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Smart
Maintenance

Order Pick Time
00:05:15

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Order Pick Time
15:14:03

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Smart Maintenance –
just do it!

Whitepaper

fir at
RWTH Aachen University

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Smart Maintenance – just do it!

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A Maintenance as the driver for digital transformation

x2

Top Performers

Followers

38 % **76 %**
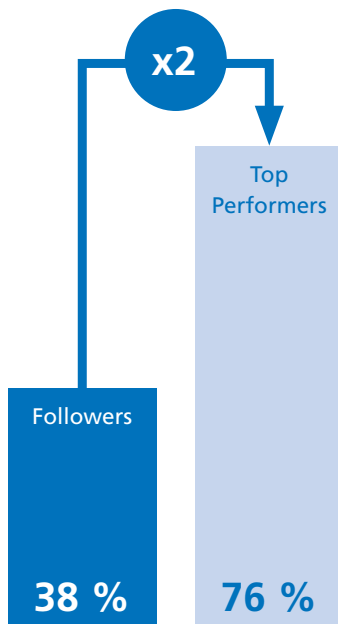
Today, maintenance exceeds this definition, it is significantly more. In many companies, it plays the role of an incubator for development and drives digital transformation forward. The very essence of Industrie 4.0 is the optimisation of the flow of information within as well as outside of a company to accelerate the adjustment of company organisations in the context of increasing competitive pressure. Because of the variety of interfaces, information and data that is available as well as its service character, maintenance lends itself easily as the area of choice for a company to make Industrie 4.0 real. Whilst doing so, the aim is not to equip employees with the latest "gimmick" for order processment or to be the company with the highest number of lighthouse projects. Instead, maintenance ensures reliable and cost-efficient production and, consequently, the primary creation of added value of the manufacturing company. Those who were identified as top performers during the "Smart Maintenance" consortium benchmarking by FIR at RWTH Aachen University gain particular useful ideas twice as often as other follower companies directly from staff, thus releasing the right potential (see Birtel u. Defèr 2019).

Information and data help to reach these goals and transfer the vision of smart maintenance into actual pratice. But what is smart maintenance exactly and how far along are you in the development of your individual smart maintenance concept?

B   Smart Maintenance as a Vision

Top Performers

x3,8

Followers
19 %   **72 %**
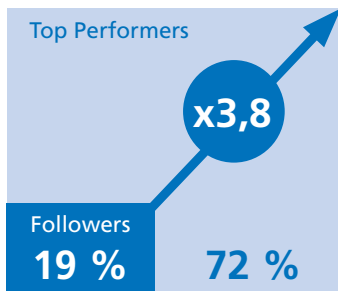
Smart Maintenance is the stand-alone maintenance concept, which develops itself further and further because of data and experience knowledge, with the goal to achieve the biggest possible added value for agile manufacturing companies.

In most companies, this form of smart maintenance currently only exists on PowerPoint slides and in the mind of a few employees. At the same time, however, 72 % of those who were identified as top performers as part of the consortium benchmarking "Smart Maintenance", consider smart maintenance to be the key to their operational goals. This number is almost four times higher than the number of followers agreeing with this statement (see BIRTEL U. DEFÈR 2019). There are many versatile reasons for this, but three substantial factors can be summarised as such:

1   **Technology issue:**

Smart Maintenance is falsely regarded primarily as a technological development, but the aspects of culture and organisation are just as important – they may even be more important when it comes to the actual realisation of smart maintenance, because they are required in order to achieve technological potential for the entire organisation.

2   **Insecurity of employees:**

The past times of cost reductions add to the fear that humans will be obsolete due to rapidly improving technology. As a consequence, transparency and an open culture of faults are seen as a tool to let staff go and reduce costs. This slows down progress and prevents the opportunity to view mistakes as a valuable resource and a first step for improvement.

3   **Use Cases outperform Business Cases:**

The resource investment and the indispensable infrastructure, which is needed to establish the lighthouse projects in everyday practice, are highly underrated. The establishment of a sufficient infrastructure and data basis requires great far-sighted vision and determination. This also leads to the question which plants and which process steps benefit economically from the use of smart maintenance.

Like any company transformation, the development of smart maintenance follows certain rules and dependancies. A clear vision, a structured procedure plan and a consequent implementation is necessary. But what does the route to a succesful creation and implementation of smart maintenance look like?
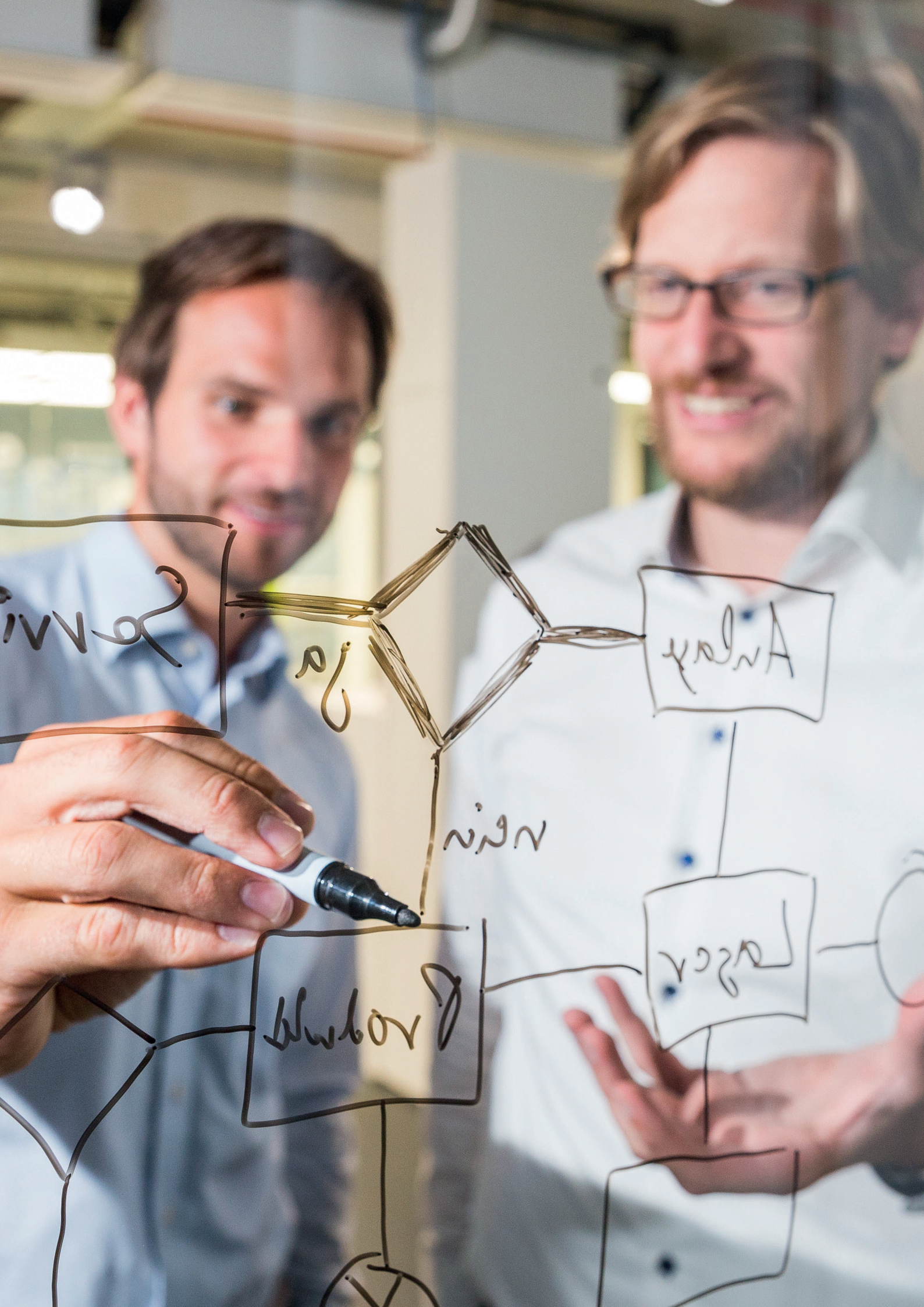
C   The route to Smart Maintenance

Top Performers

x3

Followers

28 %   **72 %**
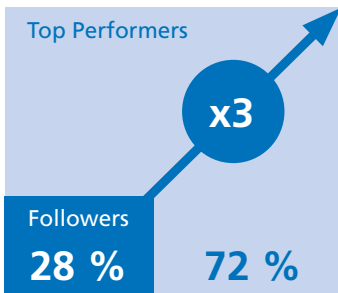
You need to know where you want to go before you set off. The consortial benchmarking "Smart Maintenance", conducted by FIR at RWTH Aachen University, shows that top performers of smart maintenance are three times more likely to have an extensive and long-term roadmap for the realisation fo their smart maintenance than followers (see BIRTEL U. DEFÈR 2019).

To design a consistent individual roadmap, the following steps must to be followed:

1   Create a joint goal definition!

As a first step, it is necessary to agree on a definition of the goal. To do so, one needs to answer the question of what smart maintenance really means for the company. And this is to be taken literally! It is necessary to agree on definitions of terms and relations to reduce the complexity of the topic and create a common basis together. Once this is achieved, the following question needs to be answered next: *What kind of specific value can smart maintenance add to my company?*

2   Identify your own position!

An honest review of your current position needs to be conducted in order to choose the right path. Due to the assesment of IT-systems, resources and organisational as well as cultural aspects, a review of the entire company can be conducted. Only if this is the case, it is possible to kick-off a sustainable development.

3   Find your own way!

Due to the comparison of the company´s current position with the previously defined goal, it is possible to create an individual roadmap for smart maintenance. The roadmap will include a number of steps that are required to reach the goal in a logical order and are necessary to implement the defined measures as part of projects without losing sight of the overall context.

4   Just do it!

The roadmap is a powerful tool to work goal-oriented on the individual projects. The most important thing, however, is to find a structured start and to closely follow the roadmap. When doing so, it is important to ensure that every individual project adds a benefit to the overall benefit the maintenance provides for the entire company.

1. Create a joint goal definition!

> "What kind of specific value can smart maintenance add to my company?"

The value proposition of maintenance is the beginning of all further ideas and planning. When trying to determine it, one should not only look at direct costs such as personnel costs, material costs etc., but also consider indirect ones such as cancellation expenses and quality decrease costs. The latter can be up to three or even five times higher but are only registered sporadically by most companies.

Nevertheless, the maintenance value proposition cannot be described by monetary factors only. Further goals can be described with the term *Return on Maintenance* (see quote), which refers to a specific value proposition of maintenance to the total value proposition of the company. The maintenance goals and those of the *Return on Maintenance* can be summarised with three points.

Find out more about our *Return on Maintenance* (RoM) concept in our associated whitepaper
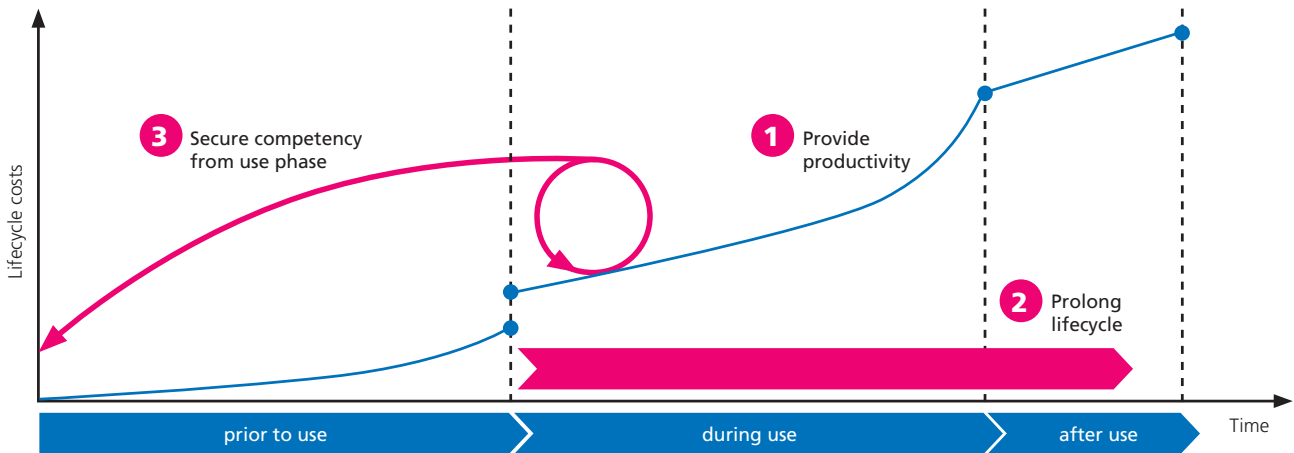
Image 1: Selected potential of maintenance based on the example of a life cycle model (with reference to Kampker et al. 2017, p. 7)

1 **Provide productivity:** Maintenance has a substantial influence on all areas of OEE (Overall Equipment Effectiveness). OEE also takes plant availability, productivity and quality into account.

2 **Extend life cycle:** The extending of plant life cycles holds the biggest potential to use all company resources efficiently, especially in asset-intensive industries. For this, various different aspects need to be considered, because shorter product life cycles, for example, lead to great challenges in obsolescence management.

3 **Knowledge management:** Skills shortage is a central challenge for all companies, in particular in the area of maintenance tasks due to the increasing complexity of plants. Knowledge management means not only to provide knowledge and information and train employees. It also means to share information and experiences with others effectively and efficiently – for manufacturing companies, this begins with the procurement process for plants.

In the context of this paper, these crucial goals are to be understood as goals of the roadmap as well, but they need to be adjusted to the individual company and its everyday practice. The beginning of the roadmap is the current maturity level of the organisation. The following chapter shows how to determine it.

2. Identify your own position!

The internal identification of one's own position is always difficult, because too many habits and individual traits of a company stand in the way of progress. It is helpful to try and look for comparisons to other companies, take on a different point of view and discover new ideas. To get a hold of the complexity of smart maintenance, it is neccessary to shed light on many different facets of the organisation. The maturity level steps of the Industrie-4.0-Maturity-Index (see image 2) represent the company's capabilities to process information and make use of it (see Schuh et al. 2017, p. 15).

Resources   IT-Systems

6 Adaptibility
5 Predictability
4 Transparency
3 Visibility
2 Connectivity
1 Computerisation

Organisation Structure   Culture

1 — Support due to IT systems: Employees are relieved of repetitive manual tasks by reducing their workload.

2 — Systems are structured and linked: Core business processes are reflected in IT systems.

3 — Companies have a digital shadow: Management makes data-based decisions.

4 — Companies understand why events happen: Findings create knowledge.

5 — Companies know what will happen: Decisions are made on the basis of future scenarios.

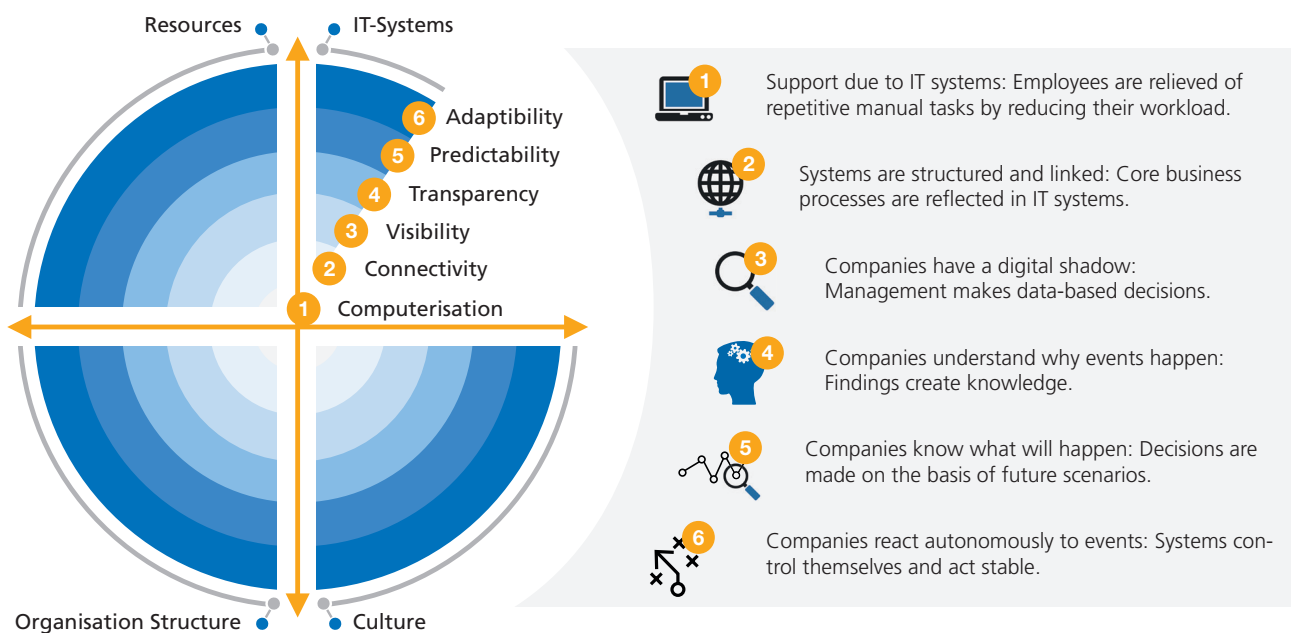6 — Companies react autonomously to events: Systems control themselves and act stable.

Image 2: Maturity levels of the Industrie 4.0 Maturity Index (with reference to Hocken 2017, p. 16)

The following chart describes the typical maintenance organisation in the process industry, just like it was audited successfully many times by FIR at RWTH Aachen University.
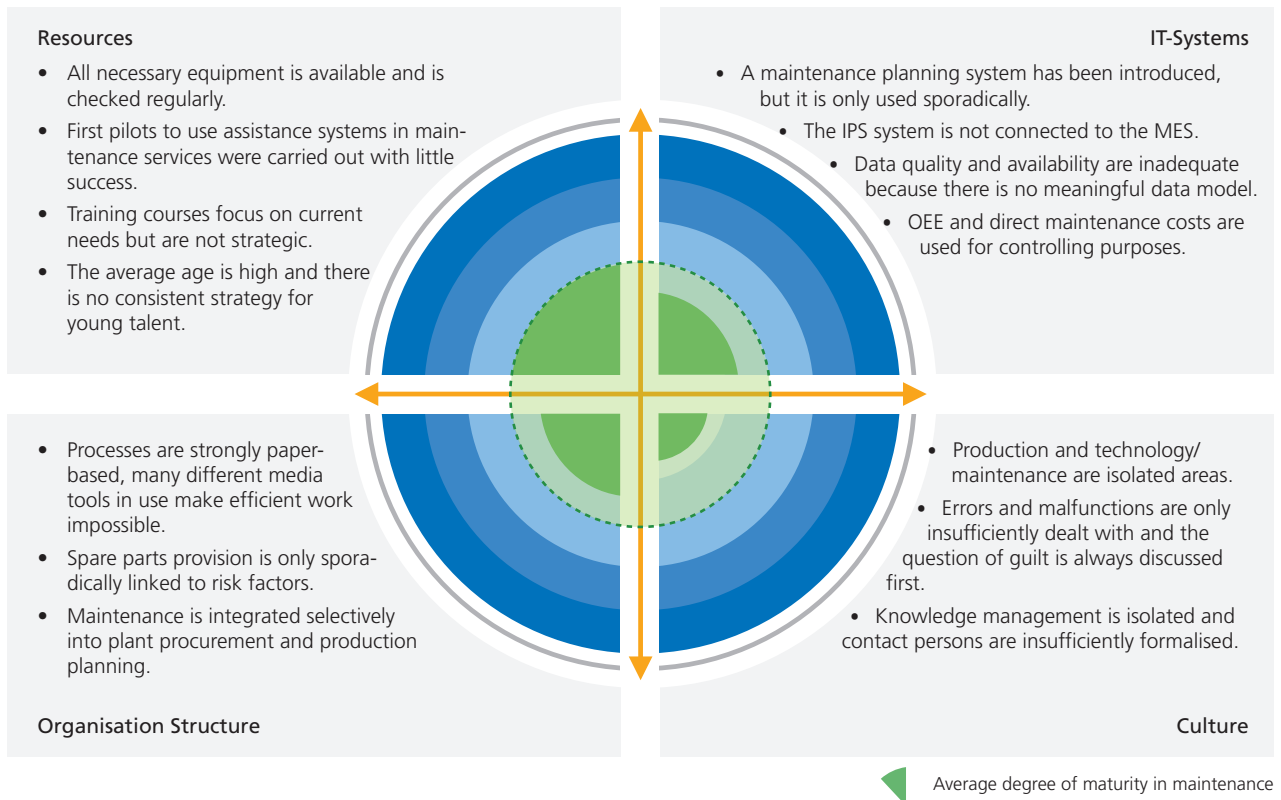
Resources

- All necessary equipment is available and is checked regularly.
- First pilots to use assistance systems in maintenance services were carried out with little success.
- Training courses focus on current needs but are not strategic.
- The average age is high and there is no consistent strategy for young talent.

IT-Systems

- A maintenance planning system has been introduced, but it is only used sporadically.
- The IPS system is not connected to the MES.
- Data quality and availability are inadequate because there is no meaningful data model.
- OEE and direct maintenance costs are used for controlling purposes.

- Processes are strongly paper-based, many different media tools in use make efficient work impossible.
- Spare parts provision is only sporadically linked to risk factors.
- Maintenance is integrated selectively into plant procurement and production planning.

- Production and technology/ maintenance are isolated areas.
- Errors and malfunctions are only insufficiently dealt with and the question of guilt is always discussed first.
- Knowledge management is isolated and contact persons are insufficiently formalised.

Organisation Structure

Culture

◀ Average degree of maturity in maintenance

Image 3: Maturity level of a typical maintenance organisation in the manufacturing industry (with reference to SCHUH ET AL. 2017, p. 19)

The chart also includes one of the biggest challenges of smart maintenance and digital transformation in general. Some design fields are well defined in comparison to others and, consequently, allow for successful lighthouse projects. However, when realising lighthouse projects in general practice, the weaknesses of the other design fields become apparent and stand in the way of successful implementation. This means that it is required to create a common basis in all design fields first and then progress from here.

Only a thorough assessment of the current maintenance service situation makes it possible to derive adequate conclusions for the design of a well-founded roadmap. This is only practicable, if a company compares itself with other companies or locations. But what does a roadmap look like that supports companies to compile a well-founded strategy and put it into practice?

3. Find your own way!

The roadmap consists of numerous elements, which make it possible to categorise the roadmap measures as well as their dependancies. It is not always possible to clearly assign the measures to maturity levels and fields of action, because complex circumstances are radically simplified in order to display them in an overview and make them comprehensible. The experts of FIR at RWTH Aachen University have extensive project experience and great knowledge about the hurdles that need to be overcome during the transfer into reality, which helps them to categorise the measures. Therefore, the field proving to be the greatest implementation obstacle was chosen during the assignment of the measures to one of the four fields of action. In general, most of the roadmap measures affect all fields of action and are not to be neglected once they have been successfully implemented.
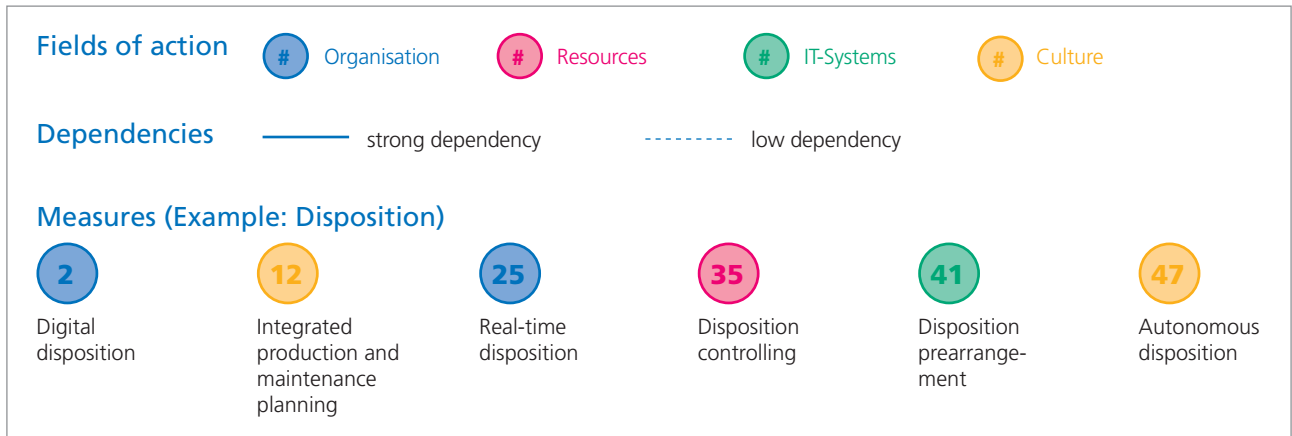
To demonstrate how the smart maintenance roadmap works, the following chapter shows the development of the disposition process based on the maturity level steps.
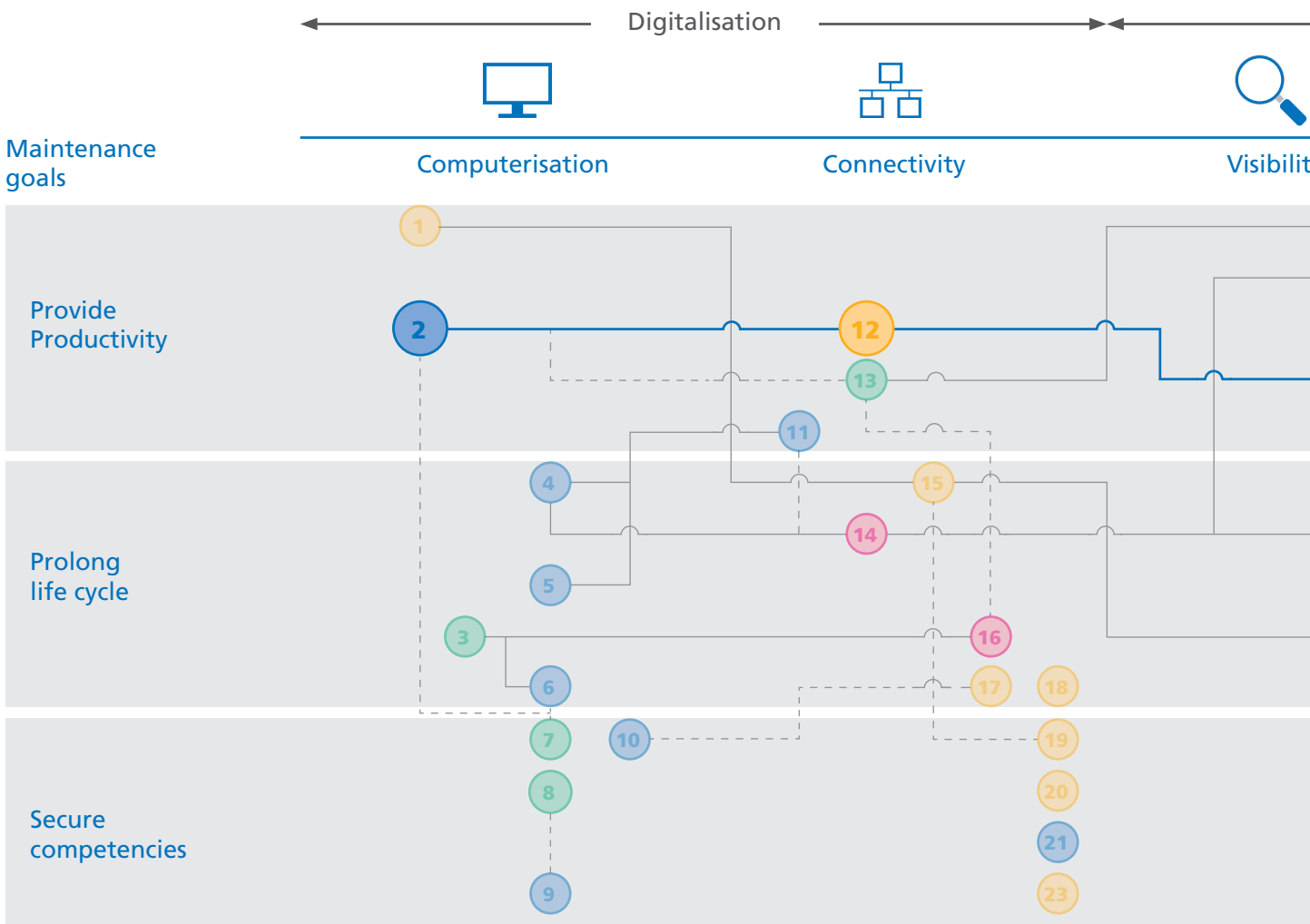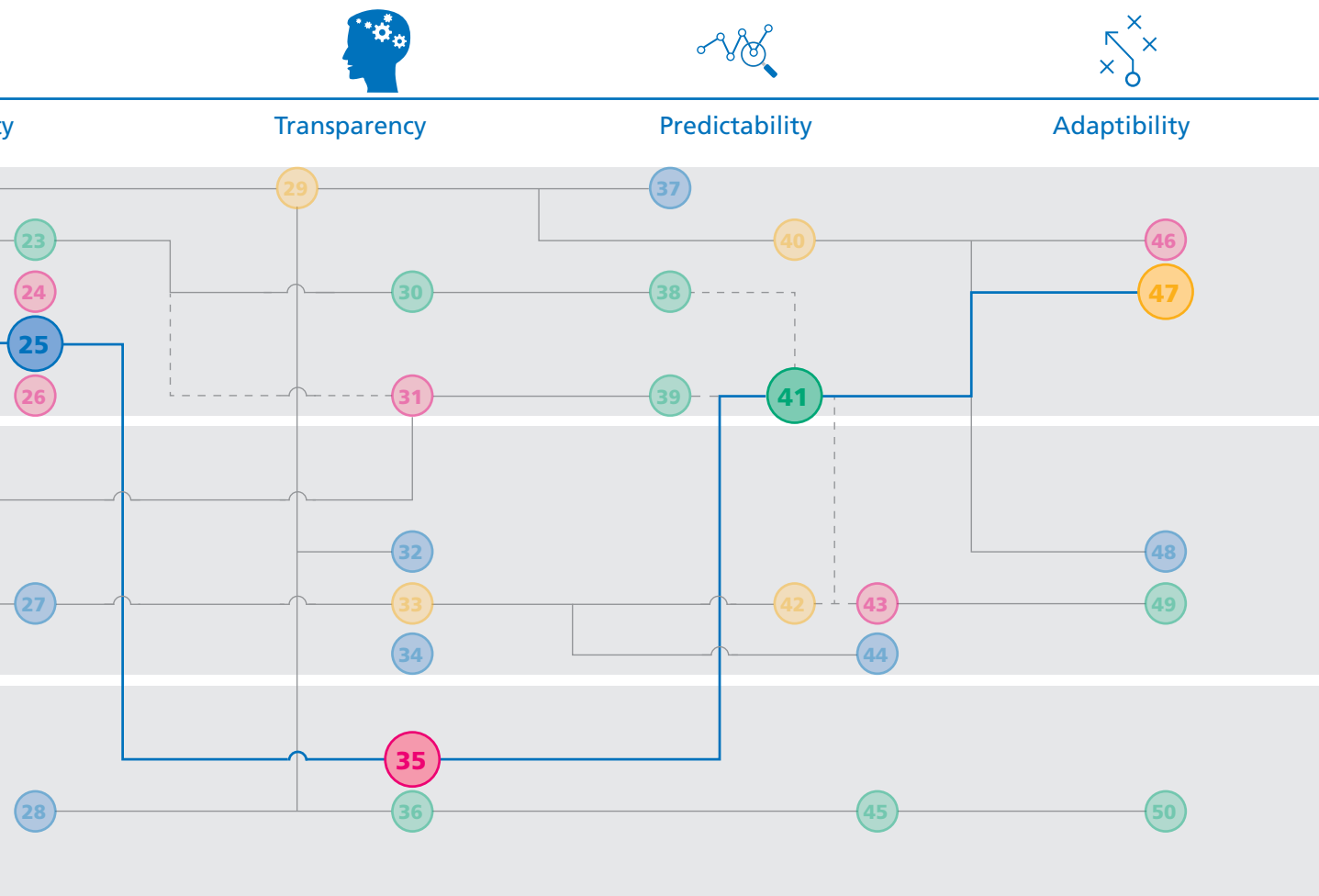
The change of the disposition process due to Smart Maintenance

Order planning and coordination is a central challenge in every maintenance process. Different requirements have to be assessed and a variety of stakeholders must be pleased. In addition, there are more or less high demands on the traceability of orders, data protection and security, depending on the industry and company.

Key

Fields of action	# Organisation	# Resources	# IT-Systems	# Culture

Dependencies	——— strong dependency	- - - - - low dependency

Measures (Example: Disposition)

2	12	25	35	41	47
Digital disposition	Integrated production and maintenance planning	Real-time disposition	Disposition controlling	Disposition prearrangement	Autonomous disposition

Industrie 4.0 →

Transparency	Predictability	Adaptibility

29 · 37
23 · 24 · 40 · 46
30 · 38 · 47
25
26 · 31 · 39 · 41
32 · 48
27 · 33 · 42 · 43 · 49
34 · 44
35
28 · 36 · 45 · 50

1 – Computerisation

Nr. **2** Measure: **Digitisation of disposition**	Goal: **Providing productivity**

Description:

Disposition is carried out via orders in the system, which can be assigned to service technicians. To do so, the request (ticket) should already be available in either the same or another connected IT-System, as this makes it possible to draw conclusions on the existing defect. The establishment of specific defect and fault codes is useful because they provide structured data and are therefore easier to analyse. During this step, silo mentality is still dominant, which means it is necessary to schedule all necessary measures with the production department.

Preconditions:	Data:	Basis for:
• Functional location • (Tickets/ notifications in the system) • (Maintenance qualification matrix)	• Plant and personal master data • Event data and usage data	• Feedback • Electronic spare part logistics • Maintenance controlling

The first maturity level is shaped significantly by organisational challenges. In most cases, IT-Systems are in place but they are not or hardly used and not sufficiently used to pursue a clear goal. There are not many cultural challenges, because competencies are not affected – although a new technology has to be handled, the challenge from moving forward from a planning board and a shift book to the digital twins of these two tools is not too serious. Nontheless, the process requries discipline and accountability.

Nr. **12** Measure: **Integration of production- and maintenance planning**	Goal: **Providing productivity**
Description: The controlling of orders is carried out in cooperation with the production, to do so, a connection between MES[1] and IPS[2] is to be created. As a result, production processes are presentable with greater transparency for the maintenance department (and the other way around) and planning is possible with less coordiniation efforts, resulting in an improved, demand-oriented availabilty of plants. The added value results from the use of down-times and the inclusion of production employees in maintenance tasks.	

Preconditions:	Data:	Basis for:
• Risk assessment of plants • Interdivisional goal system • Interdivisional qualification matrix	• Plant and personal master data • Event data and usage data • Planning data	• Real time disposition • Online order execution

The second maturity level step requires cultural and organisational change, because the silo mentality needs to be stopped and overcome. Currently, 72 % of the top performers identified during the "Smart Maintenance" consortial benchmarking do so, but only 28 % of the followers (see BIRTEL U. DEFÈR 2019). As a result, there will be no more discussions to agree on who is responsible for a machine fault or break-down, because planning and goal agreements are cooridnated with the production. Capacatity becomes available and can be used to concentrate together on new goals, pursue improvements and make them become reality. This also requires a change of thinking from everyone involved and clear rules, which need to be included in the process guidelines and in multi-dimensional goal maps.

x2,6

Top Performers

Followers

28 % **72 %**

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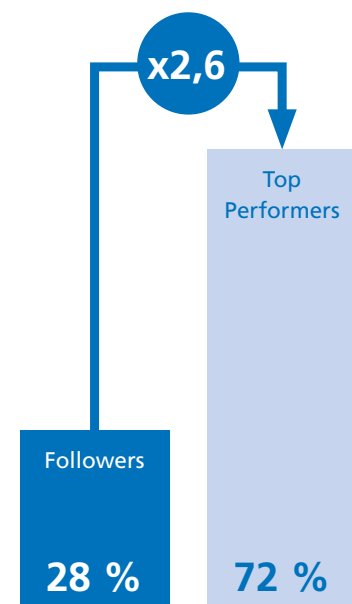
[1]Manufacturing-Execution-System: process-oriented production management system

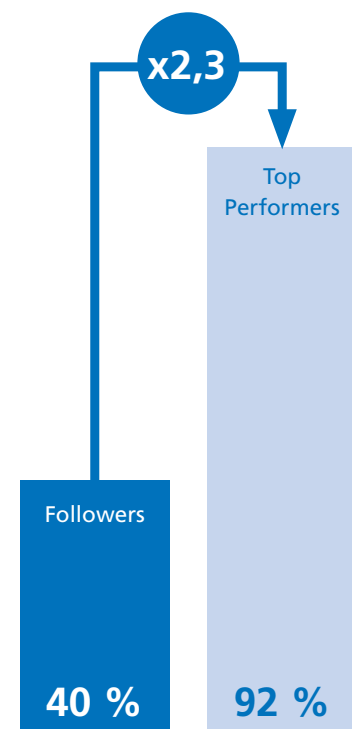[2]Maintenance planning and control system

3 – Visibility

Nr. **25** Measure: **Real-time disposition**	Goal: **Providing productivity**

Description:
Due to the digital order process, it is now possible to give feedback on the order progress to the disposition department in real time. Integrated production and maintenance planning can also be added. As a result, the planning department can take into account sudden down-times or changes from the order processing time and add to an optimised operative planning. This is supported by the integration of defect codes and automatic notifications of the machines and plants to the planning system.

Preconditions:	Data:	Basis for:
• Automatic notifications • Digital order process • Integrated production and maintenance planning	• Sensor data • Defect codes of plants	• Disposition controlling and optimisation

The real time optimisation of operative planning requires technical as well as organisational adjustments and a new way of thinking on different levels. The role of the maintenance planer will increase in importance because changes of plan need to be implemented quickly in order to achieve an added value. This is necessary to make ideal use of the limited available slots that remain during phases of high plant workload.

Nr. **35** Measure: **Optimisation and controlling of the disposition**	Goal: **Knowledge management**
Description: Due to the connection of different planning systems, product-related quality monitoring, the integrated key performance indicators and the digitisation of order dispositioning and processing, time stamps create data which can be put into a data model displaying the production and maintenance processes. Data gained from this can be used for tactical and strategical optimisation. For example: Process mining can be used to identify resource shortages and derive suitable measures for training purposes, material logistics and disposition.	

Preconditions:	Data:	Basis for:
• Data-based error identification • Quality monitoring	• Planning data • Event data	• Automatition of disposition pre-planning • Data-based error catalogues

It is required to integrate systems, establish data models and have large amounts of data analysed from trained personnel. The interpretation requires domain-specific knowledge from maintenance staff who needs to assists with data evaluation. The challenge of step 4, the tactical and strategical optimisation of the disposition, is, above all, the well-planned creation of the business case and the availability of the required resources. It needs to be decided which intensity the optimisation should have and where added value can be created. A structured process needs to be established, which accelerates innovation and helps to analyse use cases quickly with regard to their profitability and practibility. The evaluation of economic efficiency is therefore a key success factor and an important capability for the introduction of smart maintenance, something that 92 % of the top performers of the consortial benchmarking „Smart Maintenance" already master (see Birtel u. Defèr 2019).

x2,3

Top Performers

Followers

40 %   92 %

Nr. **41** Measure: **Automatition of disposition prearrangements**	Goal: **Providing productivity**

Description:

The collected data can be edited and used for disposition with the help of machine learning algorithms. Whilst doing so, feedback patterns can be recognised and used to automatically calculate planning times as well as tool and spare part needs. Data stemming from condition monitoring and predictive maintenance can also be processed and added to the algorithm in real time. Because of the combiniation with the dynamic risk assesment of the plants – depending on the production programme, personnel availability and material availability – scenario prognoses and disposition suggestions can support the maintenance planner.

Preconditions:	Data:	Basis for:
• Data-based error catalogues	• Occasion data	• Autonomous disposition
• Condition monitoring	• Error data	• Autonomous spare part
• Predictive maintenance	• Production data	procurement
	• Sensor data	• Autonomous troubleshooting
	• Feedback data	
	• Condition data	

The challenges mostly arise due to the creation of a data basis and the training of suitable algorithms. The prognosis of probabilites and dynamic risks of plants requires a large number of data and interdependancies, which need to be well thought through and categorised. At the same time, cultural change is not to be underestimated because it provides the requirement for algorithms to replace specific domain knowledge. At the same time, cultural change should not be underestimated, because it is the prerequisite for algorithms to support the processing of tasks that could only be solved with specific domain knowledge previously. Often, this change is met with mistrust or suspicion because recommendations based on algorithms are not easy to understand.

Nr. **47** Measure: **Introduction of autonomous disposition**		Goal: **Providing productivity**
Description:		
Planning can be fully automatised over time due to the generation of solution propositions and prognoses of success probabilities combined with an automatic disposition prearrangement. To achieve this, high-quality data of all operation conditions of the installed plants has to be available as well as extensive data on trouble-shooting, in order to plan material requirements and planning times. The algorithm also has to decide which measures should be taken if a certain fault occurs, which resources are required and which escalation level should be initiated. It has to be decided if the plant should be switched off, if this requires adjustments for operation parameters or if it is sufficient to schedule the defect as part of the next upcoming maintenance cycle.		
Preconditions:: • Automatic disposition prearrangements • Suggestions for trouble-shooting	**Data:** • Plant- and personnel master data • Event data and usage data	**Basis for:** This is the highest level of maturity, therefore no further measures can follow.

Requirements for data and algorithms are, naturally, the most complex once the final maturity level is reached. Nonetheless, the technology that is neccessary for the prediction remains the same that is required for the adaptibility. Currently, 26 % of the top performers of the consortial benchmarking "Smart Maintenance" state that they have an automatic disposition of resources in place (see Birtel u. Defèr 2019). The crucial difference is the quality of the statements, because the controlling factor "human" does not apply anymore and fatal predictability errors have a direct influence on the company results. The cultural aspects of the lack of a maintenance planner are not to be underestimtated, because it requires a lot of trust in the capabilities of the algorithm in order to let it be "the boss" and the one in charge.

Top Performers

x2,4

Followers

11 % **26 %**
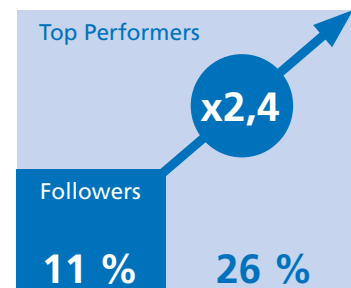
Added value of the roadmap

x1,8

Top Performers

Followers

48 %

87 %
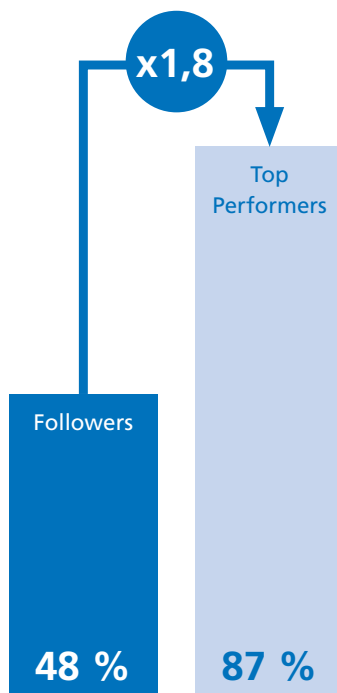
The roadmap offers the possibility to allocate necessary company resources and create added value for the company with help of a structured procedure. It offers a specific starting point to assess the current situation and create a suitable goal to reach. During this, ongoing changes of the situation (such as technological ones or ones regarding the customers requirements) need to be observed at all times. It is necessary to adjust and improve the roadmap as these changes occur. If this is accomplished, it offers the chance to create a dynamic target that is tailored to customer needs (internal/external) and to support the change process. Necessary steps and correlations are presented and the employees are given support during the digital transformation. The target prospects are tangible and range from an increase in OEE (Overall Equipment Effectiveness) to an increase in the degree of planning, which 87 % of the top performers were able to significantly increase with smart maintenance in recent years (see Birtel u. Defèr 2019).

4   Just do it! – we offer support.

Companies never start at point zero – there are always cultural, strcutural or organisational units that need to be considered during a strategic orientation. With the help of an indivdual roadmap, we can focus on your individual requirements and needs and help you create an overview of your ideal route towards smart maintenance. At the same time, we help you to think out of the box and see past the boundaries of your own company. Whilst doing so, we always make sure we focus on your value-added process, your individual demands regarding aspects such as security, environment and quality and, of course, your customer.

Every beginning is difficult and there are many hurdles to overcome. Dismotivated employees and huge amounts of data pose great challenges for many companies. Companies that proceed with courage and provide the means to do so are those that are successful. The "Smart Maintenance" consortium benchmarking showed that 19 % of the top performers surveyed worked with free innovation budgets, four times more than the group of followers.

We not only support you in creating your personal route towards Industrie 4.0, we also accompany you in the implementation and design of your measures. Together, we can then answer the following questions:

- Which data do I have to collect and how do I have to collect it in order to create a solid basis for further development of my maintenance measures?
- How do I design change management for my employees in such a way nobody feels left behind?
- What do multidimensional key performance indicator systems look like that allow me to control my maintenance?
- Which technologies and IT systems are suitable for my company?

Feel free to contact us and profit from the experience and expertise of the Competence Center Maintenance!

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Top Performers

x4

Followers
5 %   19 %
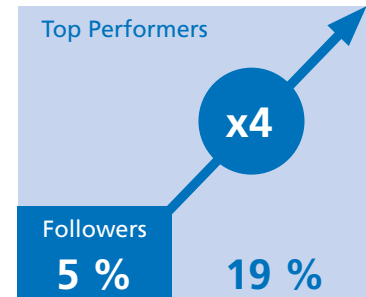
Industry project: Development of an Industrie 4.0 roadmap and benchmarking within the chemical industry

Chemical company

Industry sector:
Chemical industry

Employees: > 10.000 FTE
(Project location: > 2.000 FTE)

Turnover: > 3 billion Euro

Thanks to a standardised and established approach, a profound roadmap was developed in the shortest possible amount of time. In addition to technologies, other important aspects such as organisation and culture were covered as well to ensure the sustainable effectiveness of the measures.

The roadmap provides a strict procedure. Because of the maturity levels it contains, the roadmap already includes milestones during the implementation phase, which create a clear added value for the company. The many existing as well as new measures and projects were arranged and prioritised with the roadmap, so that a clear focus can be established. During the elaboration, information and experience across all areas and hierarchical levels were brought together and processes were evaluated with an end-to-end concept. Due to the inclusion and addressing of challenges in the various areas, change management is actively supported and employees are helped on a sustained basis

Results

▶ A common target image was created across all areas.

▶ The way towards "Smart Maintenance" was presented in a simple and understandable way with a well-founded roadmap.

▶ Investments in projects, infrastructures and technologies were justified and secured with the roadmap.

D   Sources

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> 80
Industry consulting projects / year

> 25
Industry research projects / year

> 20
publicly funded research projects / year

founded
1953

fir at
RWTH Aachen University

> 70
Employees

Qualification of
> 110
managers in eight RWTH certificate courses / year

88 %
loyal customers (Net Promoter Score)

> 250
Projects / year

founded
2010

> 20
Spin-offs

65
Matriculated members

RWTHAACHEN CAMPUS SMART LOGISTIK

> 350
Scientists / Consultants / Data-Scientists & Developers

> 500
Clients and partners in running Projects

E   A competent partner: FIR

FIR is a non-profit, intersectoral research and educational instituti-on at RWTH Aachen University focusing on business organisation, information logistics and corporate IT with the aim to establish the organisational basis for digitally integrated companies of the future.

By researching and transferring innovative solutions, FIR contributes to increasing the competitiveness of companies. All of this takes place in a suitable infrastructure for experimental organisational re-search, methodically sound, scientifically rigorous and with the di-rect participation of experts from industry.

The institute supports companies, researches, qualifies and teaches in the areas service management, business transformation, informa-tion management and production management.

To strengthen the location of NRW, FIR supports the research strate-gy of the country as an official Johannes Rau research institute and participates in the appropriate state clusters.

As a member of the Federation of Industrial Research Associations, FIR promotes research and development for the benefit of small, medium-sized and large companies.

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