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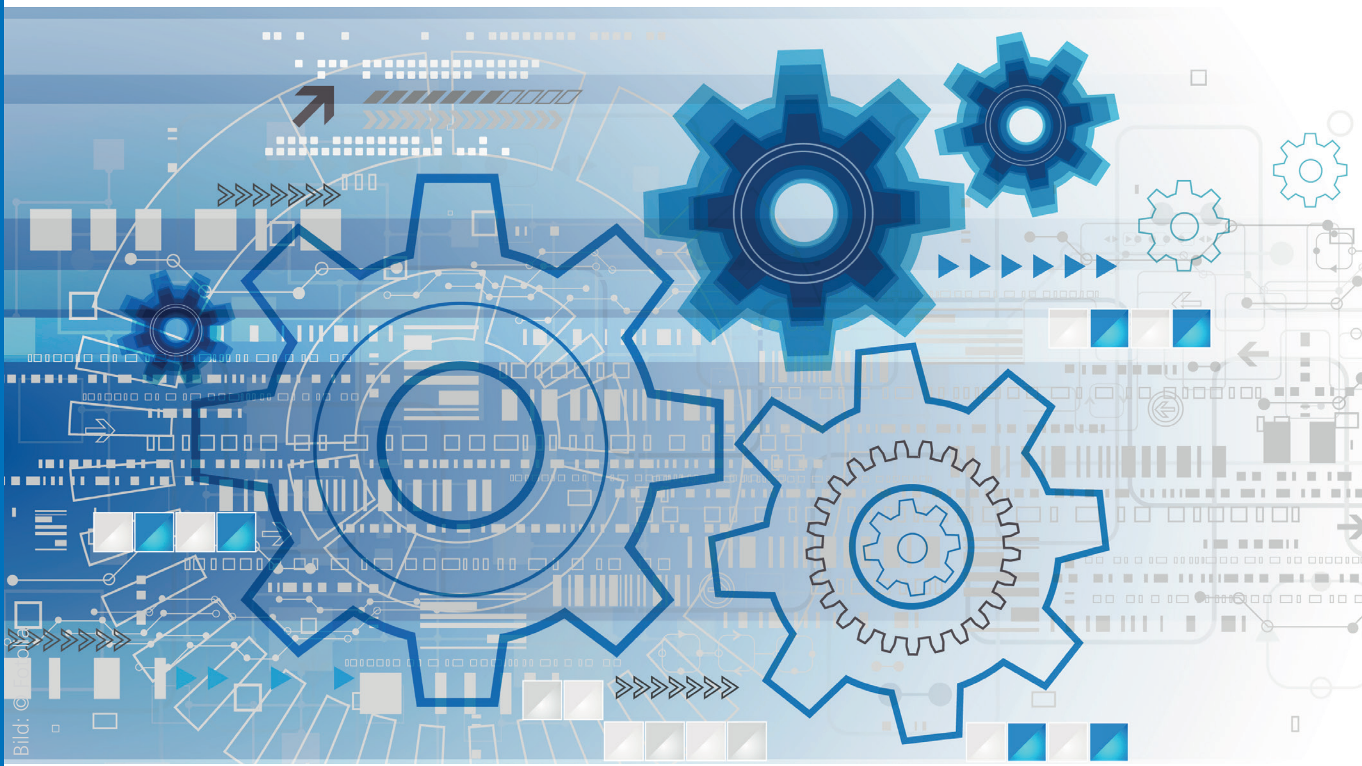

Return on Maintenance

A paradigm shift in maintenance services due to Industrie 4.0

Whitepaper

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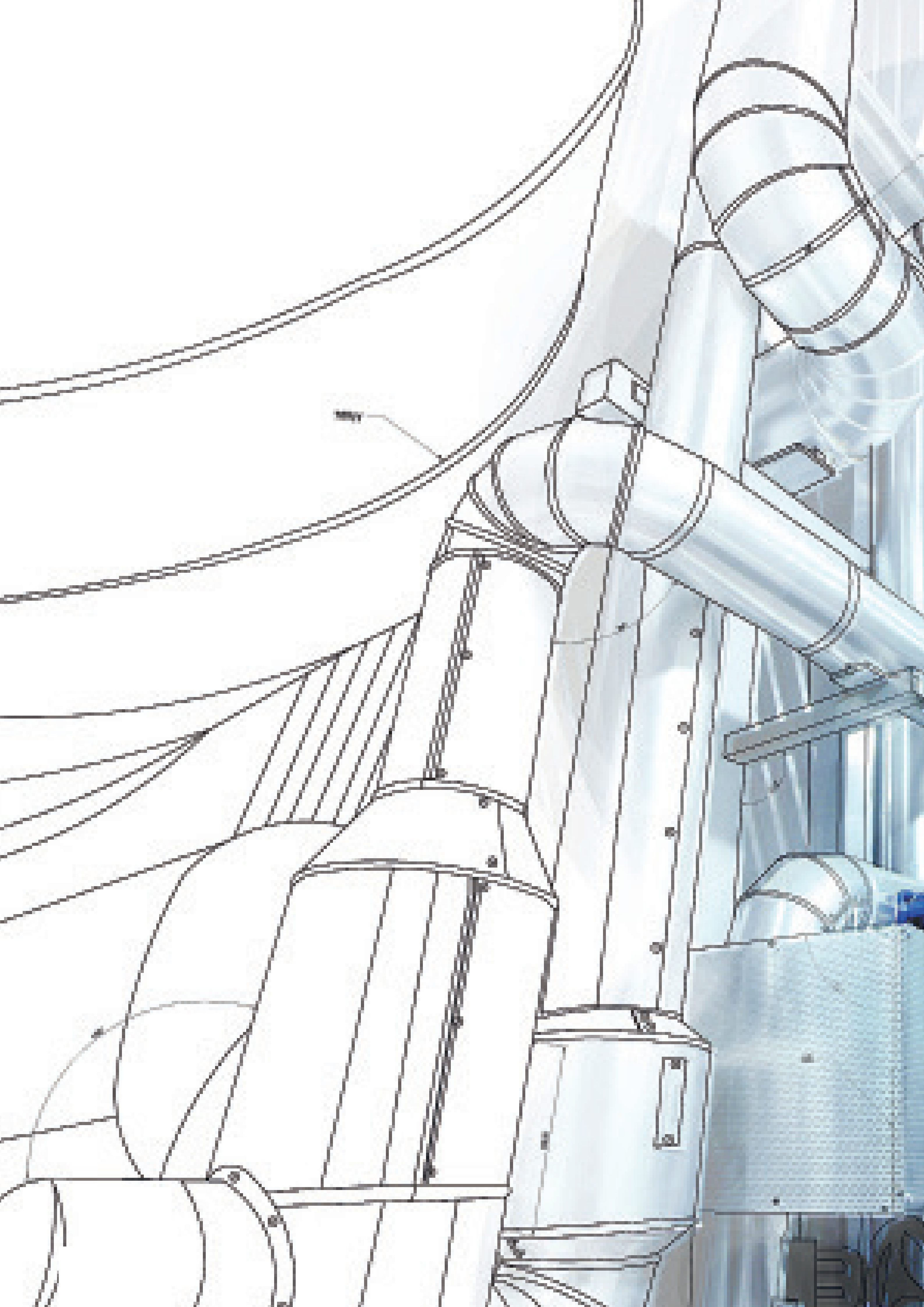

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Return on Maintenance

A change of paradigm in maintenance services due to Industrie 4.0

Contents


SERVICE &MAINTENANCE AUGMENTED REALITY

1 A change in the maintenance industry

For the last 20 years, the importance of maintenance measures for manufacturing companies in high-wage countries such as Germany has been highlighted repeatedly by scientific research. Day-to-day practice has also made it clear that maintenance services play an increasingly important role for the overall success of manufacturing companies. However, many of these companies often consider maintenance tasks merely as factors that add to their general costs. Very often, they do not pay a lot of attention to the positive effects and the high potential of a successful maintenance concept (see Figure 1). Most manufacturing companies know of the various possible benefits but do not take them into consideration when making decisions regarding the operative practice. One of the positive effects of successful maintenance measures is their influence on operation and production costs, which is an effect that is relatively easy to evaluate and measure. However, if companies need to decide whether the maintenance or the production department should have prioritised access to technical assets in need of maintenance services, this decision is very often in favour of the production department and, therefore, the fulfilment of customer orders. As a result, any long-term problems caused by this decision, such as an over-use of the machine or plant, need to be solved by the maintenance department.

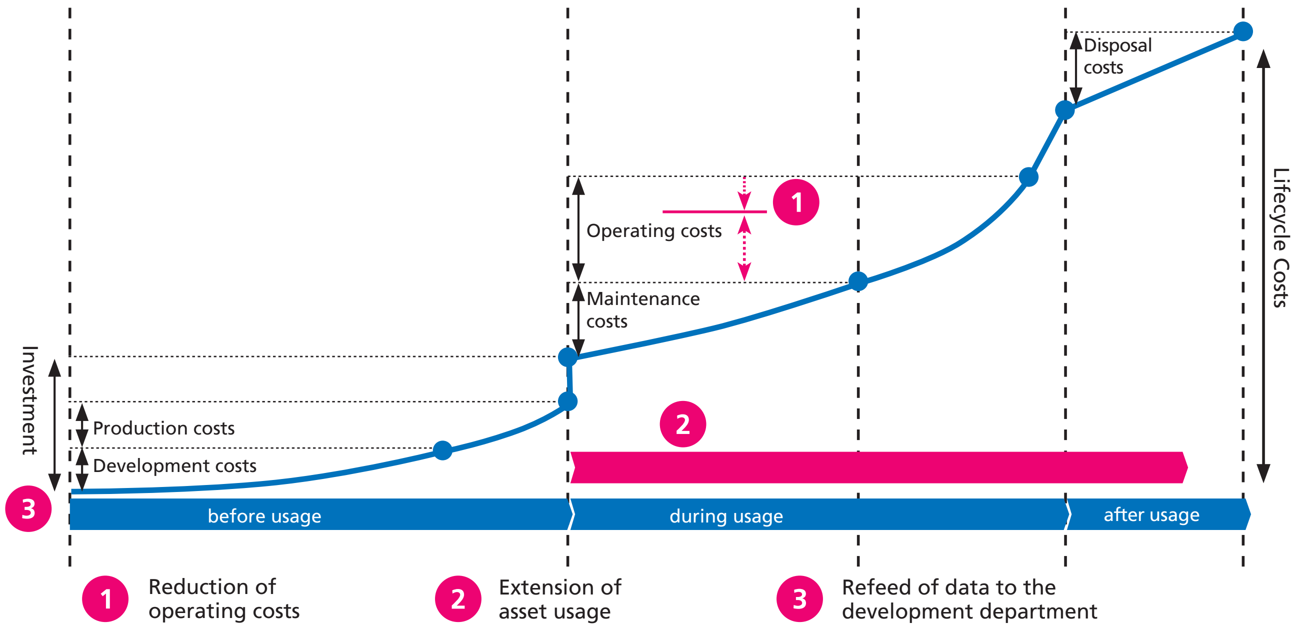


Figure 1: Selected possible benefits/potential of maintenance shown on the example of life-cycle costs. (in the style of: VDI 2884)

Another positive potential effect of successful maintenance activities is the increased longevity of a technical asset – especially when condition-based or predictive maintenance is performed instead of reactive maintenance. Additionally to this, well-organised maintenance measures can help to gather experienced-based information from machines and make them available for the development or production department.

Transparency-based data is the first step towards value-based maintenance measures

Technically, many companies could already make use of the named potential benefits but choose to neglect them systematically. The reasons for this are very diverse: One of the main reasons is the lack of a database, which is required to quantify the impact of decisions or potentials of maintenance concepts. Solving the lack of transparency is the first and most crucial step towards a value-based maintenance concept. It is very likely that the image of maintenance in manufacturing companies as well as the public debate about it will be renewed or rather intensified as a result of Industrie 4.0. From a maintenance perspective, this is beneficial as the standing of maintenance within the company may be reevaluated.

2 Effects of Industrie 4.0 on maintenance measures

Industrie 4.0 refers to "real-time, intelligent, horizontal and vertical interconnection of people, machines, objects and IT systems to enable dynamic management of complex systems." (Bauer et al. 2014, S. 18). Its focus is on the connection and the broad use of information and communication technology in industrial production.

By adding "4.0" to the term Industrie 4.0, the potentially revolutionary effects of this industrial development are underlined. In essence, these effects make it possible to perform organisational adjustment processes significantly quicker than before.

Organisational adjustment processes are characterised by a number of latencies nowadays. The sum of these latencies is the reason why companies tend to implement necessary changes only very slowly. This includes simple continuous improvement processes as well as product innovations or the readjustment of business models. Many times, necessary data is not available on time, has to be processed first in order to be interpretable, or the general quality of the data is not sufficient. Analyses with the aim to allow data-based decision-making require a high manual workload and are only used very selectively. Decision-making processes often take weeks or even months, and the actual implementation processes are not undertaken rigorously enough by the affected departments or only with a long delay. The results of this are diverse:

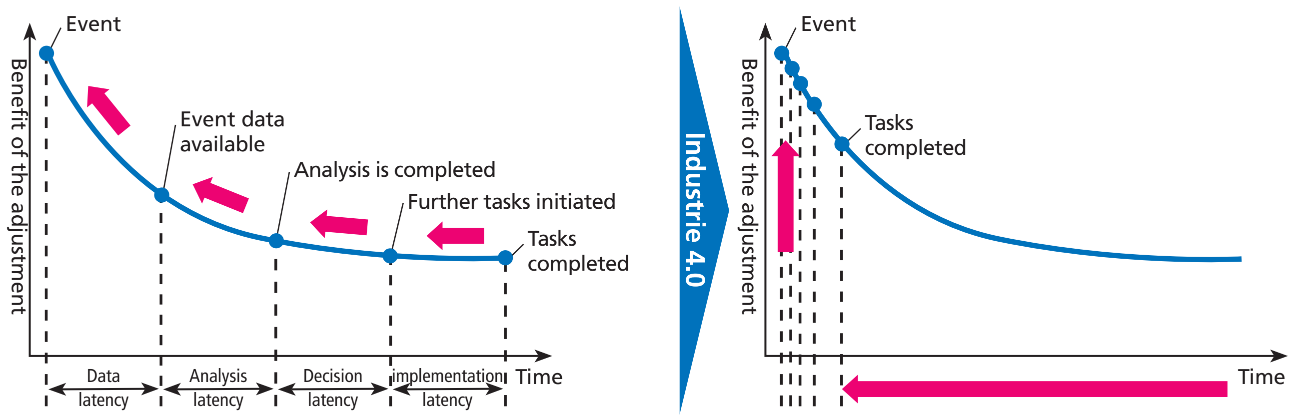


Figure 2: Shortening of the adjustment process in the framework of Industrie 4.0 (own presentation, in the style of: Muehlen u. Shapiro, S. 11)

Decisions are often made based on a "gut-feeling" rather than on actual data. Necessary process improvements are not made, leading to inefficient organisations and dissatisfied employees. New products and services are developed with a high workload – but due to the outlined issues, they do not meet the actual customer demand.

Because of the many technological developments characterising Industrie 4.0 (e.g. Big Data, Machine learning etc.), it has the potential to accelerate organisational adjustment processes significantly. Today, data is already collectable, processable and transferable in real-time. Thanks to processes performed by and with Artificial Intelligence and Big Data, important analyses are available in a very short time. With the help of context-sensitive assistance systems, analysis results can be made available to the responsible person at the right time and the right place, making it possible for them to make decisions quickly. Thanks to the horizontal and vertical integration of IT systems and assets there is no need to carry out any changes manually in different systems – instead, the changes are implemented in a variety of departments with the "click of a button", so to speak. The possible benefits of this development include the increased speed of process and product innovations as well as the ability to adjust business models very quickly. Because of the combination of its technological and organisational abilities, Industrie 4.0 paves the way to the agile company.

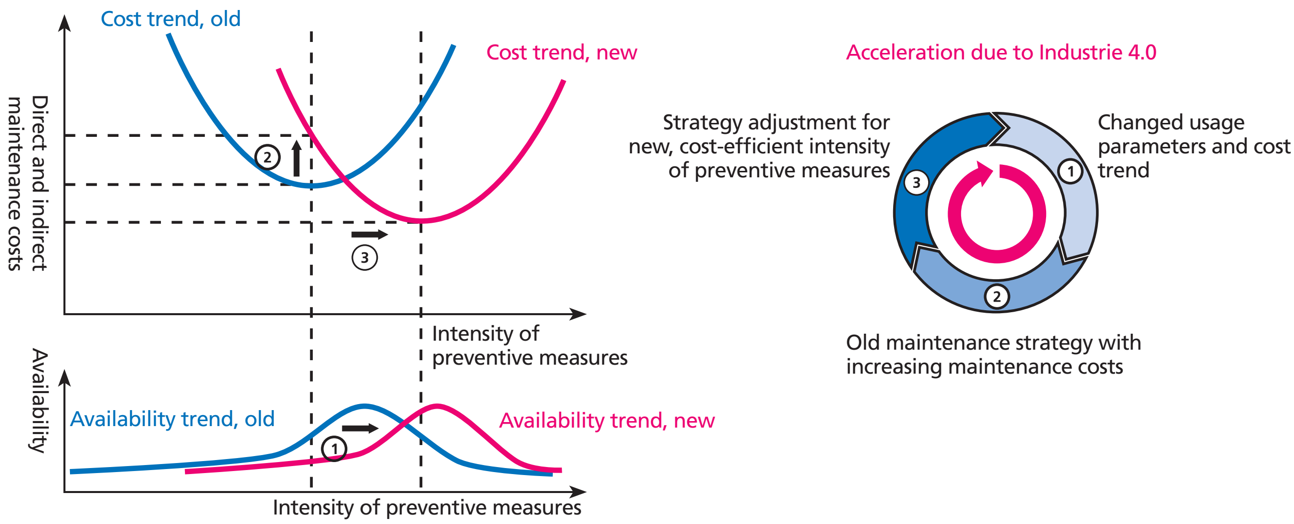


Figure 3: Shorter innovation cycles cause the need for an adjustment of the maintenance strategy in agile businesses (own presentation)

In terms of maintenance, the development towards an agile company in the course of Industrie 4.0 plays an important role. Because of frequent and quick adjustments to products and processes, it is necessary that the maintenance concept is able to follow these adjustment processes at the same speed. The example in Figure 3 shows how a maintenance strategy needs to be adjusted as a result of previous product and process changes.

The term maintenance strategy refers to the chosen strategy mix, which may include reactive, preventive and predictive maintenance measures. Changed production parameters often result in the need to change the strategy mix. Correlations between the extent of prevention measures and the frequency of machine breakdowns are changing – and they are reflected in direct as well as indirect maintenance costs. In order to stay cost efficient, the maintenance department is forced to adjust its strategy mix from time to time – e.g. by increasing predictive measures. In agile companies, increasingly short innovation cycles and faster adaption cycles in the production phase require equally fast adaption processes of the maintenance strategy.

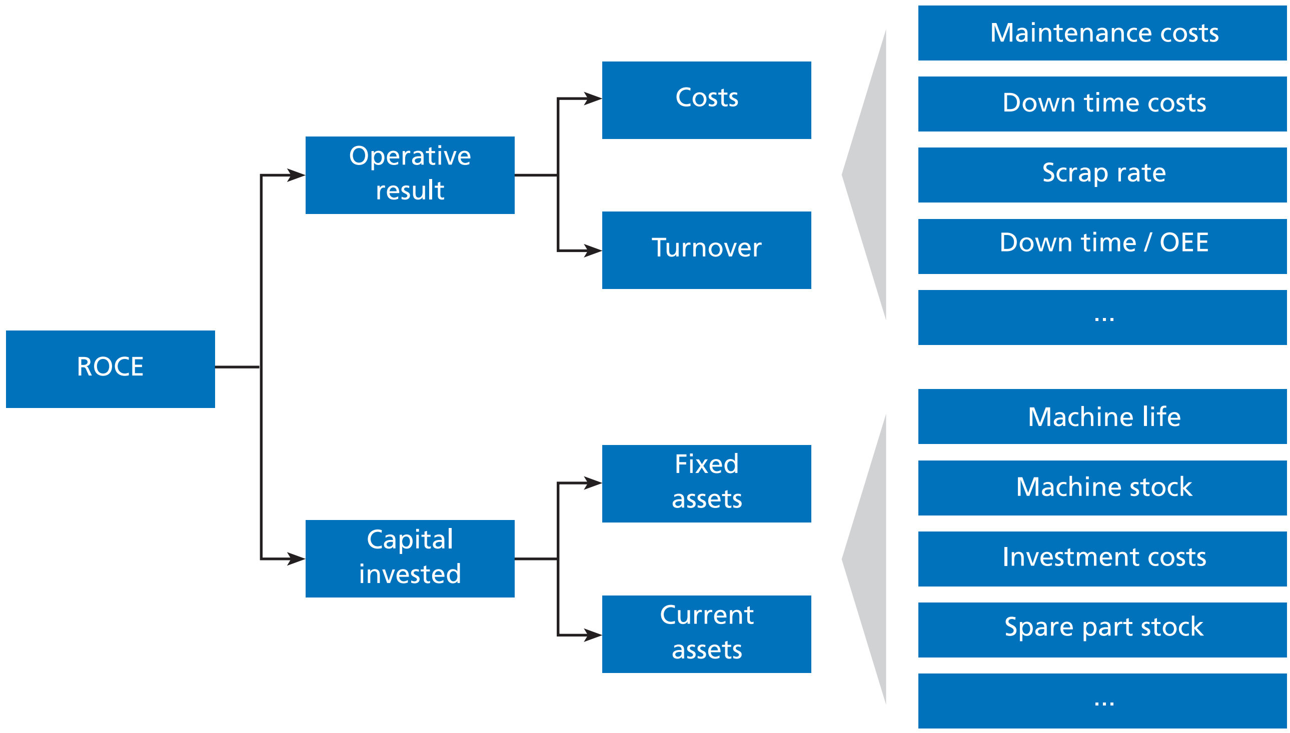


Figure 4: The added value of maintenance using the example of Returns on Capital Employed (ROCE) (in the style of Stiefl 2008, p. 24; Biedermann 2016, p. 75ff.)

Shaping the world of to-morrow is impossible with the methods of yesterday

The already complex decision regarding an ideal maintenance strategy will have to be reassessed significantly more often in the future. To do so, the availability of a broad database and the establishment of transparency are are essential basic requirements. It is also crucial that adjustment processes can be implemented very quickly in organisational and operational structures. Transparency and speed of adjustment processes are key abilities that will characterise successful maintenance concepts in the future. Manufacturing companies that master this will have significant competitive advantages. Therefore, maintenance activities become not only a crucial strategic factor of success but also an important driver of company value.

To achieve all of the described benefits, a change of paradigm is required. This change can take place in the course of the Return on Maintenance (RoM) concept. At the very centre of the concept is the question of how the value of maintenance for manufacturing companies can be maximised in times of Industrie 4.0, in which agility plays an increasingly important role.

In the concept of RoM, the financial return of successful maintenance activities, exceeds the simple low-cost reinstallation of the machine or asset availability by far. Target values such as rejection rate, energy and material efficiency, and minimisation of set-up-times show that many different aspects need to be considered to ensure the success of maintenance measures. Based on the knowledge of how maintenance can and cannot be beneficial for for a company and based on which potential it really offers, business cases, investment calculations and maintenance strategies need to be reevaluated.

An adequate quantification of these target values, however, is difficult to do in this context. Figure 4 shows an example of possible key indicators that follow the concept of RoM. It shows that a large number of different maintenance-specific factors (e.g. downtimes, machine or asset life expectancy, spare part stock etc.) have a direct or indirect impact on the technical figures of ROCE. However, the effect of all of these influence factors in total is very complex, since there is often no direct relation to the costs.

Abandoning a valuation that is solely based on direct costs, a paradigm shift in the guiding principles for maintenance is initiated. With the help of these new principles, it becomes possible for the maintenance department to maximise its Return on Maintenance.

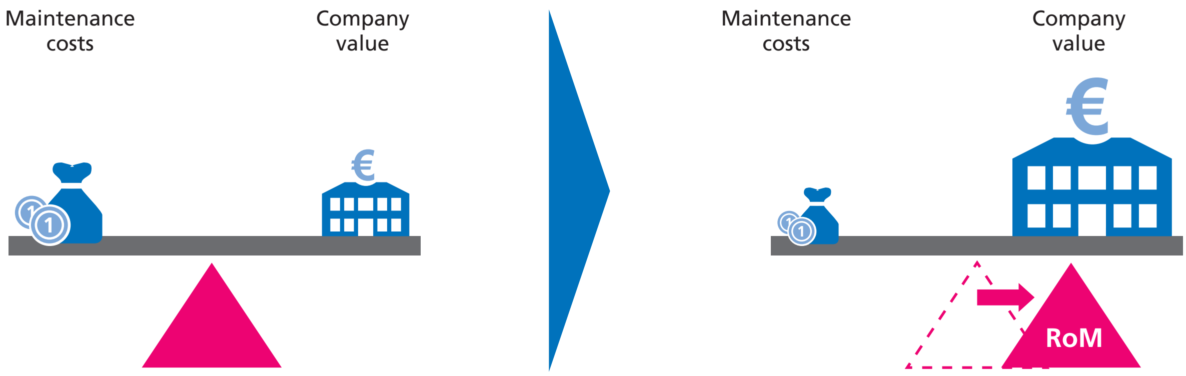


Figure 5: Return on Maintenance: Maximisation of the value contribution of maintenance activities (own presentation)

3 Success principle 1: Transparency with the help of the digital shadow

Due to constantly changing production parameters, a maintenance department is faced with the challenge of continuously examining its optimal strategy, understood as a mix of reactive and preventive or predictive activities. In order to be able to evaluate the current situation, to analyse the link between cause and effect and to make goal-oriented strategic decisions, it is very important to ensure the availability of data and adequate information , as both provide the basis for evaluation. For example, conclusions regarding wear behaviour in connection with operating parameters of machines and facilities can only be drawn if relevant key factors are collected and stored on a regular basis. The same applies to the evaluation of efficiency and effectiveness of individual maintenance orders: Orders can only be evaluated if order details are registered, saved, and associated with machine data such as performance, quality and reliability. Order data refers to the income and successful resolution of a maintenance request, the spare parts and tools used, the employees involved, and the final result of the maintenance measure applied. All of these details help to virtualise the process and its result digitally (see Figure 6).

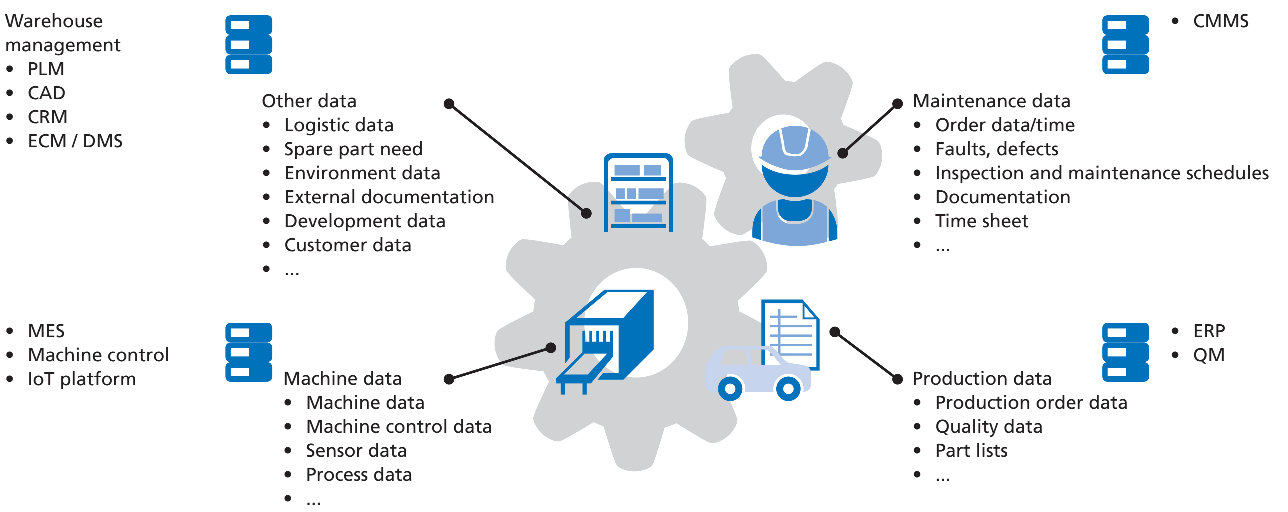


Figure 6: Different data sources in a manufacturing company (own presentation)

This is where the so-called digital shadow comes into effect: It is the goal of a digital shadow to keep relevant data and information available in real-time, in case the data is required for important decisions. To achieve this, two key capabilities are required: First, it needs to be possible to collect data from different operating systems (e. g. ERP, MES, CMMS) and different data sources (machines and sensors etc.) (see Figure 6). Second, a conceptual model of all underlying processes needs to be available – it is required to identify the further need of data collection (see Figure 8). When doing so, it is essential to collect data that helps to create a digital visualisation of real processes and conditions. Additionally, it is necessary to keep cost effectiveness in mind when data is collected. By reducing the data collection effort (e.g. with the help of cost efficient sensors and process-integrated auto-ID-technologies as well as a limitation of manual entries by staff), investments for technology and hardware can be kept low and the quality of data can be increased. The digital shadow combines data stemming from processes, machines, assets, application systems and other sources into one digital representation. This representation is then edited for different departments for different purposes.

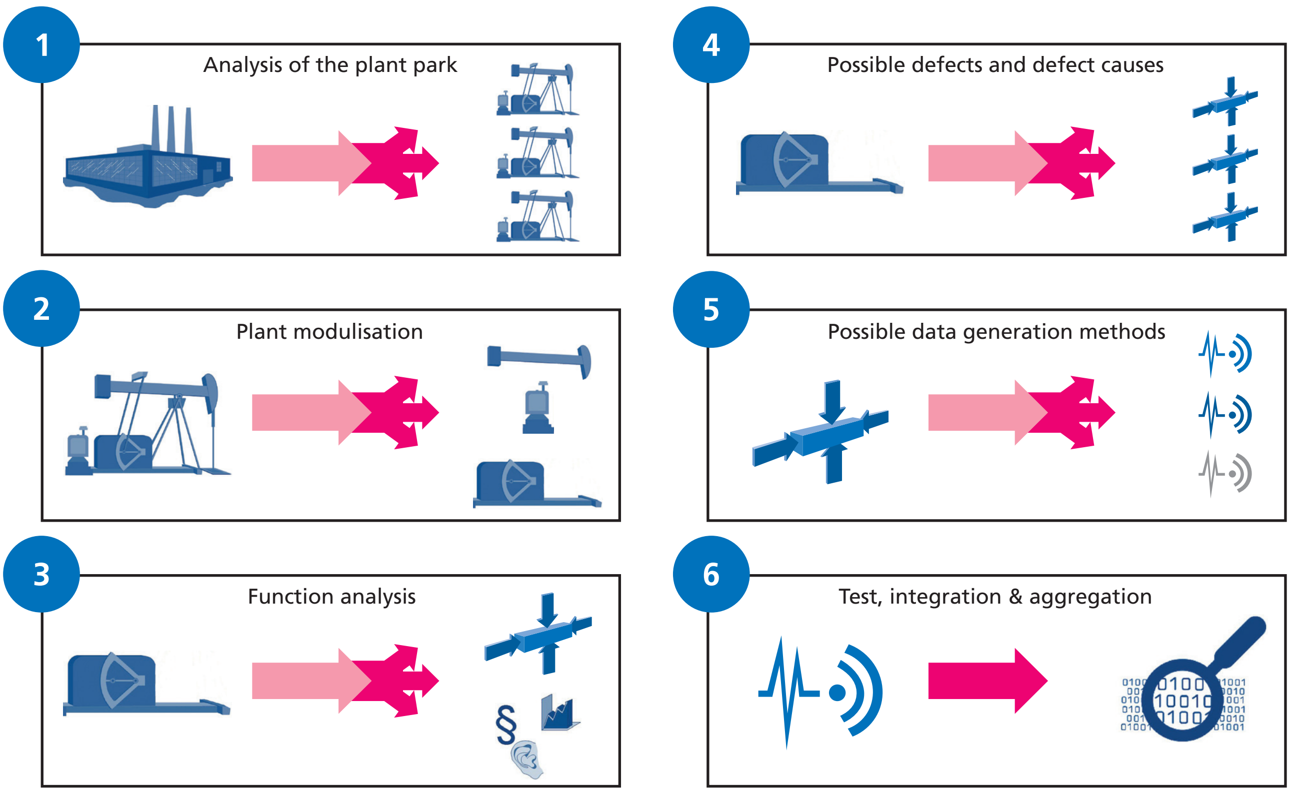


Figure 7: Method for the creation of a digital shadow of a plant park (own presentation)

Digital shadow for machines and plants

An essential part of the digital shadow in maintenance is the digital representation of machines and plants. On the one hand, this includes the availability of historical data, e.g. in form of a detailed record, which includes all past defects, inspections, maintenance orders and improvements but also production orders that were carried out. On the other hand, the digital representation also includes real-time data on the condition regarding the condition of the machines – this is a necessary step in order to be able to make forecasts regarding possible machine failures in the future. A general procedure for defining the necessary data and data collection methods is shown in Figure 7.

First, an in-depth analysis of the selected machines must be made. The machines and installations are to be categorised with regard to their importance in the production process in order to identify those that cause a bottleneck effect. From an economic point of view, it is important to first focus on these machines before considering others. The existing technical equipment of the systems, such as already existing sensors and the possibility to connect the system to a network, also plays an essential role for the creation of the digital shadow. At this point, it must be decided which machines meet the minimum requirements that justify retrofitting from an economic perspective and with regard to the process.

In a second step, specific machines and their components are looked at in more detail. Each component is checked, and it is examined which functions it actually serves. By doing so, a functional model of the machine is created, which makes it possible to categorise the different functions with regard to their criticality for the production process. Based on the critical functions that, in case of failure, would lead to an immediate stop of system operations, possible causes of malfunction are identified.

As soon as possible causes of defects are identified, the corresponding data and data sources (measuring points) can also be identified. As a result, it is also possible to "measure" the causes of defects and to detect indicators for their occurrence or future occurrence. This data is therefore most suitable for digitally mapping the state of the machine component or module. Following this, adequate recording methods to collect this data can be selected. When doing so, economic aspects should also be considered, because it is possible that the cost of the technical data collection exceeds its benefit. Frequently, the selected data collection method has to prove itself in a practical test, which also helps to ensure economic feasibility.

One of the challenges of creating a digital shadow for maintenance activities is not only the actual generation of data but its structured processing and merging. A data model is required that reflects the real process as accurately as possible. Just like a flight data recorder, the data model saves real-time data from various different sources with a time stamp. Once this data set is generated, the current condition of a system can be accessed "at the press of a button". In addition, by having access to and analysing historical dataset, it becomes possible to identify trends and cause-effect relationships.

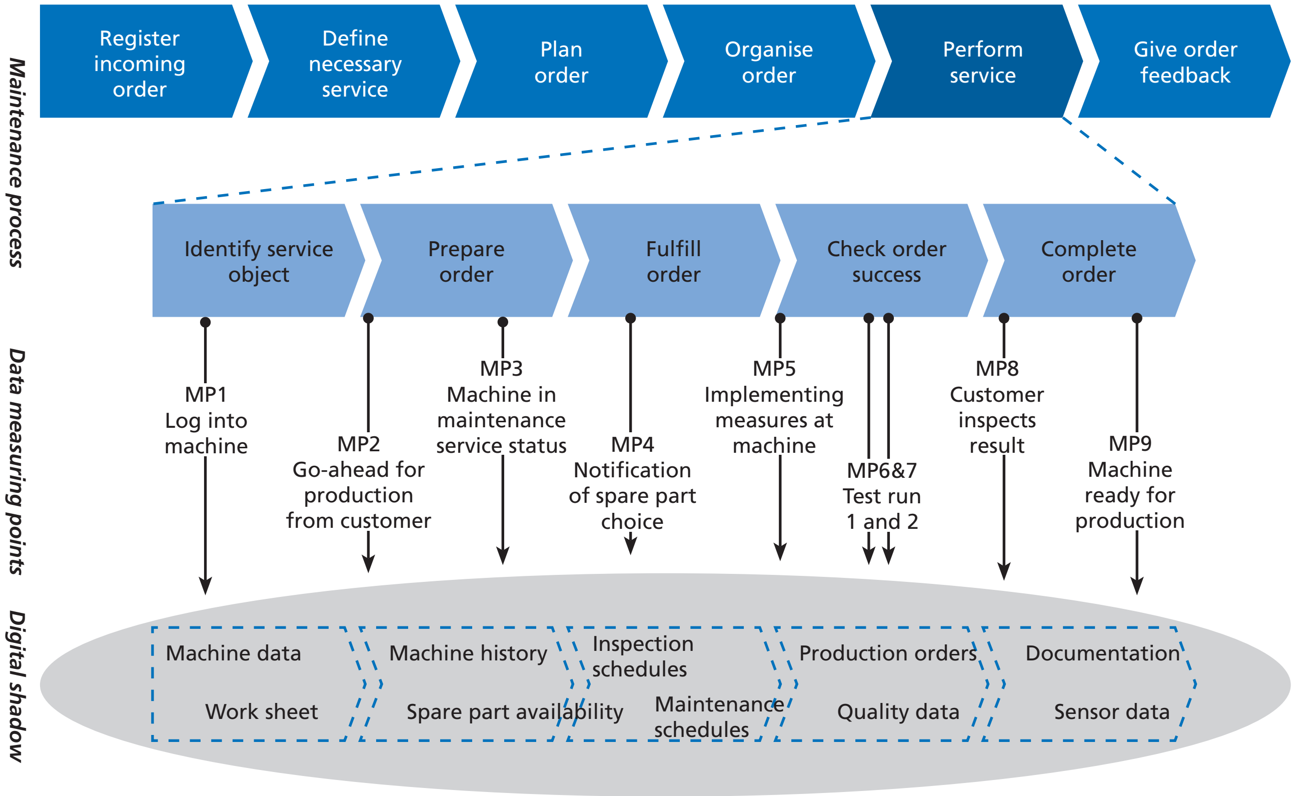
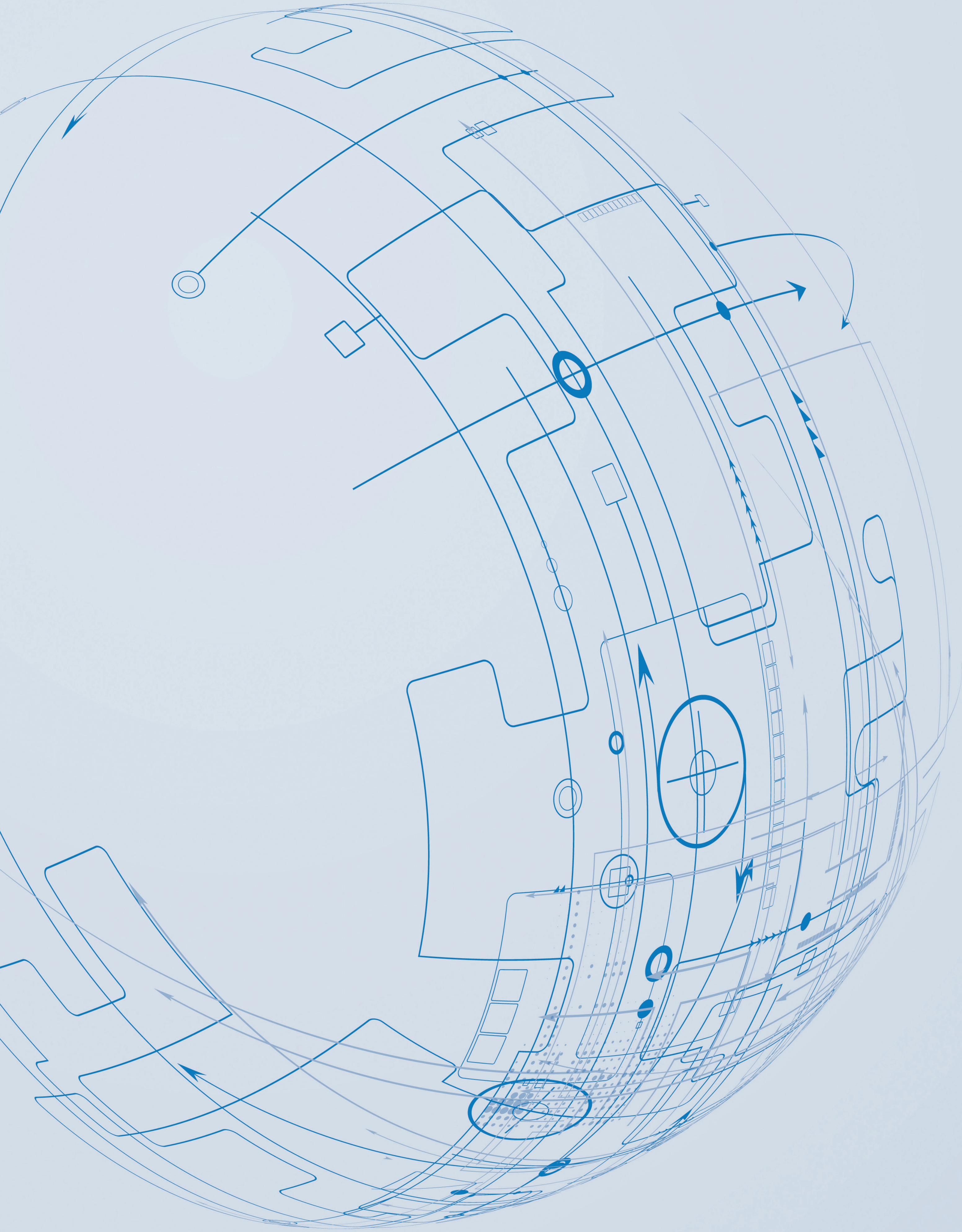


Figure 8: Relevance of a digital shadow for maintenance measures (in the style of: Kallenberg 2002, S. 91ff.)



4 Success principle 2: High implementation speed due to Minimum Viable Services

Short product innovation cycles and highly frequent adjustments in production lead to shorter maintenance cycles for the development and implementation of technological innovations. At the same time, a variety of development options for maintenance measures exists thanks to digital technologies. Among these options are procedures in the field of predictive maintenance, assistance systems (e.g. based on augmented reality) and the set-up of a consistent data basis. When considering this variety of possibilities, it becomes apparent why it is important to validate the value contribution of a new technology very quickly via real-life use cases.

The main ides of the Minimum Viable Service concept (see Figure 9) is to focus on a few highly important aspects and functions of a service in the initial phase of development. The most important target value is to achieve high development speed, because if a service is realised and introduced to the market quickly, feedback and the possibility to improve the service accordingly are also available very quickly. To achieve this, the creation of a complete set of functions for a service before bringing it to the market is dismissed deliberately. Instead, iterative measures and learning by doing are the guidelines of the minimum viable service principle.

Figure 9: Change of implementation and development cycles in maintenance services within the scope of Minimum Viable Service (own presentation)

> Done is better than perfect

These principles require a change of thoughts. Conventional project procedures have a complex stage-gate process and often make it impossible to achieve the desired development speed. Frequently, launching a project and assigning the first budget already takes months. Apart from the cost of creating such a project template, valuable time is wasted. Likewise, this approach often tries to predict the project progression and its costs in detail for several years, without having the necessary knowledge and details to do so. Thus, fast and effective innovation is systematically prevented.

Companies must dare to be more experimental and put already developed concepts to the test at an early stage. Early and active testing leads to important results. Although this approach does mean more frequent failures of initially well-thought ideas, the overall results are often much cheaper and faster and more likely to be accepted from employees than the traditional approach. This, however, requires a major shift in organisational culture, especially a company's culture of error, as well as comprehensive risk management.

5 Success principle 3: Low implementation costs due to the use of standards

Use standards, save resources, be successful

Most manufacturing companies face the challenge of having to accomplish the digital transformation with their existing machines and systems. This problem is often referred to terms such as "brownfield approach" (for existing machinery and equipment parks) or "legacy" (for an existing software landscape). Obstacles to the success of the digital transformation include the use of hardware (machines and systems) of different age, from different manufacturers, requiring different technical prerequisites. Furthermore, the software landscape in most companies is also characterised by numerous differences, which further complicates the transformation process. Often, data cannot be merged across different systems without complications, or it only exists in (locally stored) office applications. In order to achieve a high speed of transformation and implementation, it makes sense to rely on proven standard solutions whose integration does not require any new developments or broad adaptations to the hard- and software of already existing systems.

This is particularly relevant considering the fact that numerous different data sources need to be integrated into the digital shadow in order to ensure its transparency. The actual costs of closed, proprietary solutions often only show after a couple of years, when system adjustments or improvements have to be carried out.

In the area of the Internet of Things, cloud-based platforms such as PTC ThingWorx in combination with the middleware Kepware offer a broad range of suitable solutions for problems in the field of connectivity, communication between IoT protocols, and application development.

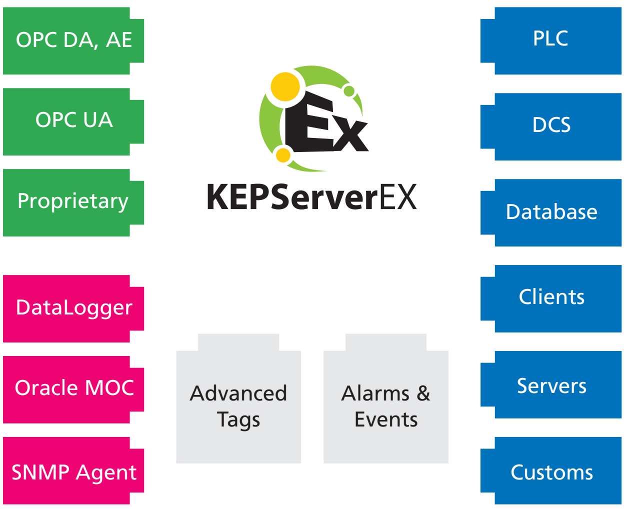
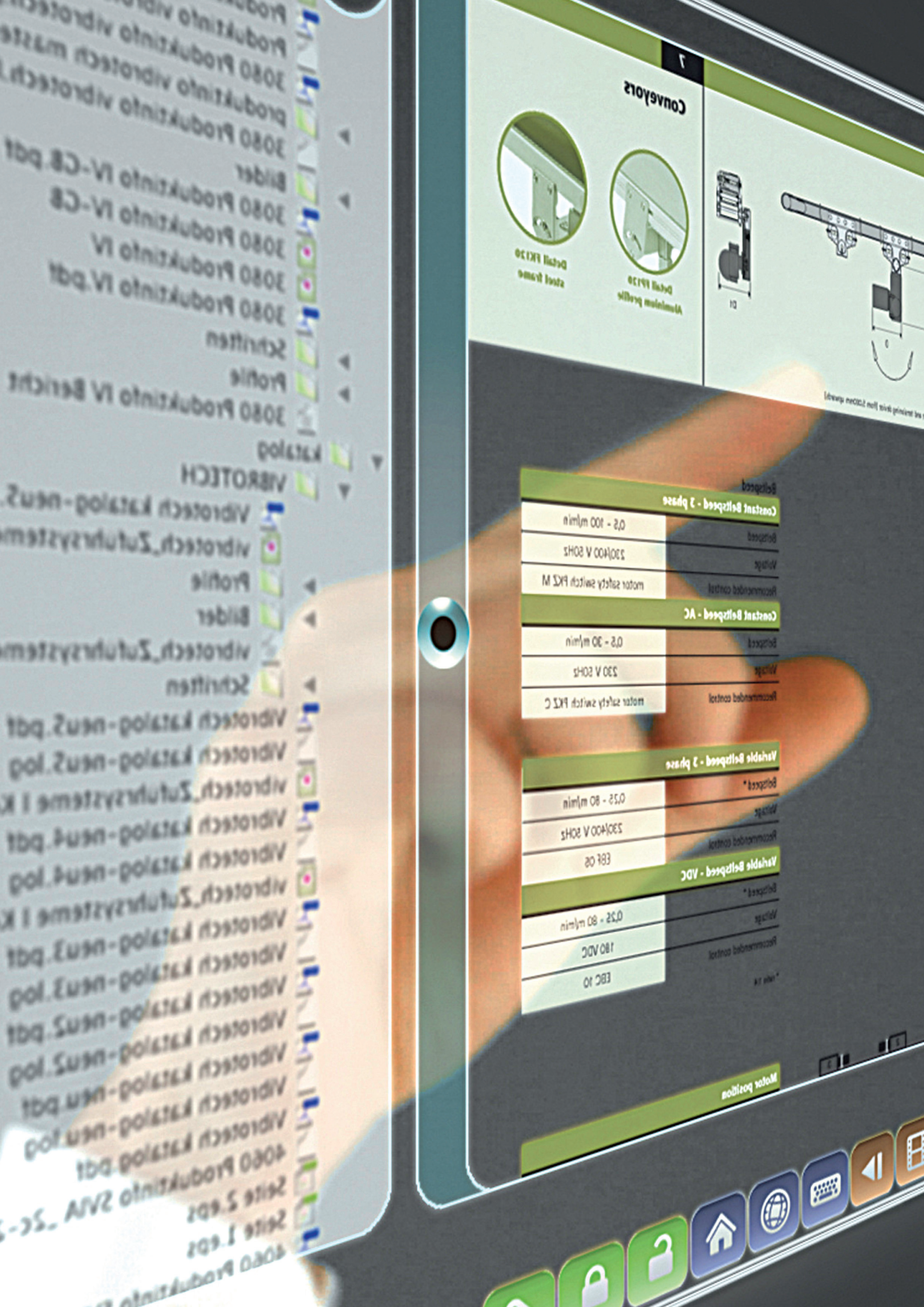


Figure 10: Integration of standard solutions, illustrated based on the example of PTC ThingWorx Middleware „KEPServerEX"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Constant Beltspeed - 3 phase
0,5 - 100 m/min
230/400 V 50Hz
motor safety switch PKZ M
Constant Beltspeed - AC
0,5 - 30 m/min
230 V 50Hz
motor safety switch PKZ C
Variable Beltspeed - 3 phase
0,25 - 80 m/min
230/400 V 50Hz
EBF 05
Variable Beltspeed - VDC
0,25 - 80 m/min
180 VDC
EBC 10
Motor position
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6 Success principle 4: Long-term success due to a knowledge and innovation culture

The Return on Maintenance paradigm is based on a cultural change in manufacturing companies. This change requires the company to transform itself and adopt a culture of knowledge and innovation. This culture means that decisions are made based on data and facts, and not on a subjective 'gut feeling'. Employees seeking specific career paths receive support in becoming experts in relevant fields. Too often, in traditional companies, career success is defined in terms of staff responsibility, i.e. the number of employees under your supervision. In the future, a career will also be defined by the amount of expertise someone has gained. A successful knowledge and innovation culture is also characterised by the sharing of knowledge and skills between employees. New employees benefit greatly from this, and the open sharing of expertise helps to retain existing knowledge within the company despite unavoidable employee turnover. Results of business experiments are evaluated on a regular basis by co-workers with different areas of expertise. The reliability and trust of members of staff towards and amongst each other is one of the most important factors that makes the implementation of a knowledge and innovation culture successful in the first place.

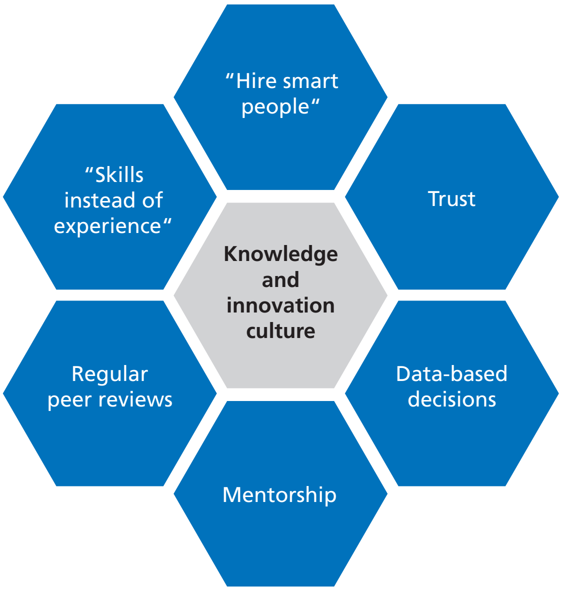

Figure 11: Placement of RoM within the company structure (own presentation)


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7 Summary: RoM as a crucial competitive factor

> Not those with extensive knowledge but those who share it freely with others are an integral part of an open maintenance culture.

The FIR at the RWTH Aachen University continuously develops the concept and the principles of RoM further.

It is already noticeable that the gap between companies that began preparing their maintenance departments for Industrie 4.0 years ago and those that are still struggling with the mere foundations of a professional maintenance organisation is rapidly increasing.

The first driver of the development sparked by Industrie 4.0 is the collection of and work with condition data. It is used to create a digital shadow of a service, e.g. maintenance measures in a specific context. In the future, critical machine functions will be monitored continuously within production processes. Based on these observations, the likelihood of machine failures can be predicted, which makes it possible to prioritize data-based maintenance measures. This means that maintenance activities, i.e. production plans, are based on prognoses regarding machine failures. By doing so, the currently existing separation between inspection, maintenance and reactive measures can be overcome, resulting in a holistic approach to maintenance.

Maintenance specialists receive support from assistance systems, which give them access to all relevant information (e.g. machine history, spare part availability, proposals for measures, etc.). As a result, they can take on routine tasks in different areas as well and contribute to the increased flexibility of the production process.

Although data is becoming an increasingly important driver of successful maintenance strategies, maintenance employees continue to be central to specific tasks, machines and systems. In the future, it can be expected that they choose to become experts in a certain field and, ideally, actively share their knowledge with others within an open maintenance culture. Systems for interdisciplinary collaboration will be made part of everyday practice. The maintenance department will be a center and distributor of knowledge in the agile company of the future.

Only through the interaction of the outlined success principles, which amount to a paradigm shift within the maintenance department, the potential benefit of maintenance as defined by RoM can be fully exploited, creating a long-term competitive advantage for those who consistently follow the path towards Industrie 4.0 in maintenance.

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8 FIR – A competent partner in practice

The Institute for Industrial Management FIR is a non-profit, intersectoral research and educational institution at RWTH Aachen University concerned with business organisation and corporate IT with the aim to establish the organisational basis for the digitally integrated company of the future. Through the development and transfer of innovative solutions, FIR contributes to enhancing the competitiveness of companies. This is undertaken within an infrastructure that is ideally suited for experimental organisational research – methodologically sound, scientifically rigorous, and conducted in close collaboration with experts from business and industry.

The activities focus on the application of research to industry verticals. Currently these include Future Logistics, Smart Services/Maintenance, Smart Buildings, and Smart Mobility. The institute provides research, qualification programmes and lectures in the fields of service management, information management, production management and business transformation.

Since 2010, Professor Volker Stich, the managing director of FIR, has also been heading the Smart Logistics Cluster on RWTH Aachen Campus. Within the Smart Logistics Cluster, FIR offers a unique form of collaboration between representatives from research and industry. As a research institution of the Johannes Rau foundation, FIR supports the research strategy of the Federal State of NRW and participates in research clusters to strengthen NRW as a hub of research and innovation.

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9 Literature

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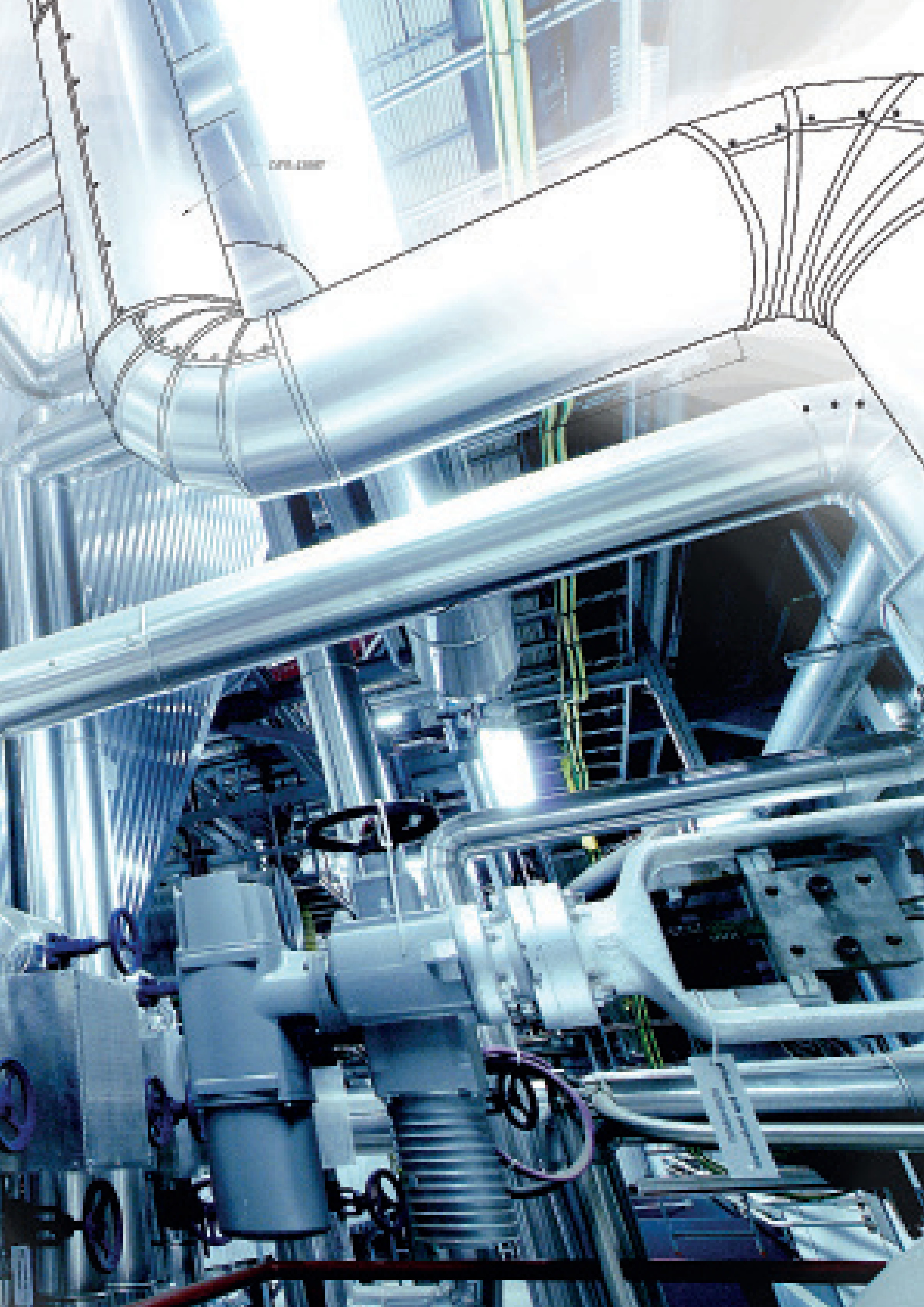

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