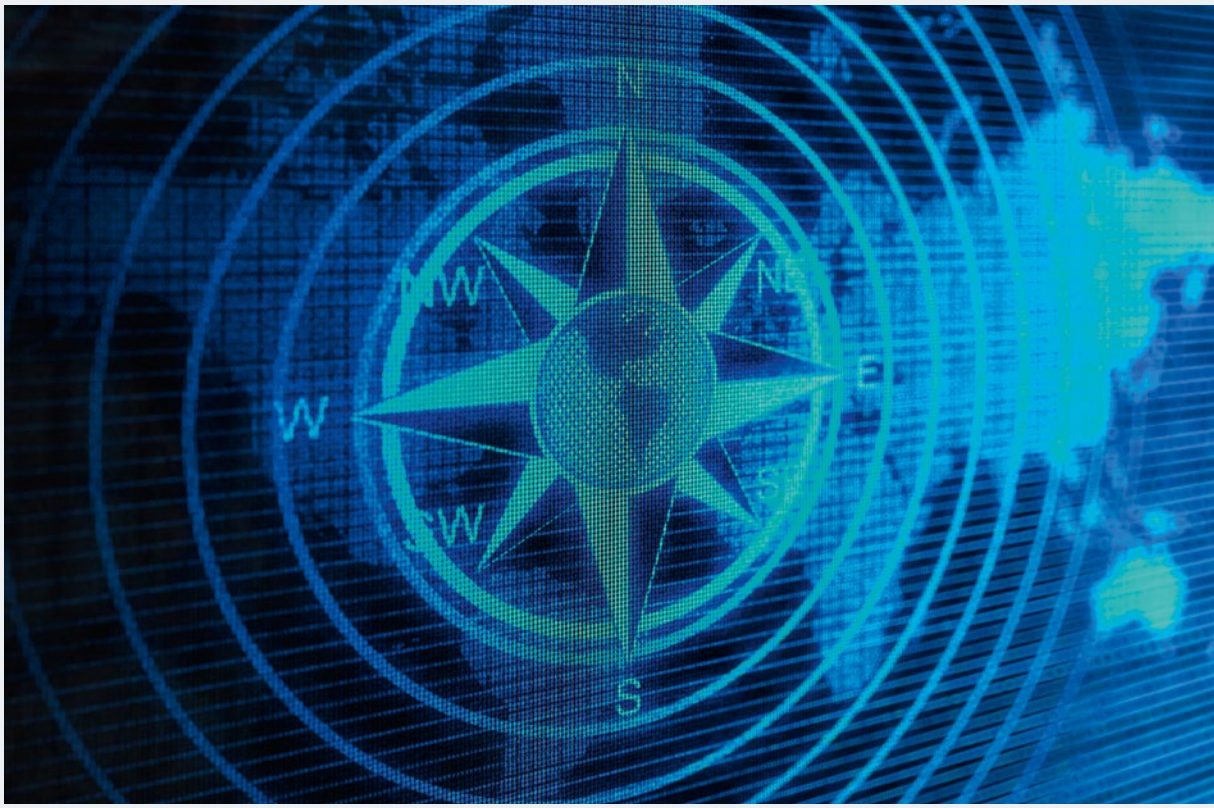
Guideline Industrie 4.0

Guiding principles for the implementation of Industrie 4.0 in small and medium sized businesses



in cooperation with

Editorial

Hartmut Rauen

Innovations, problem-solving expertise and highest quality are key characteristics of the German mechanical engineering industry. That is also what Industrie 4.0 stands for. It is about combining information technologies with production engineering and creating new innovative products and solutions. Without doubt, there are numerous challenges linked to it: data security, technical standards as well as necessary legal frameworks. In addition, there are investments in research, education and training to be made and a strong demand for new business models to be satisfied. As international competition around Industrie 4.0 will increase, we have to face these challenges. There can be no doubt about it.

The German mechanical engineering industry as a provider and user of Industrie 4.0 technologies plays a vital role in this endeavor. It integrates the latest technologies into products and processes and hence asserts its leading position as an enabler. At the same time, it represents a data source for Industrie 4.0: It collects data, interprets it, uses it for innovation and develops new business models. But Industrie 4.0 shall not only be of interest to large companies. It must also be economically viable and benefical for small and medium sized businesses.

Against this background, the Industrie 4.0 guideline from the VDMA (German Engineering Federation) regards itself as a practical tool for the identification and implementation of company-specific approaches to Industrie 4.0. The VDMA guideline shall also encourage and arouse curiosity to see Industrie 4.0 as an opportunity for the own company.

Many other activities of the VDMA forum Industrie 4.0 also pursue this aim, for example the “Lab Touren I40” that take the visitor on a journey to innovation sites at German universities or the “Forschungskreis I40” which initiates cross-industry research projects in the interest of the VDMA members as part of the Industrial Collective Research (IGF).

Speaking of research and science: Special thanks are due to Prof. Dr.-Ing. Reiner Anderl of Darmstadt University of Technology and Prof. Dr.-Ing. Jürgen Fleischer of the Karlsruhe Institute of Technology as well as to their research assistants for editing this guideline scientifically. In addition, I would like to express my gratitude to the involved VDMA members for their commitment as pilot companies.

The VDMA guideline Industrie 4.0 can therefore also be seen as an example for excellent cooperation and networking of German machine and plant manufacturers.

I wish you all an interesting and inspiring read.

Hartmut Rauen

Deputy Executive Director
VDMA German Engineering Federation

Guideline Industrie 4.0 – Guidance for German small and medium sized companies

Reiner Anderl

Jürgen Fleischer

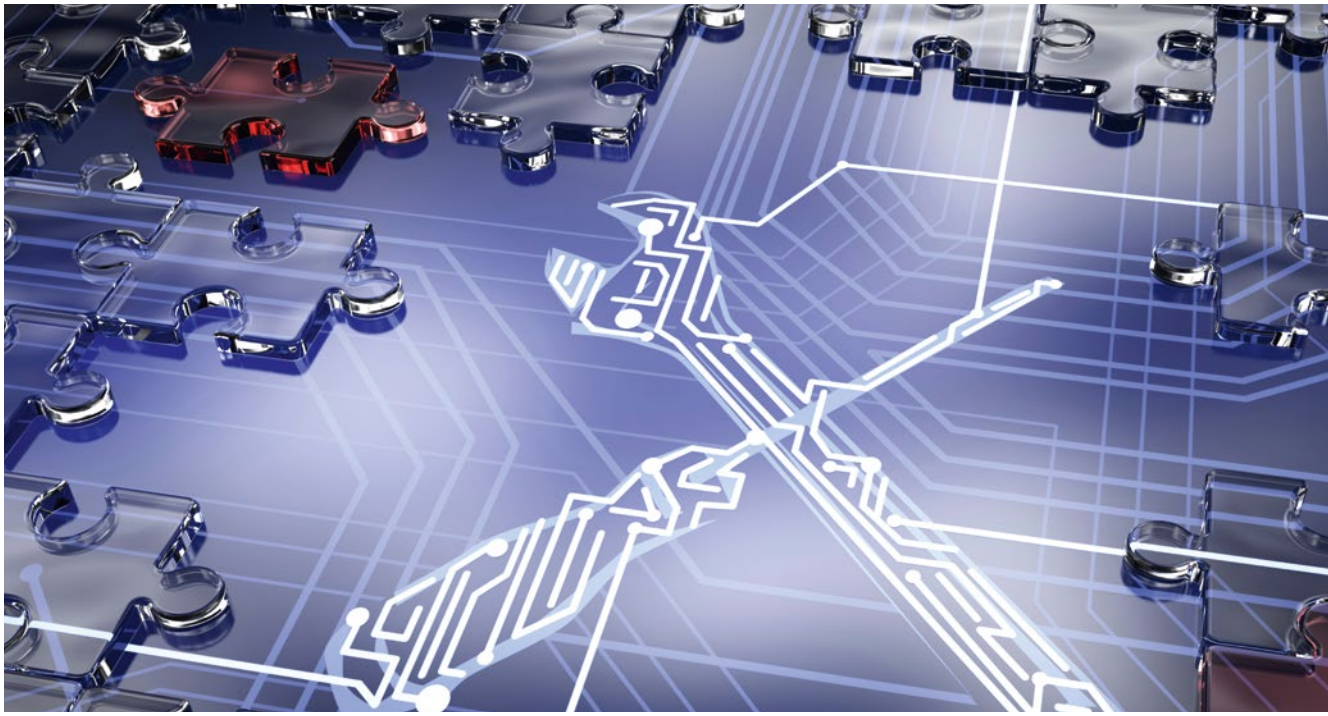
With Industrie 4.0, the fourth industrial revolution has started. Modern information and communication technologies are merging with production technologies to form a new stage of value creation. The availability of information in real time through networking of all partners involved in the entire value-adding process leads to dynamic, real-time optimizing and self-organizing, cross-company value-adding networks.

The small and medium sized companies in the German mechanical engineering industry are the backbone of German industry. They guarantee growth and prosperity in our society. According to a study of the Commerzbank [1], the majority of companies (86 percent) has recognized the opportunities offered by Industrie 4.0. Nevertheless many of them are still reluctant to introduce solutions.

They are reluctant despite the opportunity that the introduction of Industrie 4.0 solution approaches offers them to respond to the changing conditions of global markets. Ever shorter product and innovation cycles and the increasing predatory competition are only some examples of the challenges that small and medium businesses have to face today. In practical terms, the introduction of Industrie 4.0 means to these companies that they can adapt more individually to the needs of their customers and that they can offer a high variant diversity down to a batch size of 1 at prices close to mass production prices. The approaches of Industrie 4.0 allow to build production networks that produce efficiently and effectively at low costs.

But other sectors are aware of the potential of Industrie 4.0 as well. Companies from the field of information technology are pushing onto markets characterized by production technology. In order to become an innovation and market leader on the global market or to continue to remain it, time is becoming a decisive factor for the introduction of Industrie 4.0.

This guideline should support small and medium-sized businesses of the German mechanical engineering industry in rapidly introducing business models for Industrie 4.0. For this purpose, the guideline describes a procedure model that takes into account the visions around Industrie 4.0 and reduces them to viable



stages of development. The application of these development stages in one's own company helps in finding ideas for new business models, innovative products and improved production. The conception of business models will be carried out in workshops within the company. The guideline presents the structure and the procedure of such a workshop.

This way, the guideline offers guidance to the small and medium businesses of the German mechanical engineering industry to find their own definition of Industrie 4.0, to see the benefit for their company and to be able to specify it in monetary terms.

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Management Summary

Many companies regard Industrie 4.0 more as a challenge rather than a chance or an enabler for new business models. Concrete solutions lie as much in the dark as the question what Industrie 4.0 actually stands for. The diversity in the business landscape of the German mechanical engineering industry, however, means that every company has to create its own view of Industrie 4.0 and to develop its own ideas for using the new potentials.

Therefore, the aim of this guideline Industrie 4.0 is to provide small and medium sized machine and plant builders with a tool for developing their own Industrie 4.0 business models and thus support them in their own Industrie 4.0 implementations. For this reason, the guide does not represent a ready-made strategy for implementing Industrie 4.0 in one's own company. It rather shows tools and procedures for the individual further development of one's own strengths and expertise.

The guideline is divided into five sections: preparation, phase of analysis and creativity, evaluation and implementation of the developed business models. The core forms the realization of an in-house workshop. Its proceeding and methods are presented in detail in this guideline. The practicability of this guideline was tested in four workshops in the pilot companies ARBURG GmbH & Co KG, HAWE Hydraulik SE, SCHUNK GmbH & Co. KG and SMS Group. The experiences gained in these workshops were then again included in this guideline.

The objective of the workshop concept for the companies is to develop their own approaches of business models in the context of Industrie 4.0 with the help of creativity techniques. Core elements are an analysis of the company's initial situation in relation to Industrie 4.0 and the so called "Toolbox Industrie 4.0". The toolbox illustrates different application levels of Industrie 4.0 approaches and breaks them down into single realizable development stages. To support generating ideas in the company, the toolbox is divided into the parts "Products" and "Production".

The workshop concept sees the use of the toolbox in connection with established creativity techniques for generating ideas and business models. Interdisciplinary teams from the respective company develop their own ideas around Industrie 4.0 in individual and group work, assess these and further develop them to create company-specific concepts for business models. It concludes with the transfer of these concepts to projects which can be worked on as part of an individual Industrie 4.0 strategy.

The workshops carried out in the four pilot companies brought up innovative ideas for business models. It was shown that the procedure model can be used successfully for elaborating ideas for business models in the context of Industrie 4.0. Therefore, the guideline offers companies a suitable basis for developing their own concepts within the Industrie 4.0 setting.

Small and medium businesses turn towards Industrie 4.0

German machine and plant manufacturers are facing the challenge of Industrie 4.0. Numerous companies are not able to see the objectives and the specific benefit of the solution approaches provided by or around Industrie 4.0. They are reluctant to introduce Industrie 4.0 technologies to their own business. However, the solution approaches of Industrie 4.0 offer the very potential to establish new business models through digitalization and cross-linking of products and production. The challenge for small and medium businesses of the German mechanical engineering industry lies in the task of reducing the visions of Industrie 4.0 to viable development stages that show tangible benefits for their own company and are also monetarily quantifiable.

The time factor is decisive when implementing Industrie 4.0 solution approaches. Because information and communication technology is used in production, companies based on information technology are increasingly penetrating the production technology characterized markets. By introducing the Industrie 4.0 solution approaches, German machine and plant builders have a suitable instrument at hand to assert their market position or to expand it even further.

The time factor plays a decisive role in shaping the fourth industrial revolution.

How can Industrie 4.0 be used to earn money?

Industrie 4.0 in itself does not represent any value. The solution approaches of Industrie 4.0 are rather paving the way for new product innovations, product-related services and improved production processes. This way, on the one hand, Industrie 4.0 can help companies to reduce costs of their own production. And on the other hand, an increase in sales can be achieved through the enhanced usefulness and value of their own products.

How can the vision of Industrie 4.0 become reality?

Many technologies for the Industrie 4.0 solution approaches are already available. But the benefits of Industrie 4.0 will only unfold with a clever combination of these technologies. Still, many companies are unaware of the road leading to the identification and successful combination of Industrie 4.0 solution approaches. The vision of Industrie 4.0 must be turned into reality.

The benefit of Industrie 4.0 unfolds with a clever combination of already existing technologies.

The guideline will aid orientation

It is for this reason, that this guideline for introducing Industrie 4.0 to small and medium businesses has been developed. It equips companies with a procedure model that helps them to successfully develop innovations in the context of Industrie 4.0 and launch them in their companies.

The guideline primarily addresses the decision makers in small and medium businesses of the German mechanical engineering industry. With this guide they are given a tool that will accompany them step by step in finding their own concepts based on the Industrie 4.0 vision.

What are the contents of this guideline?

Industrie 4.0 means change: German small and medium businesses are given the chance to actively participate in shaping this change. This may be achieved by launching new, innovative products but also by improving processes within the company, especially within their own production. Ahead of the introduction of these innovations goes a process that needs to be actively shaped and that takes into account the potentials and peculiarities of the company. The aim is to develop new products, processes, services or business models in general.

Objective of this guideline

This guideline supports small and medium sized companies of the German mechanical engineering industry in identifying potentials for products and production with a systematic process in relation to Industrie 4.0 and in developing their own specific ideas in this respect. In doing so, the guide describes a suitable procedure for direct application in the company.

The introduction of Industrie 4.0 starts with a commitment of the senior management.

What is needed for the implementation?

Industrie 4.0 affects all business units of a company from development and production all the way to service and disposal. Therefore, the commitment to the implementation of Industrie 4.0 needs to be expressed by the top management prior to applying the procedure of the guideline.

The solution approaches of Industrie 4.0 may involve fundamental changes in the production or in designing business models. It is therefore necessary that the decision for implementing Industrie 4.0 solution approaches within the company is taken at the management level and that the projects are staffed accordingly.

The first implementation step is the forming of a suitable project team. The interdisciplinary project team should consist of employees from production and information technology as well as from the development division. This is especially vital when generating ideas around Industrie 4.0 that require close networking between information technology and engineering sciences.

The Toolbox Industrie 4.0

A key element of the guideline is the Toolbox Industrie 4.0 (pages 11 to 16). This toolbox combines the different application levels of Industrie 4.0 in reference to product innovations and production-related technical applications. The application levels are each broken down into five technological and sequential development stages. The Toolbox Industrie 4.0 becomes the starting point for classifying the fields of expertise offered by the company and thus serves as a basis for new ideas in the course of an Industrie 4.0 implementation process.

How is this guideline structured?

This guideline is to be understood as a chronologically arranged procedure model. To check its practicability the procedure was tested in four workshops in the following pilot companies: ARBURG GmbH & Co KG, HAWE Hydraulik SE, SCHUNK GmbH & Co. KG and SMS group. The experience gathered was included in the further development of this guide.

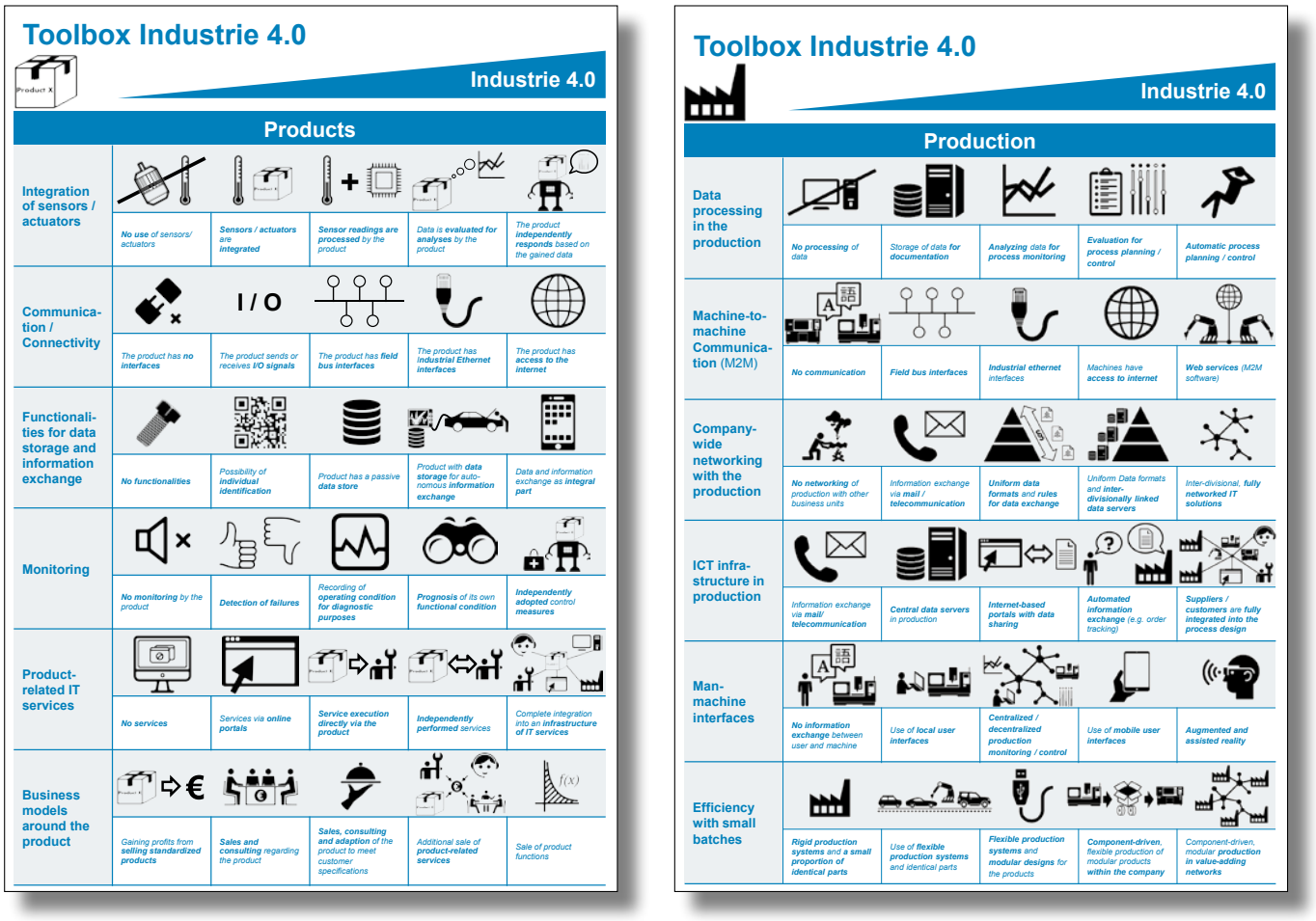


Figure 1: Toolbox Industrie 4.0

The procedure in this guide is divided into five process steps. These process steps have to be accompanied by a project team that is also responsible for the preparatory work and organization of the workshop. The procedure illustrated in figure 2 starts with a period of preparation. In this preparation phase, a suitable starting basis for companies to develop their own ideas in the Industrie 4.0 setting is created. Building on that, in a subsequent analysis phase the company's fields of expertise are identified and presented in a comprehensible way. Based on this analysis and the development potentials derived therefrom, in the following creativity phase ideas relating to products and production are generated in an in-house workshop. The workshop has to be perceived as a key element of this guide's procedure model. It helps to elaborate and assess the ideas for introducing Industrie 4.0. To this end, the participants are informed about the results of the analysis phase and brought up to the same level of knowledge during the workshop. Afterwards they purposefully develop concepts for business models. In the following evaluation phase, the participants evaluate these concepts in terms of their market potential and the necessary resources for their implementation.

The approach of the guideline will be presented in detail in the following sections.

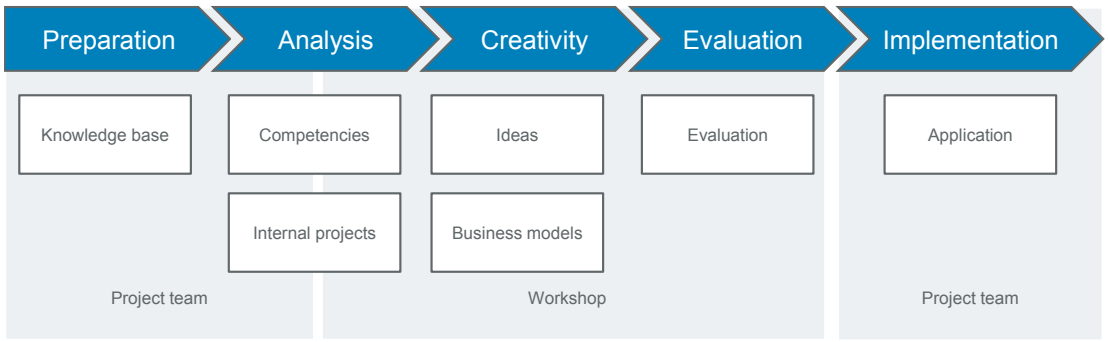


Figure 2: Structure of the guideline

Preparation phase

An in-depth knowledge of the relevant market or of one's own production respectively is the starting point for elaborating product ideas and improving production. A solid knowledge base of all participants of the workshop in the matters related to Industrie 4.0 will also support the later development of ideas. It is therefore the objective of the project team to create a common understanding of the subject Industrie 4.0 within the company.

The workshop brings together the know-how of different departments and specialist areas. It is the key element for a creative elaboration of concepts for business models.

Analysis phase

The analysis phase aims at identifying the expertise available in the company concerning Industrie 4.0 technologies. For this purpose, the market position of the company and the company's own expertise regarding Industrie 4.0 are ranked in this phase. This ranking is confronted with the outside image of the company.

The analysis of the competencies or fields of expertise in this respect is carried out for the products as well as for the production. It is inspired by the application levels and development stages of the Industrie 4.0 toolbox. The result is a first starting basis for the later idea generation.

Creativity phase

The aim of the creativity phase is the generation of new ideas and the subsequent elaboration of concepts for business models. The implementation will be realized on the basis of the fundamentals created in the analysis phase in a process consisting of two stages. In the first part of the process, the participants of the workshop identify and collect initial ideas. These ideas will then be discussed and further developed in the second part. At the end of this period, business models related to Industrie 4.0 have been developed into concepts.

Evaluation phase

The objective of this phase is the assessment of the previously elaborated concepts for business models. For this purpose, the participants classify the concepts for business models elaborated in the workshop according to their market potential or to their potential for production respectively as well as according to the required resources for implementation. The aim is to identify business models with a high potential and a low resource input or a valuable utilization of the company's strengths.

Implementation phase

Finally, the project team draws up the generated proposals and prepares them for further examination or for presenting them to the company management. This way the results of the workshop can be transferred to suitable projects for practical implementation.

Toolbox Industrie 4.0

How do you break down Industrie 4.0 into manageable development stages?

Many discussions about the topic Industrie 4.0 revolve around terminologies, visions and technological principles of a fourth industrial revolution. In most cases, no agreement can be reached. In fact, due to the debating on principles, the practical implementation of the various ideas around Industrie 4.0 is in danger of failing.

The Industrie 4.0 toolbox points out development stages for different application levels of Industrie 4.0.

The hereafter presented Industrie 4.0 toolbox shall reduce the visions and fundamental technologies to development stages which allow a stepwise implementation of innovative ideas in small and medium sized companies of the German mechanical engineering industry. The toolbox becomes part of the presented procedure model of the guideline and is applied in the analysis phase as well as during the internal workshop.

The objective of the toolbox is to render the various ideas and approaches of Industrie 4.0 tangible and to point out development potentials. Since the developments of the fourth industrial revolution are still on-going and far from being complete, it is impossible to fully predict technological development stages. Consequently, the Industrie 4.0 toolbox needs to be viewed as a source of inspiration that must be constantly refined.

How do you read the toolbox?

Industrie 4.0 not only has the potential to increase the usefulness of products but also to reduce production costs. Therefore, the Toolbox Industrie 4.0 is divided into the two sections “Products” and “Production”. These two sections of the toolbox cumulate a great variety of application levels of Industrie 4.0 and point out different development stages.

The carried out breakdown allows a structured and clear illustration that proves to be helpful in identifying innovative business models in the context of Industrie 4.0.

For both units, the single application levels are displayed in the rows and the development stages in the columns of the toolbox. Both sections are depicted below.

The toolbox can be used for supporting the generation of ideas in the context of Industrie 4.0. From the left column to the right column the different development stages represent the road to a vision of Industrie 4.0.

Toolbox Industrie 4.0

Industrie 4.0

Products

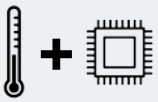
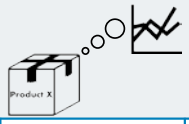
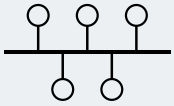
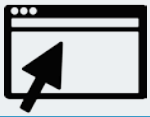
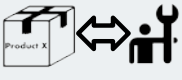
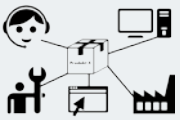
Integration of sensors / actuators					
	No use of sensors/ actuators	***Sensors / actuators** are **integrated***	***Sensor readings are processed** by the product*	*Data is **evaluated for analyses** by the product*	*The product **independently responds** based on the gained data*
Communication / Connectivity					
	*The product has **no interfaces***	*The product sends or receives **I/O signals***	*The product has **field bus interfaces***	*The product has **industrial Ethernet interfaces***	*The product has **access to the internet***
Functionalities for data storage and information exchange					
	No functionalities	*Possibility of **individual identification***	*Product has a passive **data store***	*Product with **data storage** for autonomous **information exchange***	*Data and information exchange as **integral part***
Monitoring					
	***No monitoring** by the product*	***Detection of failures***	*Recording of **operating condition for diagnostic purposes***	***Prognosis** of its own **functional condition***	***Independently adopted** control **measures***
Product-related IT services					
	No services	*Services via **online portals***	***Service execution directly via the product***	***Independently performed** services*	*Complete integration into an **infrastructure of IT services***
Business models around the product					
	*Gaining profits from **selling standardized products***	***Sales and consulting** regarding the product*	***Sales, consulting and adaption** of the product to meet customer specifications*	*Additional sale of **product-related services***	*Sale of product functions*

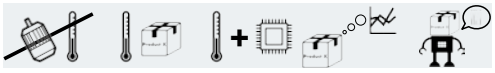
Figure 3: Toolbox Industrie 4.0 – Products

Toolbox Industrie 4.0: Products

The section of the Toolbox Industrie 4.0 named “Products” supports the generation of ideas during the development of innovative Industrie 4.0 products. The toolbox can be applied to entire products as well as to single components of products. The key question is: To what extend can new products be developed or existing ones be further developed with the help of Industrie 4.0? How can this create an added value for prospective customers?

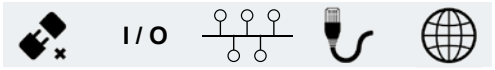
The section “Products” is divided into different application levels: sensors and actuators, communication and connectivity, data storage and exchange of information, monitoring, product-related IT services and business models.

Integration of sensors and actuators



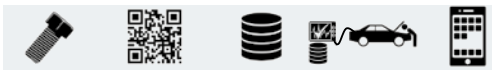
The integration of sensors and actuators as well as computing capacities in physical objects is one central idea of Industrie 4.0 or that is to say of cyber-physical systems. Here, the spectrum includes products with no sensor and actuator functions at all as well as products with their own sensor data evaluation and autonomous responses based on this evaluation.

Communication and connectivity



Suitable communication interfaces allow new applications that can be provided physically decoupled and that benefit from an improved availability of the collected data. On the path towards realizing the vision of a fully web based network in the sense of “Internet of Things”, intermediate steps can be seen in field bus or Industrial Ethernet systems.

Functionalities for data storage and information exchange



Products can differ in terms of differently designed functions for data storage and information exchange. The spectrum includes simple barcodes and rewritable data storage devices as well as information presentation and exchange as an integral product component.

Monitoring

The wide application range of monitoring represents a key aspect of many Industrie 4.0 applications. The spectrum of possible applications ranges from the mere detection of failures and the diagnosis and prognosis of one’s own operational capability all the way to opportunities for autonomous control, which could avoid costly consequential damage in case of failures.

Product-related IT services

The often discussed product-related IT services in the context of Industrie 4.0 can be physically decoupled from the product (for example in online portals for presenting lists of spare parts) or they can be directly linked to the product. Services for condition-based maintenance or product support with remote diagnosis functions are conceivable.

Business models around the product

Innovative technologies allow the development of new business models. A stronger adaptation of products to the needs of customers can be supported by using Industrie 4.0 approaches, for example, in combination with flexible production. Even the selling of product functions where the product remains the property of the manufacturer and only a function fulfillment is compensated can be facilitated through technologies around Industrie 4.0. An extensive recording of operational states or the control of a status-based maintenance by the manufacturer can be named as examples enabling such a selling of functions.

Toolbox Industrie 4.0

Industrie 4.0

Production

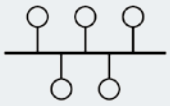
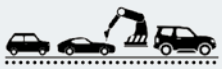
Data processing in the production					
	***No processing** of data*	*Storage of data **for documentation***	***Analyzing** data **for process monitoring***	***Evaluation for process planning / control***	***Automatic process planning / control***
Machine-to-machine Communication (M2M)					
	No communication	***Field bus interfaces***	***Industrial ethernet** interfaces*	*Machines have **access to internet***	***Web services** (M2M software)*
Company-wide networking with the production					
	***No networking** of production with other business units*	*Information exchange via **mail / telecommunication***	***Uniform data formats** and **rules for data exchange***	*Uniform Data formats and **inter-divisionally linked data servers***	*Inter-divisional, **fully networked IT solutions***
ICT infra-structure in production					
	*Information exchange via **mail/ telecommunication***	***Central data servers** in production*	***Internet-based portals with data sharing***	***Automated information exchange** (e.g. order tracking)*	***Suppliers / customers** are **fully integrated into the process design***
Man-machine interfaces					
	***No information exchange** between user and machine*	*Use of **local user interfaces***	***Centralized / decentralized production monitoring / control***	*Use of **mobile user interfaces***	***Augmented and assisted reality***
Efficiency with small batches					
	Rigid production systems** and **a small proportion of identical parts	*Use of **flexible production systems** and identical parts*	***Flexible production systems** and **modular designs** for the products*	***Component-driven**, flexible production of modular products **within the company***	*Component-driven, modular **production in value-adding networks***

Figure 4: Toolbox Industrie 4.0 – Production

Toolbox Industrie 4.0: Production

The second section of the Toolbox Industrie 4.0 focuses on approaches related to production. The starting point for considerations is the question of how production processes can be optimized and how production costs can be reduced with the help of Industrie 4.0.

The application levels of the Industrie 4.0 toolbox unit “Production” are divided into: data processing in production, machine-to-machine communication, company-wide networking with the production, infrastructure of information and telecommunication technology in production, human-machine interfaces and efficiency with small batches.

Data processing in production

The processing of data for various applications is a key issue for Industrie 4.0 applications in production. Data processing in production can be used for simple documentation as well as for objectives aiming at process monitoring, autonomous process planning and control.

Machine-to-machine communication

Interfaces for automated data exchange between machines form the basis for numerous Industrie 4.0 applications. Field bus interfaces as well as industrial ethernet and web interfaces are applied in the industrial environment. Web interfaces and applications with autonomous information exchange (web services) offer the advantage of a possible separation of information and location.

Company-wide networking with the production

An improvement of the networking between the production and other company levels opens up synergies and avoids duplication of work. The networking between production and other departments facilitates unified IT solutions, standardized work flows or consistently used file formats from which the entire company benefits.

Infrastructure of information and telecommunication technologies in production

The infrastructure of information and telecommunication technologies in production determines the possibilities of implementing innovative applications and potential improvements for technical and organizational processes. In addition to the use of central data servers, web-based communication portals may be used. Automated processes for exchanging data with external partners of the value chain or rather value network represent further steps towards an Industrie 4.0 vision.

Human-machine interfaces

Considering the increasing complexity of production systems, human-machine interfaces move into focus. In industrial reality, the starting point is often represented by local display units that do not have user-friendly operating concepts. New operating concepts such as mobile tablets or data glasses that conveniently provide the right information at the right place are potentially promising for simplifying the work of employees and for increasing the production efficiency.

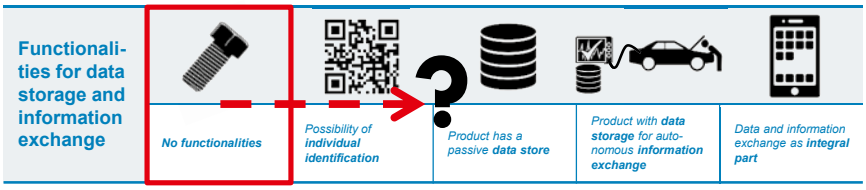
Efficiency for small batches

The trend towards individually produced goods and continuously smaller batches leads to a rising complexity of production processes. Reaching higher efficiency with small lot sizes is thus becoming a decisive competitive factor. In this regard, a modular structure of the respective products or the use of flexible production facilities with the appropriate coordination in the respective value chain can open up new potentials.

Application of the Toolbox Industrie 4.0 – From vision to practical implementation

Steps in generating ideas

- **Application example:** Which example from the product portfolio or production could have potentials?
- **Application levels**: Which application level(s) appear/s to be attractive for further development of the example? (rows of the toolbox)
- **Development stage:** To which development stage(s) can the example currently be assigned?
- **Idea generation:** Where could the example be usefully brought to higher development stages?



What makes sense, what does not?

Not every part of Industrie 4.0 can be usefully transferred to every example. Simple screws will not need functionalities for data exchange in the future. However, ideas for increasing the efficiency of screw production or the further development of business models could be quite promising.

The toolbox encourages individually adapted further thinking – The user always has to see the next development stages towards the vision of Industrie 4.0 in the context of her/his application case.

Analysis phase

The identification of the company's starting position in terms of its own Industrie 4.0 abilities is a prerequisite for the generation of ideas. The following analyses shall present an approach for estimating this starting position. They shall be presented and discussed in the analysis phase of the workshop.

Objective of the analysis phase

The core of the competence analysis forms the elaboration of a company-wide competence profile as well as its disclosure to the participants of the workshop.

A common understanding of the own competencies constitute the starting point for the introduction of Industrie 4.0.

The results of the analysis present a common starting point for the generation of ideas in the course of the workshop. During the creativity phase, the participants develop ideas for the conceptual design of Industrie 4.0 business models based on this common mind set.

How is the competence analysis carried out?

The competence analysis is carried out prior to the workshop. It is divided into internal and external considerations. The competence analysis shall answer two core questions:

- Which Industrie 4.0 competences does the company possess?
- How does the company's external image regarding Industrie 4.0 competences look like?

In companies, competencies related to specific Industrie 4.0 specialist subjects often exist but are not known to all departments of the corporation. The internal competence analysis reveals those Industrie 4.0 competencies and brings them together. The company's existing Industrie 4.0 approaches, technologies and strategies of the individual departments need to be identified. This way, the participants of the workshop may obtain an understanding and awareness of their own competencies.

The external competence analysis reflects the external perception of the company's Industrie 4.0 competencies. Exemplarily, it stands for the perception of external partners and clients. It clarifies, to which extent the public image is designed in regard to Industrie 4.0.

There are two perceptions of the own competence profile: The corporate one and the external one.

The methods for performing the external and internal competence analyses are explained below. The focus of both approaches rests upon the identification of competencies, in other words, of operational expertise – even if it might not be significant for the turnover or the product portfolio.

External competence analysis

The external competence analysis examines the company's portrayal of the product portfolio regarding Industrie 4.0 competencies. The analysis provides indications to which extent the company has already established Industrie 4.0 capabilities and skills. Furthermore, it gives indicators to which degree the company has developed Industrie 4.0 technologies for products or employed them in production.

The external competence analysis examines the company's external presentation in relation to Industrie 4.0.

Execution of the external competence analysis

The external competence analysis is methodologically based on the section "Products" of the Toolbox Industrie 4.0. Since the internal production processes are usually not part of the public appearance, they are not in the focus of the external competence analysis. The public appearance, for example on the internet or in press releases, is analyzed in view of the development stages of the Toolbox Industrie 4.0. The respective approaches are allocated to the application levels of the toolbox.

Evaluation of the external competence analysis

The external competence profile shows the highest development stages in the toolbox's levels of application. A project team performs the evaluation prior to the workshop.

Spider charts are well suited for graphically depicting the competence profile. Figure 5 exemplarily shows an external competence profile. The individual areas of application of the toolbox form the axes. The development stages of each application level generate the spider chart.

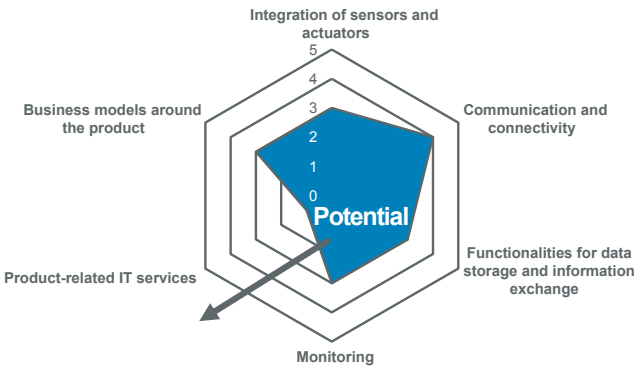


Figure 5: Exemplary depiction of the external competence profile

The external competence profile is to be presented during the workshop and discussed by its participants. In particular, less developed areas of the competence profile are to be critically questioned (cf. Figure 5). This way, the participants of the workshop gain a more profound understanding and awareness of their own competencies. Since the participants usually possess detailed knowledge on the product portfolio of their company, the external competence analysis allows detecting areas for the development of the public portrayal of Industrie 4.0 competencies.

Internal competence analysis

The internal competence analysis examines the company's existing Industrie 4.0 competencies. In contrast to the external competence analysis, which exclusively focuses on the field of "Products", the internal competence analysis provides a more comprehensive picture of the company's Industrie 4.0 competencies by analyzing all areas of the Toolbox Industrie 4.0.

The internal competence analysis examines the corporate competencies in relation to Industrie 4.0.

Experience has shown that the product portfolio as well as the technologies already used in the in-house production do not reflect the entire range of competencies that are existing in the company. Thus, the internal competence analysis pursues the objective of identifying Industrie 4.0 competencies which go beyond market-mature, saleable products and solutions already implemented in the in-house production. Those competencies are to be identified and communicated to the participants of the workshop to allow them to gain an understanding and awareness of in-house capabilities and skills.

Execution of the internal competence analysis

The Toolbox Industrie 4.0 defines the methodological frame for identifying these competencies. It provides a scheme according to which various business segments can be questioned on the degree of implementation of the Industrie 4.0 approaches. Oftentimes, the individual business segments, such as product development, production and service, display different views of Industrie 4.0 during the questioning. Interviews with representatives of the various business segments allow identifying these different perceptions. Thus, the interviewees should be interdisciplinarily mixed to be able to holistically identify the competence profile. Based on experience, at least ten decision makers should take part in the questioning.

Evaluation of the internal competence analysis

The evaluations of the interviewees may be entered into two spider charts analogous to the external competence analysis: One spider chart on the topic of “Products” and one on “Production”. The application levels of the toolbox shall constitute the axes. The stages of development of each application level generate the respective spider chart.

The analysis and discussion of the internal competence diagrams reveal potential for implementing ideas referring to Industrie 4.0. In particular, less developed areas need to be discussed. They demonstrate fields of action for the implementation of problem-solving approaches of Industrie 4.0. It is the interdisciplinary discussion which creates a sophisticated understanding of the company’s Industrie 4.0 competencies.

Internal research and development projects

The knowledge of internal research and development projects or solutions already implemented in the area of Industrie 4.0 equips the participants of the workshop with a common understanding of already identified starting points.

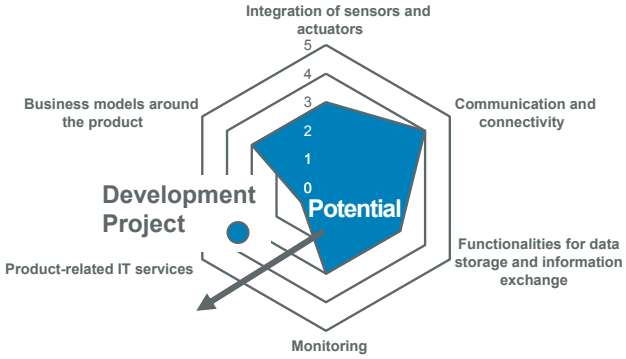


Figure 6: Depiction of the internal competence profile together with a respective project

The projects that have already been initiated or implemented are presented after the discussion of the competence analysis. The participants disclose the internal research and development activities in informative presentations. Each presentation aims at showing the benefit of the envisaged solution, the target group and key activities. On sides of the participants, the presentation shall lead to a common understanding of the company’s projects in the field of Industrie 4.0 that have already been implemented or are in the process of being developed. Classifying the findings in a competence diagram, as depicted in Figure 6, supports the generation of a common understanding of the corporate competencies.

Often, the company already possesses competencies necessary for Industrie 4.0 approaches.

The internal and external analyses of the competencies lay the foundation for the introduction of Industrie 4.0 in the company. Furthermore, they can be discussed with regard to a common understanding of Industrie 4.0. The overall picture derived from the analysis and the presentation of the internal projects allows identifying potential which may be further specified during the creativity phase.

Competence analysis with the toolbox

The corporate competencies may be classified with the Toolbox Industrie 4.0.
For this purpose, the analysis of an example is given below.

Steps towards the competence analysis

Which example from the product portfolio or production could have potential?

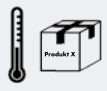
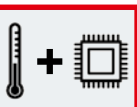
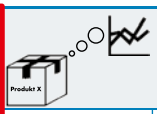
- Application levels: Which application level(s) are covered by the product?
- Development stages: To which development stage(s) may the product presently be assigned?

Example:

The exemplary product possesses built-in sensors which are processed directly with the product.

Question for the application levels:

How are sensors and actuators integrated in your products?
Example: Sensors are integrated and processed directly by the product.
The product's level of technology may be assigned as depicted below.

Integration of sensors / actuators					
	***No use** of sensors/actuators*	***Sensors/actuators** are **integrated***	***Sensor readings are processed** by the product*	*Data is **evaluated for analyses** by the product*	*The product **independently responds** based on the gained data*

Creativity phase

The Toolbox Industrie 4.0 as well as the results of the analysis phase constitute the foundation of the creativity phase. This phase pursues the objective of developing concepts for new business models which implement the problem-solving approaches of Industrie 4.0. The implementation of the creativity phase shall be outlined in the following.

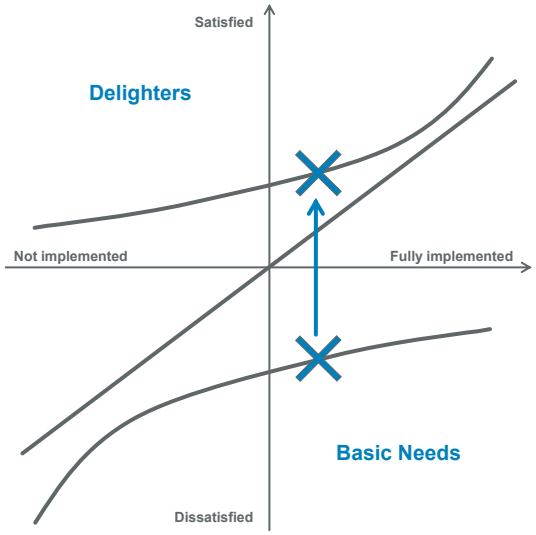


Figure 8: Kano Model – From basic need to delight [2]

How is the creativity phase implemented?

The creativity phase forms the central part of the workshop. It is composed of two segments: The creative work performed by the individual and the elaboration of ideas in groups. In the first segment, the participants individually generate ideas regarding new products or improvements of production. Subsequently, the participants split up into several groups in order to further develop these ideas into concepts for business models.

Creative individual work

Each participant of the workshop individually elaborates ideas for the units “Products” and “Production”. The ideas are generated on the basis of the conclusions drawn from the previous analysis phase. Ideas that could delight the customer are sought after. Innovation and the use of new technologies stir this enthusiasm.

The requirements for customer delight are in a continuous state of development. Things that delight today’s customers can become future basic requirements that customers will take for granted in the future [2]. In the phase of creative individual work, inspiring ideas shall be processed to practical concepts for business models.

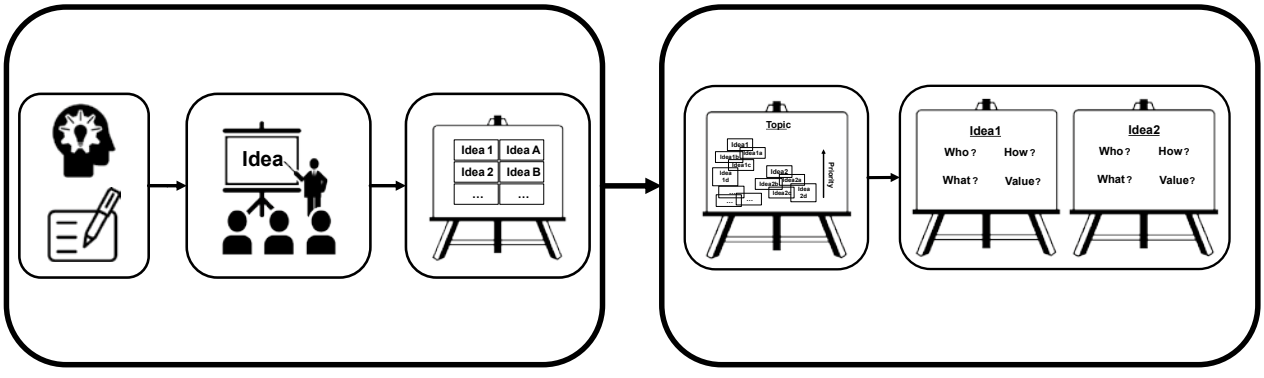


Figure 7: Stages of the creativity workshop

To systematically pursue the generation of ideas, the following procedure using the Toolbox Industrie 4.0 may be applied. In addition to the toolbox, findings from the internal and external competence analysis as well as the presentation of internal projects support the quest for ideas.

During the creativity phase, new ideas can be generated with the help of the Toolbox Industrie 4.0.

Process of idea generation

In a first step, each participant collects examples from the product portfolio or production that seems to be suitable for further development related to Industrie 4.0. Afterwards, the application levels where the further development of the examples could show potential are identified. The application levels may also be selected based on the corporate strengths and weaknesses described in the internal competence analysis. Thereupon, the participant analyzes the current state of the selected example of the respective application level and assigns it to the corresponding category of the toolbox. Subsequently, the participant conceives ideas for reaching higher development stages of the toolbox Industrie 4.0.

In the next step of the creative individual work phase, the findings of the individual work are presented. Key words of the core content of the ideas are written on presentation cards. Each participant presents his or her ideas to the entire group by giving a summary of the key content. As experience teaches, the number of ideas should be limited to three. Figure 9 exemplarily depicts the process of creative individual work.

Elaboration of ideas in groups

After each participant has summarized his or her ideas, the team clusters them into topics. These topics form the basis for splitting up the subjects for the group's idea development. This development aims at further expanding and refining the ideas to business model concepts.

Before the group's idea generation starts, the moderator splits up the participants into groups and assigns the aforementioned subjects respectively. Splitting up the group heterogeneously leads to a differentiated debate of the topics.

In the first stage of the group's idea development, the individual ideas are prioritized with respect to the development of potential business models. At the same time, identical or similar ideas are to be combined to one.

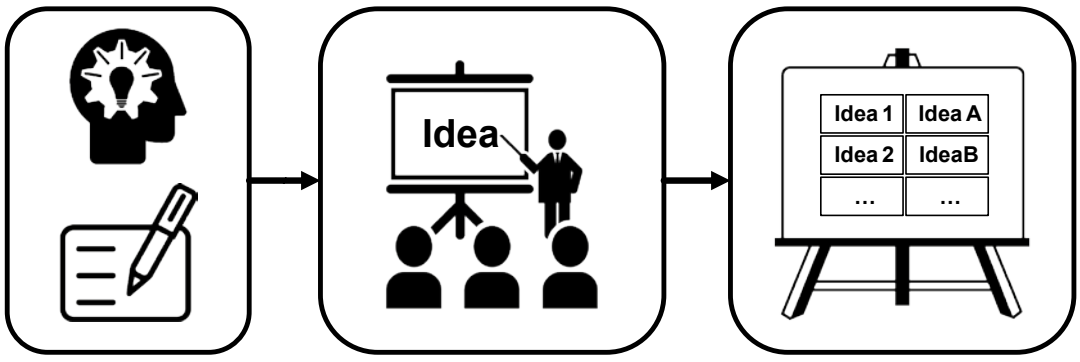


Figure 9: Process of individual creativity work

In the second stage of the group's idea generation, the participants further develop the two ideas with the highest priority according to the St. Gallen Business Model Navigator. The navigator supports the detailed examination of ideas as well as the elaboration of ideas for creating concepts of business models. In this context, four central questions are to be analyzed and answered by the group (cf. Figure 10) [3].

What?
- What do we offer to the customer?

Who?
- Who is our target customer?

How?
- How is the value proposition created?

Value?
- How is revenue created?

The project team records the results of the group work by documenting the answers to the central questions well structured on flip charts in order to allow the evaluation phase to commence.

Figure 11 exemplarily shows the process of this group work.

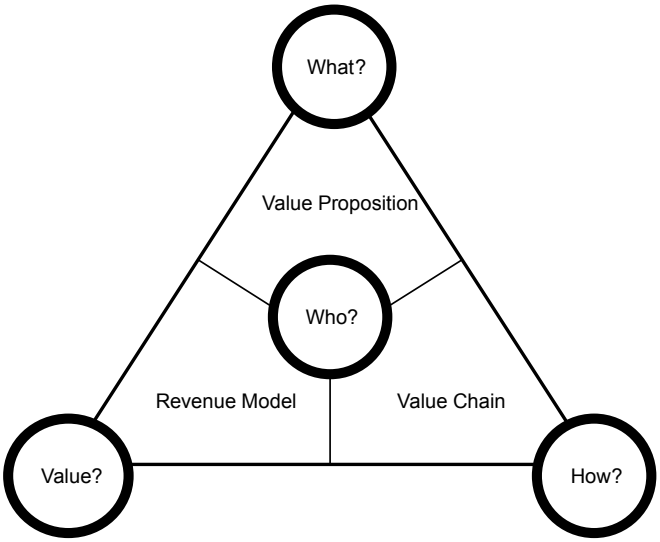


Figure 10: St. Gallen Business Model for products and production [3]

Answering the questions with the St. Gallen Business Model Navigator supports the systematic analysis of the idea. Thus, the idea is further developed to a business model concept.

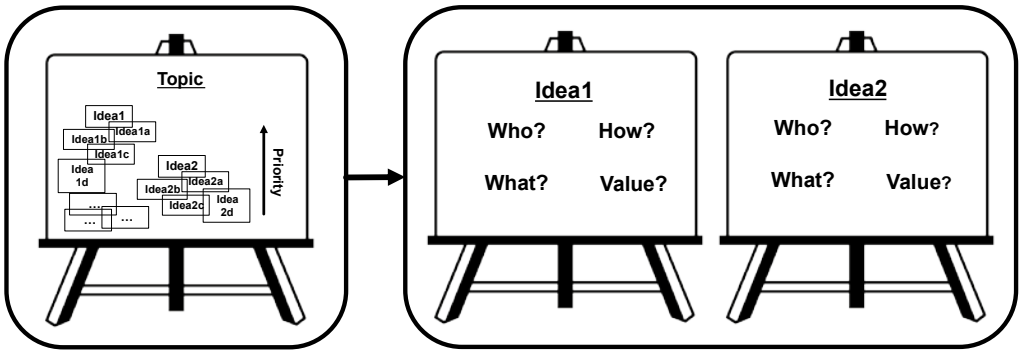
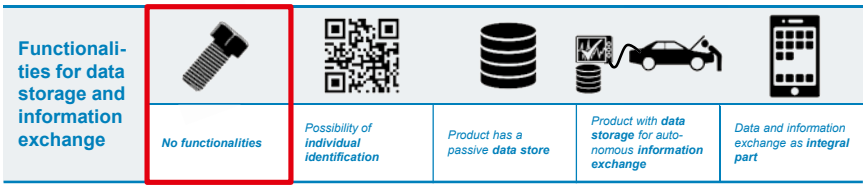


Figure 11: Process of group work

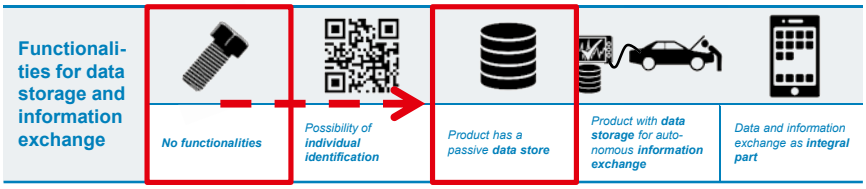
From the Toolbox Industrie 4.0 to the business model concept
Example: Machine element of a production machine

Idea generation

First of all, with the help of the Toolbox Industrie 4.0 the initial situation must be identified on a suitable application level.
Conventional machine elements do often not possess any features to store data and exchange information.



Ideas are conceived by taking a close look at the next development stages of an application level of the Toolbox Industrie 4.0. One idea would constitute in integrating a passive data memory for the purpose of filing product data directly in the machine element.



Idea: Self-describing machine element, data memory is physically attached to the machine element and can store product data.

Elaborating a business model concept inspired by an idea

What? (What do we offer to the customer?)
- A machine element with stored individual product data (identification and settings)
- Reduced commissioning time of production machines by automatically transferring the data to the machine's control

Who? (Who is our target customer?)
- Manufacturers of production machines

How? (How is the value proposition created?)
- By integrating data memories into suitable product series of machine elements
- By writing on the memory when inspecting outgoing goods
- By providing interfaces for data readout

Value? (How is revenue created?)
- Increase in sales by raising attractiveness of machine elements
- Customer loyalty through greater involvement in production processes

Evaluation phase

During the workshop's evaluation phase, the individual groups present the results of the creativity phase to the entire group of participants. The presentation shall focus on displaying a coherent and convincing business model. Subsequent to the presentations, each business model concept shall be discussed by all participants.

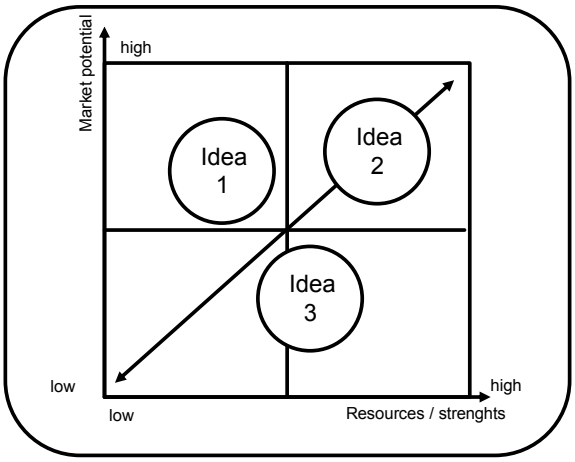


Figure 13: BCG Matrix [4]

After each group has presented its concepts for business models, all participants can evaluate the individual business model concepts. This evaluation is based on two criteria:

- the market potential of the business model and
- the available resources or suitable strengths required for its implementation.

The objective lies in evaluating and finding ideas that show high market potential and can make use of resources and competencies already available in the company.

Each participant receives two evaluation points for the evaluation, namely one for market potential and one for resources / strengths. By pinning those evaluation points to the flip charts, each participant evaluates the elaborated business model concepts.

Afterwards, the concepts are incorporated in a Boston Consulting Group matrix. Its axes are labeled market potential and resources / strengths [4]. The thus achieved evaluation of the concepts allows to deliberately select those business models that promise high potential and whose implementation calls for resources that are already well developed in the company.

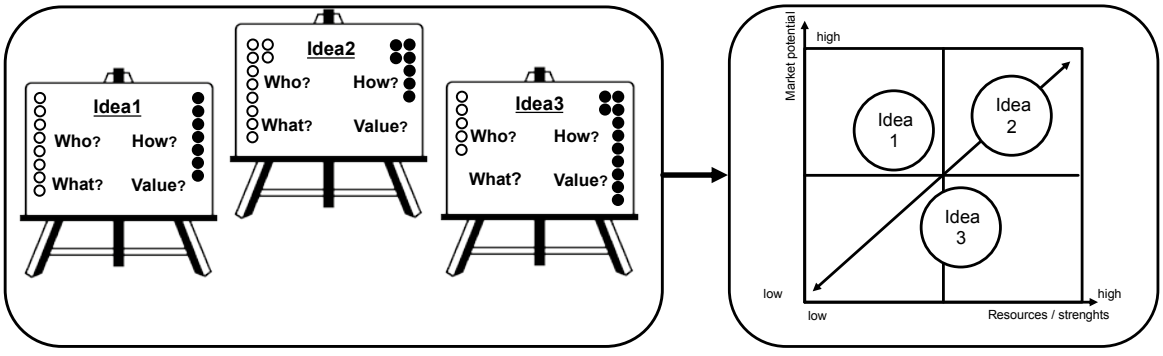


Figure 12: Evaluation of group work

The workshop

The process model presented in the guideline is composed of five phases:

- Preparation phase
- Analysis phase
- Creativity phase
- Evaluation phase
- Implementation phase

The phases of analysis, creativity and evaluation are carried out in a workshop.

The following working steps should be performed prior to the workshop:

- Composing an interdisciplinary group of participants for the workshop
- Executing a competence analysis in the company
- Preparing corresponding presentations
- Appointing a keynote speaker and a moderator

As experience teaches, the number of workshop participants should lie between 10 to 15 people. Those participants should come from different departments and thus have differentiated perceptions of Industrie 4.0.

Example of a workshop agenda:

Topic	Duration
Keynote on Industrie 4.0	30 minutes
Introduction of Toolbox Industrie 4.0	30 minutes
Presentation of competence analysis	45 minutes
Internal research projects	60 minutes
Presentation of creativity method	15 minutes
Generation of ideas (individual work)	60 minutes
Presentation of ideas	30 minutes
Elaboration of business model concepts (group work)	120 minutes
Presentation of findings and discussion	60 minutes
Evaluation of business model concepts	30 minutes

Implementation phase

During the implementation phase, the business model concepts formulated during the workshop are further specified and transferred to respective projects. Thus, they conclude the procedure presented in the Guideline Industrie 4.0.

What happens after the workshop?

The business model concepts elaborated in the workshop should become more specified. For this purpose, a person in charge who functions as a contact person and takes on responsibility for the further development of a concept has to be designated. Based on the case of application, the person in charge can coordinate the required technologies and resources with strategic partners and special departments.

A company-wide strategy consolidates the introduction of Industrie 4.0.

From vision to reality

The elaborated business model concepts are to be presented to the decision makers. The developed business models may concern all company areas: engineering, production, sales and product service. The management's initial commitment to Industrie 4.0 should thus result in a company-wide strategy based on the developed business model concepts aiming at the introduction of Industrie 4.0 solutions.

The introduction of practical Industrie 4.0 solutions allows German small and medium sized companies operating in machinery and plant engineering to extend their own business models in the areas of product technology and engineering by benefiting from new perspectives regarding information technology. German machinery and plant constructors thus receive a suitable tool to assert their position on the market and to develop new core competencies regarding information technology.

The time factor is crucial for the introduction of Industrie 4.0 solution approaches. The present guideline shall equip German small and medium-sized businesses operating in machinery and plant engineering with an instrument that reveals practical development stages for the timely and successful introduction of Industrie 4.0.

Industrie 4.0 in the VDMA

The VDMA Forum Industrie 4.0 consists of an interdisciplinary team of VDMA experts that regard themselves as partners and service providers. They support the member companies in the fields of action relevant to Industrie 4.0.

Politics & Networks

On the road to becoming a leading market and leading supplier of Industrie 4.0, essential conditions need to be agreed upon with political and societal representatives. In order to lead Germany as an industrial location into the future, high requirements in the fields of research and development, education and qualification, norms and standards, legal and IT security need to be complied with.

Production & Business Models

Industrie 4.0 places high value on networking in production by using modern internet technologies. The objective is to facilitate communication between the operating equipment, products and its components to guarantee efficient and customer-specific production processes. Automation and products of batch size 1 will no longer be mutually exclusive. The potential for networking and customer-specific production resides in innovative business models covering the entire product life cycle – from conception to disposal.

Research & Innovation

When implementing Industrie 4.0, the success in international competition and the competitiveness of industrial Germany mainly rests upon the research findings. Particularly important are reliable funding tools in the research area of production and ICT as well as the consideration of the requirements of the sector machinery and plant engineering mainly operated by small and medium sized companies. Major factors of success lie in the networking of all players and quickly transferring the research findings to all partners active in industrial operations.

Norms & Standards

Industrie 4.0 allows cross-company networking and integration of various value-added networks. For this purpose, norms and standards are of fundamental importance since they define the mechanisms of cooperation and the information to be exchanged. It is thus essential to take part in the process of standardization and the shaping of open standards for the purpose of building a reference architecture and to engage all players in an active dialogue.

IT Security & Legal Affairs

In the context of Industrie 4.0, IT security is imperative for the secure operation of cross-company manufacturing processes. Automated data exchange of networked systems must be secure and reliable. It is crucial to control the identification of the process players and to protect the know-how of products, machines and plants.

In the field of Industrie 4.0, legal repercussions can already be detected. Consequently, existing legislations need to be further developed and newly interpreted. This endeavor will constitute a central task when it comes to implementing Industrie 4.0 and incorporating it into the daily business of companies.

People & Work

Industrie 4.0 will fundamentally change work and processes. In the future, the factory employees will have to take on more responsibility when it comes to coordinating processes, steering communication and taking autonomous decisions. The tasks will be more challenging, technologically as well as organizationally, and interdisciplinary competences will gain in importance. The authorities, educational establishments and companies will have to adjust to these challenges.

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