance. You can only see a negative or positive development when comparing it to other values (e.g. development of turnover over the past 10 years).

Relative KPIs provide the proportion in relation to a total quantity. For example, good quantity in relation to the total quantity produced so far results in a percentage value for quality. If quality should run at 95%, the actual value in production is compared to the target value. If the result deviates to expectation, you can take measures.

KPIs evaluating different periods of time and having different effects on the company's objectives

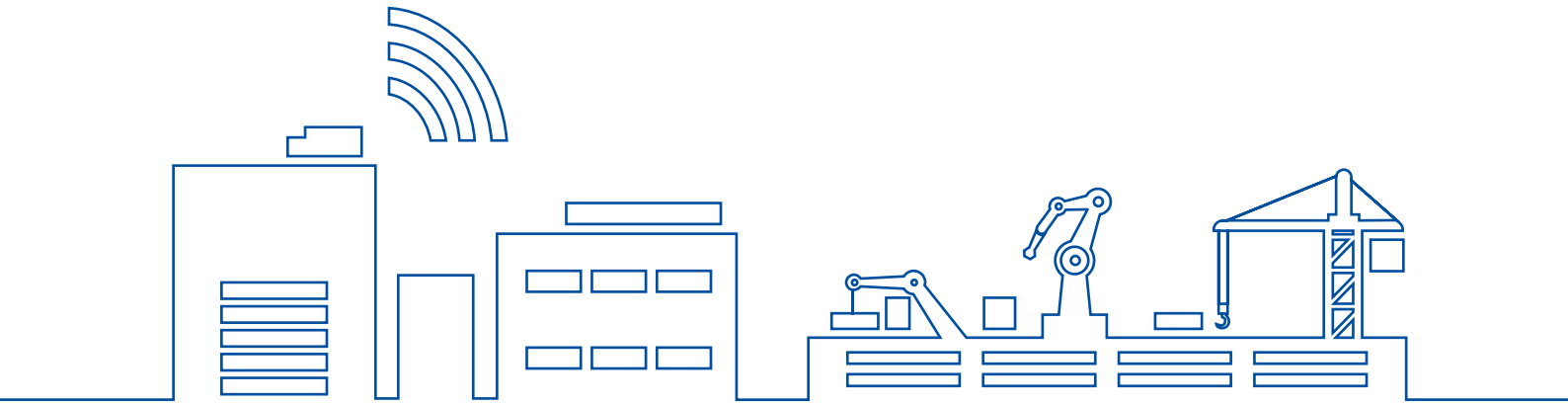
- Leading KPIs predict future results (evaluating current and planned data)
- Lagging KPIs report about past results (evaluating data of the past)

Leading KPIs provide information on current statuses and target data. They are used to predict the future result. The quality target value of a shift is set to 95%. If the average value is running at 98% after half of the shift has passed, then it is feasible to hit the target value of 95%.

Lagging KPIs are values evaluating the past. One example are financial KPIs evaluating the past fiscal year of a company by assessing turnover or profit.

KPIs for the shop floor

Operators can at all times request the current KPIs of the shift on a shop floor terminal and directly react to the KPI development. If scrap rates constantly increase at a machine, recommendations are stored asking to change the setting parameters or to trigger a tool inspection to reduce scrap.



CONCLUSION

In short: KPIs support people in making well-founded decisions — in real-time and at all levels of a company. Their real-time capability is what sets manufacturing IT apart from the higher-level BI systems (Business Intelligence). While BI systems evaluate large historical data volumes (big data), manufacturing IT uses current data to calculate only few, but meaningful KPIs (smart data) instantly available to make short-term decisions. They are therefore used to directly monitor and control the production processes. Whereas evaluations from BI systems are suitable for long-term analyses and optimization projects.

A long-standing MES user confirms:

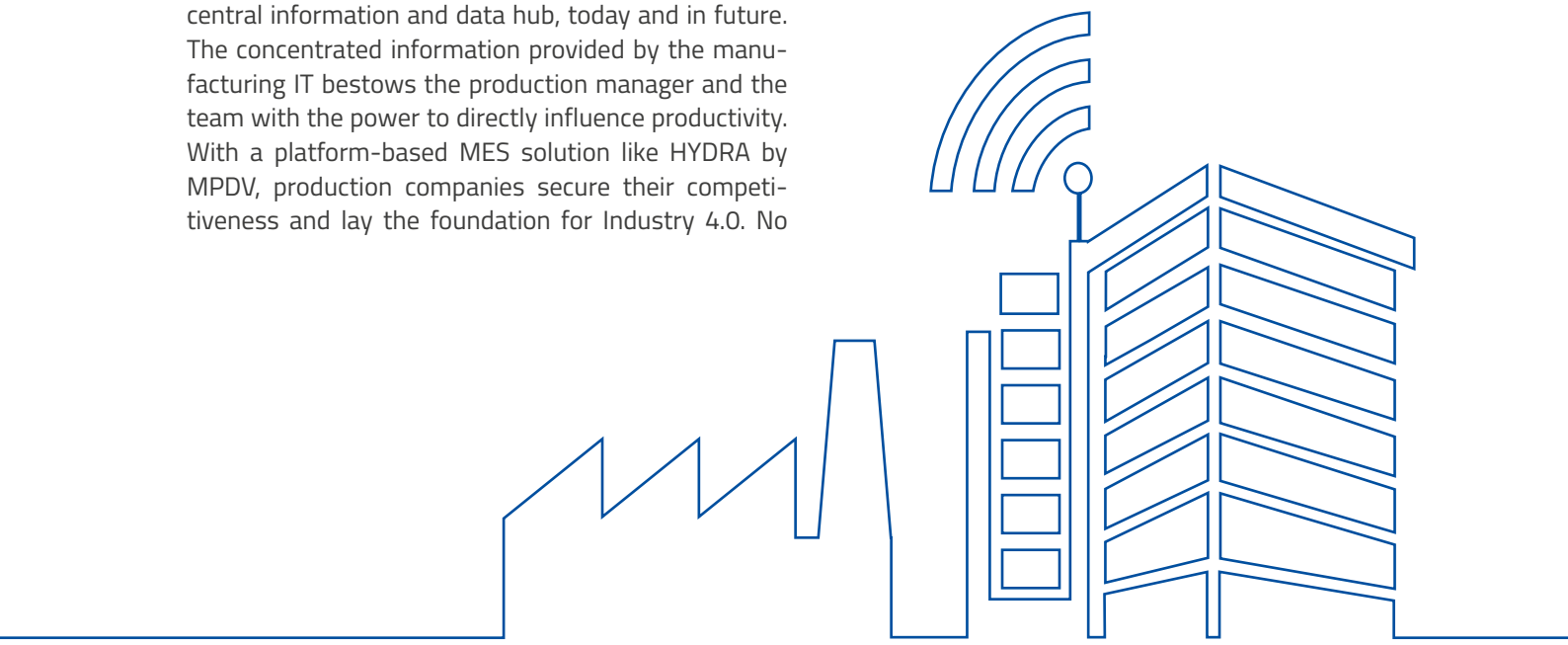
„HYDRA provides us with current KPIs on personnel and machine utilization. We also obtain current statuses and quantities from the machine that we use to plan our resources the best possible way. With the help of the MES solution HYDRA, we can build a working control loop."

KPIs for all and everywhere

Production managers can also use a mobile device (e.g. smartphone or tablet) to check current KPIs like OEE for one or all machines or machine groups. This enables the manager to compare KPIs and take measures like getting in touch with the supervisor.

The big picture

Today and in future, sustainable management decisions require sound evaluations and KPI systems (smart data). The data basis is provided by manufacturing IT and standardized interfaces. Data is then locally collected and processed by different systems. This also shows how important the manufacturing IT is as a central information and data hub, today and in future. The concentrated information provided by the manufacturing IT bestows the production manager and the team with the power to directly influence productivity. With a platform-based MES solution like HYDRA by MPDV, production companies secure their competitiveness and lay the foundation for Industry 4.0. No matter how intelligent and self-sufficient production facilities are becoming, in the end responsibility for the right decision lies in human hands – and again reliable information is crucial. Knowledge is power!



Important KPIs – definition and calculation

The VDMA standard sheet 66412 (ISO 22400) defines the most important KPIs used in MES systems. The list below provides an overview and describes how KPIs are used and calculated.

Overall Equipment Effectiveness (OEE)

The OEE illustrates the overall effectiveness of machines and provides information about availability and efficiency of machines and equipment during operation. This KPI aims at improving information about production, identifying production losses and increasing quality. It also enables comparisons of machines and lines.
Calculation:

availability * performance * quality

Availability

Availability is a value in percent providing the ratio between the machine's actual production time and the planned production time.
Calculation:

actual production time / planned production time

Quality ratio

The quality ratio identifies process failures as well as produced scrap and rework quantities. The good quantity produced is compared to the total quantity produced.
Calculation:

good quantity / total quantity produced

Performance (effectiveness)

Performance is the ratio between actual performance and planned target performance of machines. The calculation can be made with quantities or cycles in relation to times and quantities.
Calculation:

actual quantity / target quantity or
target cycle / actual cycle

Capacity utilization

This KPI identifies a machine's utilization efficiency in relation to machine time. The capacity utilization is the quotient of actual production time and actual unit busy time. It informs about the actual utilization of a machine compared to the total machine time including planned downtimes.
Calculation:

actual production time / actual unit busy time

Technical efficiency

This KPI is an indicator for the degree of malfunctions in production or the efficiency of the machine. The technical efficiency compares the actual production time of a machine and the downtimes due to technical malfunctions. All other downtimes (e.g. organizational interruptions like cleaning) are not included in this calculation.
Calculation:

actual production time / (actual production time + downtimes due to malfunctions)

Allocation efficiency

The allocation efficiency is the ratio between the actual allocation time of a machine and the planned allocation time. The KPI informs about the actual utilization compared to planning.
Calculation:

actual allocation time / planned allocation time

Setup ratio

The setup ratio is the ratio between a machine's setup time and the processing time. It is used to uncover losses due to long setup times.
Calculation:

setup time / processing time

Scrap ratio

The scrap ratio shows the relation between produced scrap and total quantity produced. A low scrap rate means high productivity.
Calculation:

scrap quantity / produced quantity

Output ratio

The output is the ratio of actual good quantity produced to target quantity per time unit in percent.
Calculation:

produced good quantity / target quantity

Worker efficiency

This KPI compares the attendance time of employees and the order-related labor times stored in the system. The objective is to make employees aware of their performance and thus increase productivity.
Calculation:

order-related labor time of personnel / total attendance time

Process capability index

The process capability indices Cp and Cpk assess the ability of a process to meet the specifications.

The Cp value indicates the deviation of measured values from the specified tolerance limits. This value does not show where the mean value of all measured values is situated in relation to the tolerance limits.

The Cpk not only indicates the deviation of measured values from the specified limits, but also shows the mean value in relation to the tolerance limits. If the mean value is right in the middle between the tolerance limits, then the Cpk value is equal to the Cp value – otherwise the Cpk value is smaller.
Calculation:

Cp= (upper specification limit – lower specification limit) / 6x standard deviation

Cpk= minimum distance of mean value to the two specification limits / 3x standard deviation

Note: The selected specification or tolerance limits have a significant impact on the process capability indices.

Machine capability index

The machine capability index assesses the ability of a machine to meet the specifications. The value is comparable to Cp and Cpk but only relates to the results of one machine instead of the whole process.
Calculation:

similar to process capability

Note: Machine capability has been superseded by process capability and is only rarely calculated.

Checklist – Using KPIs efficiently

Managers, supervisors and operators need effective software tools in order to have a 360-degree view of production. Applications should fulfill some basic requirements with regards to evaluations and KPIs.

Criteria to efficiently use evaluations and KPIs:

- Data collection and processing in real time
- Standardized interfaces to collect and read data
- Transparent calculation of KPIs
- Calculation of standardized KPIs as per VDMA standard sheet 66412 (ISO 22400)
- Company-specific customization with user-defined KPIs
- Visualization of data according to target group
- Flexible views for different users (groups)
- Drill-down principle to select the required level of detail – from overview down to individual machines, products or orders
- Comparison of machines and plants as well as overall evaluations including several sites
- Data and KPIs are only compared if calculated the same way
- At all business levels, the same data is used to calculate KPIs
- Consistent data across all internal (collected data) and external (imported data) sources

Outlook: Manufacturing Analytics – more than KPIs

Collected data only provides real added value if you gain valuable information from this data. The tools used to this end can be brought together under the heading 'analytics'. You might wonder whether all this does not yet exist, but no, by no means!

Manufacturing companies need maximum transparency to be competitive! Only if they know what is going on in the shop floor, they can take appropriate action to optimize processes. Over the years, tools like KPIs and their presentation in dashboards have proven to be useful. Today, however, much more is needed although KPIs and dashboards are far from being outdated.

Let's elaborate further

IIn MPDV's model of the Smart Factory Elements, workflows in a modern factory can be assigned to five elements making up a control loop. According to this control loop, production is planned (Planning & Scheduling) based on specifications from different sources and this plan is then implemented or executed (Execution). The collected data is analyzed (Analytics) in order to make predictions (Prediction) which, together with other findings, can then be integrated in planning. The Industrial Internet of Things (IIoT) supports this loop by collecting and providing data and adding local real-time applications.

Classic analytics applications

The analytics module includes important applications providing added value in form of information to the Smart Factory. Indeed, most of these applications are well-established on the market. Among them are evaluations, reports, dashboards as well as KPIs. Many of those applications are part of a Manufacturing Execution System (MES) like HYDRA from MPDV. Scrap statistics, machine time profile, OEE report and the classic control chart of quality assurance are widespread evaluations. These are only some examples where HYDRA generates added value by presenting information that is calculated or aggregated with collected raw data.

Self-Service Analytics

Manufacturing companies often require more than standard KPIs and evaluation templates. If analyses process large amounts of data (big data), the methods of the Self-Service Analytics lend themselves to processing this data. The pivot table we all know from Excel is a classic method, which is also used in MES HYDRA. The Failure Mode and Effects Analysis is a good example of such a table. The flexible assignment of data fields to rows and columns and the targeted use of filter and correlation functions help to narrow down data to useful values. Users can now design their own evaluation by taking advantage of the proposed tools. If data of different sources need to be correlated, the MES Cockpit by MPDV relying on Qlik technology is perfectly suited to visualize this data.

Advanced Analytics

In the age of Industry 4.0, buzzwords like artificial intelligence and machine learning are increasingly used. The underlying algorithms and methods analyze data in a way that mimics the human mind. One example is the use of big data volumes to generate a model mapping real processes. This model then enables to detect and classify deviations. In recent years, Predictive Maintenance or the ability to predict malfunctions and standstills of machines has been much talked about. Such an application can use the above model-based analysis methods. MPDV's Predictive Quality or the mApp AI-based Setup Time Prediction are further examples of Advanced Analytics. The mApp predicts setup times using historical data and thus contributes to optimized planning results.

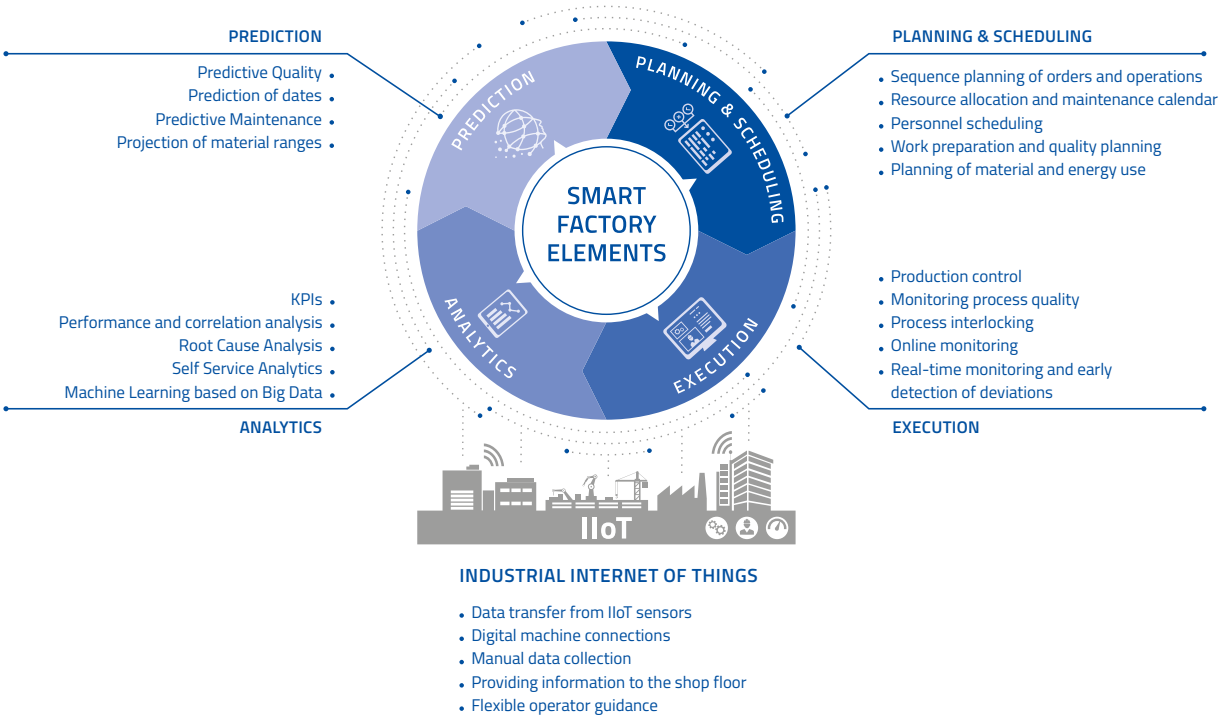
Outlook

The number of innovative applications extracting valuable information from the mass of available data will continue to grow. Technological progress in the field of artificial intelligence will not come to an end – quite the opposite.

Let's look forward to what the future will bring! But let us not lose sight of what matters: the application matters and not innovation for the sake of innovation.

Smart Factory Elements

A model for innovative manufacturing IT



The Smart Factory Elements model describes a control loop. According to this control loop, production is planned (Planning & Scheduling) based on specifications from different sources and this plan is then implemented or executed (Execution). The data collected is analyzed (Analytics) to derive predictions (Prediction), amongst other things. The findings from analytics and prediction then flow back into planning. The Industrial Internet of Things (IIoT) supports this loop by collecting and providing data and adding local real-time applications in the shop floor.

Predictive Quality

With Predictive Quality, MPDV presents a new application using process data to predict the quality of a produced article.
Predictive Quality assumes that scrap or rework can also occur if all process parameters are within the valid tolerances. The prediction of quality involves three steps:

1. Collect process data and correlate this data with true quality data
2. Develop prediction models
3. Execute model and predict quality based on real-time data

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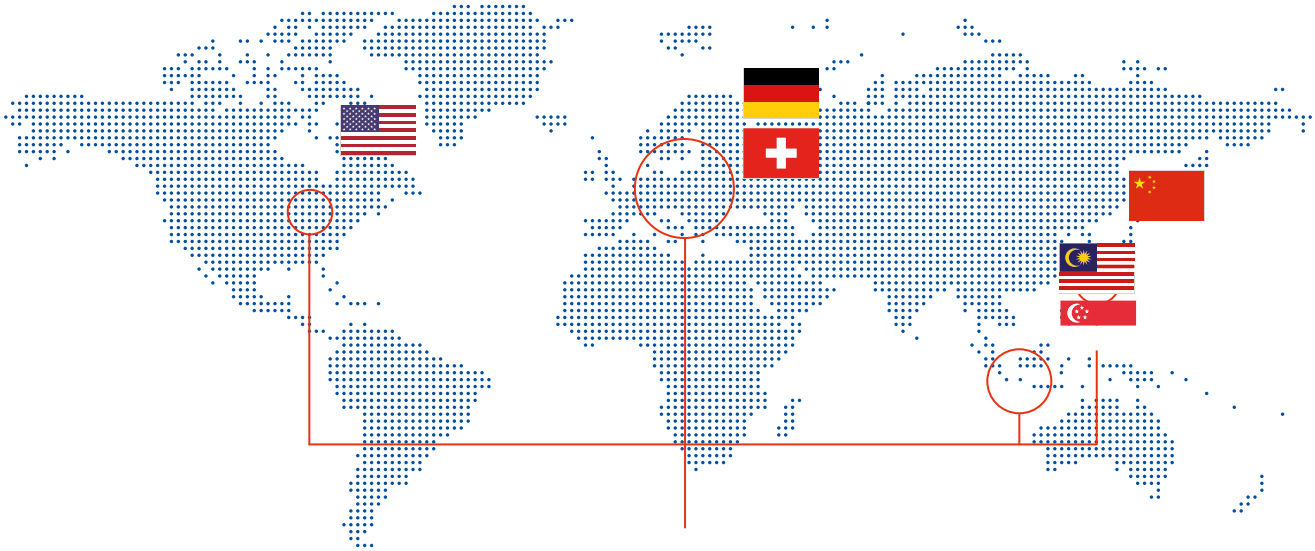
About

MPDV Mikrolab GmbH

headquartered in Mosbach/Germany, is the market leader for IT solutions in the manufacturing sector. With more than 40 years of project experience in the manufacturing environment, MPDV has extensive expertise and supports companies of all sizes on their way to the Smart Factory.

MPDV Products such as the Manufacturing Execution System (MES) HYDRA, the Advanced Planning and Scheduling System (APS) FEDRA or the Manufacturing Integration Platform (MIP) enable manufacturing companies to streamline their production processes and stay one step ahead of the competition. The systems can be used to collect and evaluate production-related data along the entire value chain in real time. If the production process is delayed, employees detect it immediately and can initiate targeted measures.

More than 900,000 people in over 1,400 manufacturing companies worldwide use MPDV's innovative software solutions every day. This includes well-known companies from all sectors. The MPDV group employs around 500 people at 13 locations in China, Germany, Luxembourg, Malaysia, Singapore, Switzerland and the USA.



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