

## Article

# Increasing Firm Performance through Industry 4.0—A Method to Define and Reach Meaningful Goals

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**Abstract:** Industry 4.0 is one of the most influential trends in manufacturing as of now. Coined as the fourth industrial revolution it promises to overthrow entrenched structures opening new pathways for innovation and value creation. Like all revolutions, it is accompanied by disruption and uncertainty. Consequently, many manufacturing companies struggle to adopt an Industry 4.0 perspective that benefits their performance. Hence, our goal was to develop a method for increasing firm performance through Industry 4.0. A key factor was to focus on the entire company as a socio-technical system to depict the numerous interactions between people, technology, and business/organization. To realize the method, we combined consortium research, design science, and method engineering. We gathered comprehensive data from workshops, interviews, and five case studies, which we used to develop the method. It consists of four phases: a maturity model to determine the status quo, a procedure to derive a target position, a pattern-based approach to design the socio-technical system, and a procedure to define a transformation setup. Our approach is the first to combine maturity models with foresight and extensive prescriptive knowledge. For practitioners, the method gives orientation for the future-oriented planning of their transformation processes.

**Keywords:** Industry 4.0; maturity model; transformation; methodology; Industry 4.0 strategy; socio-technical system



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## 1. Introduction

The root of Industry 4.0 is a German strategic initiative; the term itself was first mentioned during the Hannover Fair in 2011 [1]. Based upon the emergence of the internet of things, data, and services, it is anticipated to describe a fourth industrial revolution [2]. Fundamental concepts of Industry 4.0 include smart factories, cyber-physical systems, self-organization, new distribution and procurement systems, new systems for product and service development, adaptation to human needs, and corporate social responsibility [3]. Industry 4.0, hence, fosters radically new, highly dynamic, ad hoc networked, and real-time modes of collaboration within and between companies [4]. This is associated with a wide range of advantages, e.g., the production of custom products with minimal use of time and resources [5]. Consequently, Industry 4.0 will transform value creation, value capture, and value offer of manufacturing companies, and thus the whole business model [6].

While technology represents the origin, it is critical for the implementation of Industry 4.0 to recognize it as a socio-technical endeavor [7]. Socio-technical systems are instantiations of social and technical elements engaged in purposeful goal-directed behavior, where both, social and technical factors, are responsible for successful performance [8]. This thinking is derived from the insight, that any production system requires technology and a social structure linking human operators with the technology and to each other [9]. Ulich (2013) introduces the so-called “MTO” concept, which considers the dimensions

“people”, “technology” and “organization”, hence explicating the relevance of organizational structures [10]. In this paper, we follow a further extension of the concept and replace organization with business to further emphasize the value orientation. Simplified, business represents organization and earning money [11]. Following the initial understanding of socio-technical systems, we consider business, technology, and people as responsible for the successful performance of Industry 4.0 approaches.

These linkages can be illustrated by a simplified example: machines and end devices are increasingly equipped with sensors in the context of Industry 4.0. As intelligent cyber-physical systems (technology), they collect and process data, which is made available to networked systems via web technologies (e.g., via a digital platform). The analysis of the provided data leads to new value creation opportunities such as complementary services or new revenue models, e.g., pay-per-use (business). However, these possibilities demand reflections on the work organization within the company (business) and the necessary competencies (people).

While the overall potential of Industry 4.0 has been recognized by companies, the actual implementation imposes major, heterogeneous challenges (c.f., [12,13]). Given the multitude of possibilities and their associated challenges, companies should not strive for the introduction of the highest possible Industry 4.0 level, but rather concentrate on what is beneficial in their current position. Hence, the first step for the beneficial introduction of Industry 4.0 should be the individual determination of the company’s current performance [14]. This should be contextualized compared to the competitors [15], to strive for a competitive advantage. Therefore, the performance level of the company needs to be systematically determined and expressed in an objectively measurable way.

Next, companies need to determine the direction they want to take. This is not trivial and has to be chosen conscientiously taking the company’s contingencies into account [16]. However, one study finds in its sample that although 73 percent of companies specify that digital transformation has a major influence on their corporate strategy, more than 50 percent do not yet have a comprehensive and, above all, holistic implementation strategy [17].

Based on the initial situation and the target position, a coherent set of solutions that address the gap between both is needed. Implementation projects for Industry 4.0 often involve an uncertain and non-sequential strategic approach [15]. According to a McKinsey study, 70 percent of the companies have already introduced a pilot project for Industry 4.0, but at the same time, only 29 percent have been able to generate added value as a result [18]. Comparing large companies to small and medium-sized enterprises (SMEs), it seems to be a particular challenge for the latter to identify and select individually suitable solutions. According to another study, 65 percent of SMEs (compared with 19 percent of large companies) indicated the selection of solutions that meet their needs as a major obstacle concerning Industry 4.0 [19].

Concluding the challenges above, it becomes clear that companies need a method to support the implementation of Industry 4.0 to increase their performance. Hereby, a socio-technical approach should be adopted. The method should answer the research question “How can companies identify and attain an individual and performance increasing Industry 4.0 target position?”. Based on the considerations above and supported by our practice partners, the method should cover four fields of action:

1. **Maturity Check:** To evaluate the performance of the considered company, Industry 4.0 has to be depicted in detail as a socio-technical system in the areas of technology, business, and people. An objective evaluation scheme, i.e., a maturity model, is required to make the company’s initial position measurable.
2. **Target definition:** Based on the individual initial situation, an appropriate target maturity level is to be determined for the company, taking into account the actual and future contingencies of the market, technology, and environment.
3. **Implementation planning:** To select suitable solutions to reach the target position, it is promising to draw on the experience of Industry 4.0 pioneers. The target is to enable

companies to participate in the dynamic development of Industry 4.0 with relatively little effort. For that, implementation patterns need to be identified. They allow to tackle typical Industry 4.0 tasks. The selection and combination of implementation patterns must be supported, taking into account the effects on people, technology, and business.

4. **Transformation setup:** For the concrete implementation of Industry 4.0 the status quo, target position, and implementation solutions must be integrated into a coherent view, which can be communicated to the employees. Measures must be defined that translate the plan into action.

In this paper, we reflect on one of our recent research projects concerning this problem. The paper unfolds as follows. Next, we investigate the relevant body of knowledge in the literature. After that, we describe our research setting and methodology. Then, the results of the project are described according to an abridged and revised excerpt from our final project report [20]. A discussion of the results follows before we close the paper with a short conclusion.

## 2. Literature Review

Chapter 1 has introduced the four major fields of action in the course of our research. To further clarify the research gap, we address with our method, the literature for the fields of action is analyzed. While Industry 4.0 is a manufacturing-centric concept, in general, the term digital transformation is also used quite often [21]. Hence, in the following first the main concepts of the field of action and then both frameworks and methods for Industry 4.0 and digital transformation are considered.

### 2.1. Maturity Check for Industry 4.0

To investigate the maturity (or competency, capability, level of sophistication) of companies regarding certain domain so-called maturity models are used, which comprise a set of more or less comprehensive criteria [22]. Maturity models consist of sequences of maturity levels ranging from an initial state to an optimal stage following an evolution path of discrete steps. To this end, criteria and corresponding characteristics that need to be fulfilled for a certain maturity level are provided [23]. Using maturity models managers can determine (1) the actual performance of the company today, (2) the current status of the industry (benchmark), (3) targets for improvement, and (4) required changes between the status quo and the target [24]. There are numerous maturity models in literature today. In terms of Industry 4.0/Digitalization new maturity models keep appearing. Wagire and colleagues for example recently introduced an Industry 4.0 maturity model emphasizing organizational awareness and emerging technologies like cobots [25]. Gökalp and Martinez propose a digital transformation maturity model (DX-CMM) that allows for a process-centric, holistic, and integrated view for companies across all sectors [26]. Other approaches proved to be very successful in practice. The Industry 4.0 Maturity Index for example is continuously used in different industries by the Industrie 4.0 Maturity Center consultancy. It is structured along the four capabilities for industry 4.0 resources, information systems, organizational structure, and culture [14]. From our point of view existing Industry 4.0 maturity models are already very sophisticated but lack depth regarding the business perspective of Industry 4.0. Furthermore, they lack methodological support to define meaningful goals for Industry 4.0. Deriving concrete measures from the gap between two maturity levels is also associated with high cognitive demands.

### 2.2. Defining Target Maturity Levels for Industry 4.0

Defining a target position is one of the major activities during strategy development [27]. It is also an essential component of many methods for the Industry 4.0 transformation, whether they are based on a maturity model or not. Oleff and Malessa for example distinguish between visionary goals and operational goals. Visionary goals are derived from a maturity model investigating which maximum maturity level might be reached

within a limited project. Operative goals are derived iteratively matching current problems and potentials [28]. Tüllmann and colleagues on the other hand recommend defining the targets by consolidating the expectations of the involved stakeholders [29]. Other approaches simply recommend conducting expert workshops to define targets within a maturity model [30–32]. Another approach that utilizes expert workshops is by Jodlbauer and Schagerl, who recommend defining the target position considering strategy, (company) goals, maturity, and economic and technical restrictions [33]. The Industrie 4.0 Maturity Index defines two consecutive generic targets: first, equalize the maturity levels, then raise the maturity levels [14]. Summarizing the findings from the literature, it is clear, that most methods use only rudimentary tools to determine the target position for Industry 4.0. This does not seem to do justice to the importance and the necessary investments in Industry 4.0. Moreover, no approach even considers thinking ahead the future contingencies in which the company has to flourish in the future, which is paramount since the transformation towards Industry 4.0 is a long-term project. A future-oriented target definition for Industry 4.0 is therefore needed.

### 2.3. Solution Pattern as a Means to Close the Gap between Maturity Levels

Even when meaningful goals for industry 4.0 as defined by a target maturity level are formulated, closing the gap between as-is and should-be situations is not trivial. Suitable measures must be defined and enacted. Since Industry 4.0 is a widespread phenomenon, there are already vast amounts of solutions for typical problems of companies. However, these so-called “Best Practices” are difficult to identify and structure for individual needs [15]. Solution patterns describe recurring problems and the core to their solutions so that they can be used over and over again, without ever leading to the same result [34]. Hence, solution patterns for Industry 4.0 implementation are a suitable approach to overcome the gaps. Each solution pattern has a name and is described by context, problem, and solution [35]: (1) The name is a descriptive representation of the solution contained in the pattern. (2) The context classifies the underlying problem into the situation in which it occurs. (3) The problem describes the challenges or issues addressed by the pattern. (4) The solution provides appropriate ways and means to solve the problem. Besides that, the notation can be adapted to the application context.

Anacker synthesizes six major benefits using solution patterns from literature [36]: (1) transferability across disciplinary boundaries, (2) improvement of communication through explicit knowledge representation, (3) long-term documentation of solution knowledge, (4) reduced complexity by breaking down extensive problems, (5) increased efficiency through targeted reuse, and (6) promotion of creativity.

Solution patterns have been discussed for almost 50 years, starting with Alexander’s book “*A Pattern Language—Towns, Buildings, Construction*” [34]. Since then, their application can be investigated in numerous disciplines like software engineering, product engineering, and business model development [37]. This shows the extensive uses for solution patterns. Compared to other forms of knowledge representation solution patterns seem to be especially promising for Industry 4.0 because they (1) are focused on problem-solution-combinations and hence allow for an easy transfer into practice, (2) externalize and generalize knowledge to close knowledge gaps, (3) allow for the creation of individual solutions, (4) are comparable to each other, and (5) can be continuously extended by new patterns, which is necessary given the rapid evolution of Industry 4.0.

There are only a few solution pattern approaches for Industry 4.0. Weking and colleagues for example propose a business model pattern framework [38], while Gausemeier and colleagues describe a pattern system for Industry 4.0 business models [39]. Many other approaches can be seen as enablers for Industry 4.0, e.g., Dumitrescu’s design patterns for cognitive functions [40]. However, patterns that take into account the socio-technical transformation of the enterprise are not existing in literature as of now.

## 2.4. Transformation Setup

Adopting Industry 4.0 in a firm requires a deep transformation. A transformation involves the “redefinition of mission and purpose, and a substantial shift in goals, to reflect a new direction and therefore encompassing a fundamental shift in the business model of the organization, touching all cultural, structural, and processual aspects” [41]. This is reflected in many approaches for the introduction of or the transformation towards Industry 4.0. Merz for example includes the management of processes, technologies, organization, and employees in her method [42]. Hennegriff and colleagues define concrete projects and responsibilities and include a controlling phase for the transformation [43]. The acatech Industry 4.0 maturity index recommends defining measures, which are then clustered into action streams and are planned in a factual-logic sequence [14]. However, despite a transformation being a high-risk endeavor, no approach considers a holistic, sociotechnical management of risks within the transformation towards Industry 4.0, leaving a research gap from both theory and practice [44].

## 2.5. Summary

The analysis of the existing literature in Industry 4.0 leads to the conclusion, that besides numerous existing maturity models, there are still many open questions regarding the utilization of the maturity models to define and reach meaningful goals. Solutions to define the target maturity are needed as well as approaches to transfer a maturity level towards concrete measures. Furthermore, looking at the transformation itself, managing the risks for Industry 4.0 transformation seems to be a significant research gap.

## 3. Materials and Methods

Our research approach is inspired by Otto and colleagues (2015) [45], who combine consortium research and method engineering to develop an approach for digital business model design. This can be considered as an analogous research endeavor and, thus, it provides a first indication of what our research approach might look like [45]. Next, we describe the research process in general before we elaborate on data collection and artifact design in detail.

### 3.1. Research Process

The research need implies that the desired resulting artifact is a method. Methods can be considered design artifacts [46]. Developing a method to increase firm performance in the context of Industry 4.0 is a complex task that requires comprehensive data from the field. When we planned the research project, Industry 4.0 was still in its infancy. Hence, we chose a strong focus on case study research, which is suitable for investigating new phenomena that cannot be separated from their organizational context [47]. To this end, suitable cases had to be identified and organized.

Given these boundary conditions, we chose consortium research (CR) as an overarching research process. It especially suits research projects, where the desired result is an artifact designed to solve practical problems (e.g., a method) and where close long-term cooperation of researchers and different companies (i.e., the case companies) is necessary for data collection, artifact design, and artifact evaluation in real business settings [48]. CR gives guidelines to organize the collaboration and allowed us to create a stimulating research setting for theoretical and practical insights. A CR project follows four phases: analysis, design, evaluation, and diffusion [48]. The concrete activities and methods used in each phase during our research project are shown in Table 1. The resulting research process, hence, comprises a multilayered approach: The general research setting follows the CR approach, while the method engineering approach, which is a subdiscipline of design science research, was utilized to develop the concrete artifact.



**Table 1.** Research process with activities and methods.

Consortium Research Phase	Activities and Methods
Analysis	Literature review Interviews and consortium workshops Best practice analysis (e.g., platform Industry 4.0, it's owl)
Design	Rigor: Review of Industry 4.0 and Business Transformation (in Manufacturing) literature Relevance: Interviews and workshops with consortium partners Method Engineering as design paradigm for the development of the method Action research to solve real-world problems within the consortium, check the relevance, and iterate toward the solution
Evaluation	Case studies Pilot application Review via workshops
Diffusion	Knowledge transfer workshops Homepage, Online-Tool Research papers

It becomes clear, that a strong involvement of practitioners was the condensation point of our research process. We integrated their knowledge through case studies, interviews, and cross-case workshops. The next chapter describes how we collected the necessary data in detail.

### 3.2. Data Collection

The nature of the five main case studies was predominantly participative. Hence, the researchers were actively involved in the solving of the concrete problems within the companies [47]. In addition to the researchers, a consultancy for digital transformation and innovation worked on the cases. Data was collected through hundreds of informal interviews and talks, internal and external documents, site visits, and workshops. Table 2 shows the case studies considered in our research. Overall, we conducted 50 workshops and 69 jour fixes within the CR project.

**Table 2.** Case Study Overview.

Case	Industry	Size (Empl.)	Collection Period and Setting	Key Experts	Type of Case Study
A	White Goods	800	July 2016–June 2019, 12 workshops	Industrial engineers, strategic planning, and project management	Explorative, participatory, application company
B	Electronics and intelligent technical systems	40	July 2016–June 2019, 10 workshops	Business management	Explorative, participatory, application company
C	Engineering for printing machines	60	July 2016–June 2019, 6 workshops	Technical director, technical engineering team	Explorative, participatory, application company
D	Engineering for HVAC	130	July 2016–June 2019, 9 workshops	Research and development team	Explorative, participatory, application company

Table 2. Cont.

Case	Industry	Size (Empl.)	Collection Period and Setting	Key Experts	Type of Case Study
E	Engineering for security and access solutions	7.000	July 2016–June 2017, 6 workshops	Senior manager strategic innovation	Explorative, participatory, application company
X	Cross-case Workshops	-	July 2016–June 2019, 4 workshops	Project leads from the consortium	Explorative, interviews
Z	Individual third-party transfer	-	July 2016–June 2019, 3 workshops	Diverse	Explorative, participatory, partial application

In addition to the case studies, we conducted focus group workshops to challenge our findings with third parties from outside the consortium (see Table 3). The participants of the workshops and interviews were predominantly from the German manufacturing industry, whereby the companies themselves served a wide variety of industries (e.g., mechanical engineering, food, advertising, preliminary products, etc.). Many experts were located within the state of North Rhine Westphalia. Company sizes ranged from SMEs to international enterprises with tens of thousands of employees. In general, one expert per company attended. Only in a few cases, two or more experts from one company participated.

Table 3. Focus Groups.

Date	Topic	Method	Participants
22 June 2017, 13:00–17:15	Change of the company as a socio-technical system (technology, business, people)	World Café	28 experts from industry and research
26 June 2018, 13:00–17:00	Increasing firm performance: prototypes of Industry 4.0, patterns for Industry 4.0, use cases with the firm	World Café	34 experts from industry and research
27 June 2019, 14:00–18:00	Industry 4.0 Expert Group: From digitalization strategy to implementation	Presentation and Workshop	85 experts from industry and research

### 3.3. Method Engineering

The envisioned result of our research was a method to empower companies to adapt an individually beneficial maturity regarding Industry 4.0. A method in this context can be understood as guidance for projects employing a certain way of thinking through directions and rules structured in a systematic way applying activities and techniques to realize certain deliverables [49]. Such a method must meet three quality criteria: it has to fit the situation, consist of sufficient components to deliver the results, and its components themselves have to be proven to work [50]. To ensure this, we followed the guiding principles of method engineering (ME), which is defined as the engineering discipline to design, construct and adapt methods [51]. ME considers five concepts: metamodel, results, activities, techniques, and role. The metamodel describes relevant concepts and relationships of the application domain (e.g., organizational structure). Results are the artifacts to be delivered by the application of the method (e.g., transformation setup). Activities (or phases) describe how results are created, e.g., determine the degree of maturity. All activities as a whole form the procedure model. Techniques describe in detail, how a result is created within an activity, e.g., using a maturity model. Furthermore, activities are carried out by roles within the project team, e.g., software developer [45,52]. Such a method should always follow a distinct method rationale explicating the values and goals behind the method. The

method rationale structures the requirements for the method derived from practical needs (relevance) and an existing knowledge base (rigor) [53].

According to the method rationale, the method was developed in close collaboration with the practitioners. First, the key results were defined. Then, the procedure model was drafted, roughly defining the method phases (i.e., general activities). Following, the concrete activities and techniques for each phase were chosen or developed when no suitable technique was available. Activities and techniques were discussed within the consortium and tested within the case studies. Learning from the experiences during the application, they were further improved until they fit the requirements regarding usability and usefulness.

#### 4. Results

The result is a method for the improvement of firm performance through the adoption of Industry 4.0. In the following, we will first introduce the method rationale as the basis for our method. Then, an overview of the method components is given before the components are described in detail. As stated in the introduction, the results shown here are a shortened and revised excerpt from our final project report to which we refer for further information [20].

##### 4.1. Method Rationale

The research process is guided by the so-called method rationale, which includes the arguments complementing the method to be developed. In that way, the method rationale gathers requirements from theory and practice for the research [53]. The requirements fall into four categories: maturity check, target definition, implementation planning, and transformation setup. Table 4 gives an overview of the relevant requirements identified through literature review and workshops with the consortium.

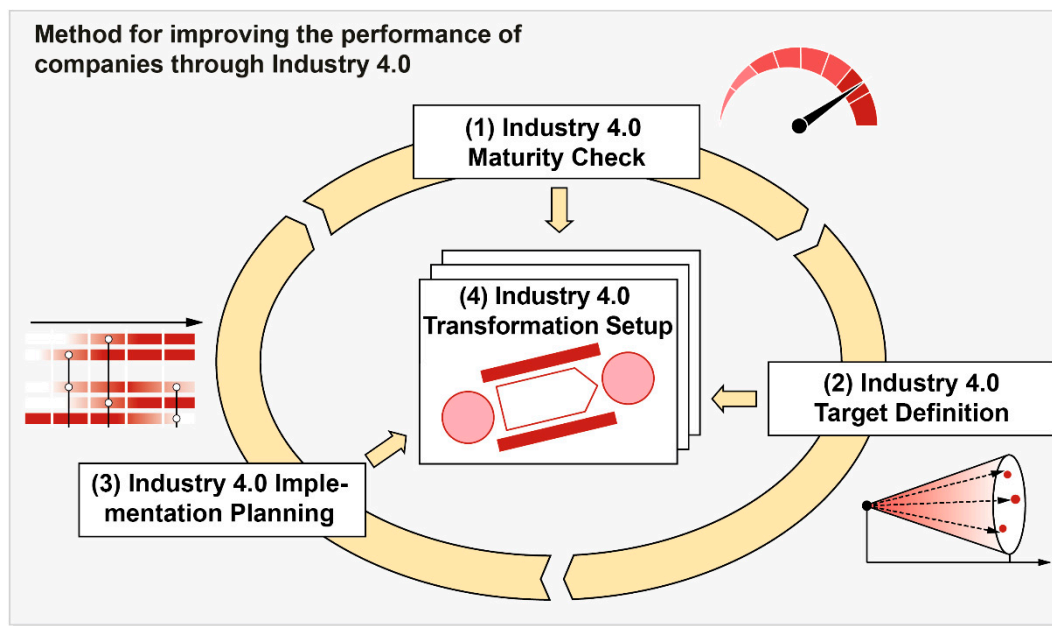
**Table 4.** Method requirements.

Cat.	Req.	Description	Supporting Literature
Maturity Check	R1	Consideration of the relevant aspects of Industry 4.0	[54,55]
	R2	Objective evaluation criteria for Industry 4.0	[56]
	R3	Benchmarking with similar companies	[15,57]
Target definition	R4	Integration of foresight into target definition	[58]
	R5	Internal and external consistency of the target	[59]
Implementation planning	R6	Inductive development of Industry 4.0 implementation patterns	[35,60]
	R7	Interdisciplinary notation scheme	[61,62]
	R8	Identification of consistent pattern paths	[63,64]
Transformation setup	R9	Socio-technical view on transformation	[10,65]
	R10	Transparent and holistic transformation set-up	[66–68]

##### 4.2. Method Overview

An overview of the resulting method is shown in Figure 1. The method is structured into four major phases: (1) Industry 4.0 Maturity Check, (2) Industry 4.0 Target Definition, (3) Industry 4.0 Implementation Planning, and (4) Industry 4.0 Transformation Setup.





**Figure 1.** Method for improving firm performance through Industry 4.0 adapted from [20].

**(1) Industry 4.0 Maturity Check:** The first phase aims to determine the actual state of Industry 4.0 in the focal company. For that, an Industry 4.0 quick check is used. It allows assessing the maturity utilizing 59 criteria, spanning the categories technology, business, and people. The 59 criteria are then evaluated to determine the most relevant fields of action for the company at hand. Analyzing those criteria in-depth with a tool kit leads to concrete improvement potentials.

**(2) Industry 4.0 Target Definition:** This phase aims to define adequate goals for Industry 4.0 maturity of the firm. Using foresight methods, the future of markets, technologies, and business environments is anticipated. Based on these insights, the target maturity is determined.

**(3) Industry 4.0 Implementation Planning:** The third phase leads to generic solutions for the implementation of the envisioned target position. To that, solution patterns for Industry 4.0 are used. The solution patterns characterize the socio-technical system, that realizes the target position of the firm. Fields of action are prioritized. Then, pattern combinations are built and arranged.

**(4) Industry 4.0 Transformation Setup:** The implementation of Industry 4.0 is a complex task, that must be set up comprehensively. Socio-technical risks of each implementation project are determined and managed. At last, the insights are consolidated within a master plan of action, that summarizes the transformation setup.

Table 5 gives a detailed overview of the corresponding method components and their concrete goals.

**Table 5.** Method components and goals for each phase.

Phase	Method Components	Goal
<i>Maturity Check</i>	Quick check Industry 4.0	Determine the current maturity level
	Relevance ranking	Find the most important maturity criteria
	Derivation of fields of action	Find fields of action for further investigation
	In-depth analysis	Identify concrete potentials for improvement within fields of action and rank them
<i>Target definition</i>	Anticipation of the future	Gain an idea of the future environmental conditions
	Impact analysis	Find out how the future environment influences the different maturity criteria and levels
	Target position definition	Define medium- and long-term target maturity levels
<i>Implementation planning</i>	Implementation patterns for Industry 4.0	Provide generic solutions for recurring problems/potentials within Industry 4.0, that can be concretized for the specific company
	Identification of relevant implementation fields	Narrow down the solution space according to the concrete transformation needs
	Assessment of implementation patterns	Find established solutions that contribute to reaching the target position
	Combination analysis	Build a set of solutions that support each other and sort them in a meaningful way
	Definition of measures	Break down general solutions into concrete work packages
<i>Transformation setup</i>	Risk assessment	Identify risks associated with the implementation and measures to mitigate them
	Masterplan of action	Condense the previous results into a document, that can be used for communication
	Transformation controlling	Continuously check if the assumptions are still correct and if the transformation is going according to plan

#### 4.3. Method Phases

Next, the four method phases (1) Industry 4.0 Maturity Check, (2) Industry 4.0 Target Definition, (3) Industry 4.0 Implementation Planning, and (4) Industry 4.0 Transformation Setup are described in detail.

##### 4.3.1. Phase 1: Industry 4.0 Maturity Check

For the successful introduction of Industry 4.0, it is first imperative to determine the current performance level regarding objectively measurable criteria. Only then, a realistic transformation setup may be developed. When assessing the current Industry 4.0 level, it

is important to understand Industry 4.0 as a socio-technical endeavor [8]. Therefore, the dimensions people, technology, and business must be considered integratively.

A socio-technical maturity model is employed for this task. Its' application and analysis are conducted in four steps. First, the maturity model "Quick Check Industry 4.0" is used to determine the current performance profile (status quo). Then, the criteria of the maturity model are prioritized. Within the most relevant criteria, fields of action for improving performance are identified. At last, an in-depth analysis leads to concrete improvement potentials. Below, the individual activities are explained in more detail.

**Quick Check Industry 4.0:** The basis for deriving customized fields of action is the determination of current maturity in the context of Industry 4.0. This results from using a so-called "Quick Check Industry 4.0", which is structured according to the socio-technical dimensions technology, business, and people. It allows the assessment of a company using 59 criteria. For each criterion, one of four performance levels has to be chosen, with the fourth performance level reflecting the ideal vision of Industry 4.0. They are based on established literature, existing maturity models, and empirical values. The final criteria were selected in workshops within the consortium, taking into account the perspectives of researchers and practitioners. The criteria selected were those that both parties agreed would have the greatest impact. Within the technology dimension it is sometimes necessary to differentiate criteria regarding product and production (e.g., data storage for products and data storage for production). Table 6 shows an overview of the criteria of the Quick Check Industry 4.0.

**Table 6.** Criteria of the Quick Check Industry 4.0.

Technology	Business	People
T1 Horizontal Integration	B1 Industry 4.0 Strategy	P1 Scope of activity and autonomy
T2 Vertical Integration	B2 Strategy Controlling	P2 Variety of requirements
T3 IT Process Support	B3 IT Security Concept	P3 Flexibility of Working Hours
T4 Tool Landscape	B4 Value-creation Cooperation	P4 Co-dependency
T5 Systems Engineering	B5 Access to capital	P5 Performance Feedback
T6 Sensor Technology (production)	B6 Approach to New Product Development	P6 Collaboration and Social Interaction
T7 Actuator Technology (production)	B7 Customer Integration	P7 Ergonomics
T8 Information Processing (production)	B8 Pioneering Spirit	P8 Continuing Education
T9 Human Machine Interface (production)	B9 Technology Transfer	P9 Documentation of Experiential Knowledge
T10 Data Storage (production)	B10 Participation in Innovation Networks	P10 Availability of Support
T11 Data Usage (production)	B11 Innovation Organization	P11 Leadership Transparency
T12 External Data Integration (production)	B12 Approach to Business Model Development	P12 Employee Participation
T13 Digitalization of production processes	B13 Product-Service-Systems	P13 Strategy for Change
T14 Connectivity (production)	B14 Penetration of Digital Services	P14 Software Usability
T15 Intralogistics	B15 Data Collection and Analysis	P15 Assistance Systems

**Table 6.** *Cont.*

Technology	Business	People
T16 Organization of Production Planning and Steering	B16 Data Exploitation	P16 Human-technology Dependency
T17 Production Flexibility	B17 Digital Customer Channels	
T18 Assistance Systems in Assembly		
T19 Sensor Technology (product)		
T20 Actuator Technology (product)		
T21 Information Processing (product)		
T22 Human Machine Interface (product)		
T23 Data Storage (product)		
T24 Data Usage (product)		
T25 External Data Integration (product)		
T26 Connectivity (product)		

For the assessment, a workshop with representatives from various disciplines is conducted. To avoid misinterpretation, the assessment is supported by a question for each criterion and an explanatory text for each performance level. After the completion of the Quick Check Industry 4.0, a database with results from over 250 companies allows for a benchmark with a comparative collective. Based on this and the organizational framework conditions, a first estimation of the target position in five years is requested.

**Relevance ranking:** To reduce the number of criteria to investigate in detail to a manageable extent, a relevance ranking of the criteria is conducted. The relevance of the criteria can depend on the difference between the actual and target position, resources, organizational structure, customer requirements, or further aspects. Hence, an individual evaluation of different stakeholders is necessary to integrate different perspectives. For that, a workshop is held in which each participant is asked to identify the five most relevant criteria from their point of view. The quantity of five has proven itself to be manageable in practice and was chosen for this reason. It is recommended to select at least one criterion from each one of the dimensions people, technology, and business. The resulting criteria are those, that the experts agree to present the greatest need for action.

**Derivation of the fields of action:** Based on the relevance assessment, the prioritized criteria are to be checked for synergies and dependencies. The goal is to determine relevant fields of action that support the selection of suitable methods for Industry 4.0 in-depth analyses. In total, 17 fields of action are available—five fields of action in the dimension technology (*digitalization of processes, human-technology-interaction, process organization, value chain, self-optimization*), six fields of action in the dimension business (*I4.0 strategy, innovation culture, data management, digital services, strategy controlling, business models*), and six fields of action in the dimension people (*work design, communication and change, usability, qualification, human-machine-interaction, ergonomics*). Selecting the fields of action is facilitated for the company via guiding questions and investigating the assigned Quick Check criteria. An example is shown in Figure 2.

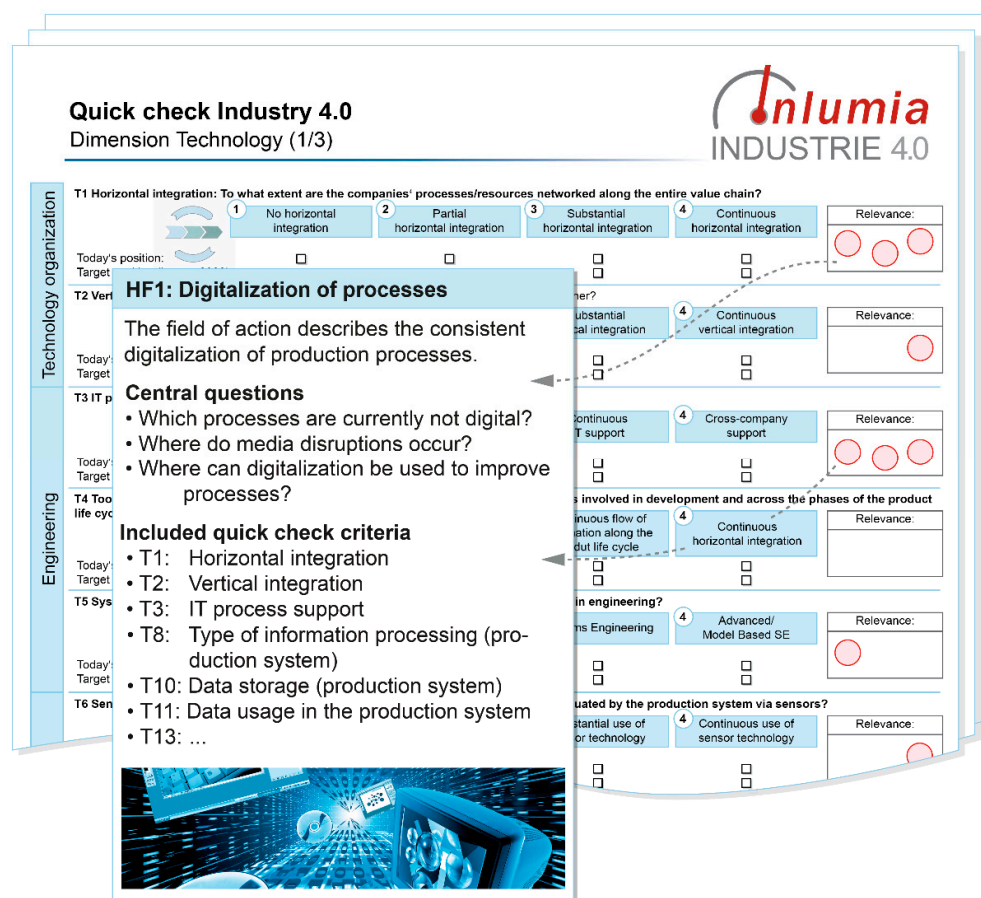
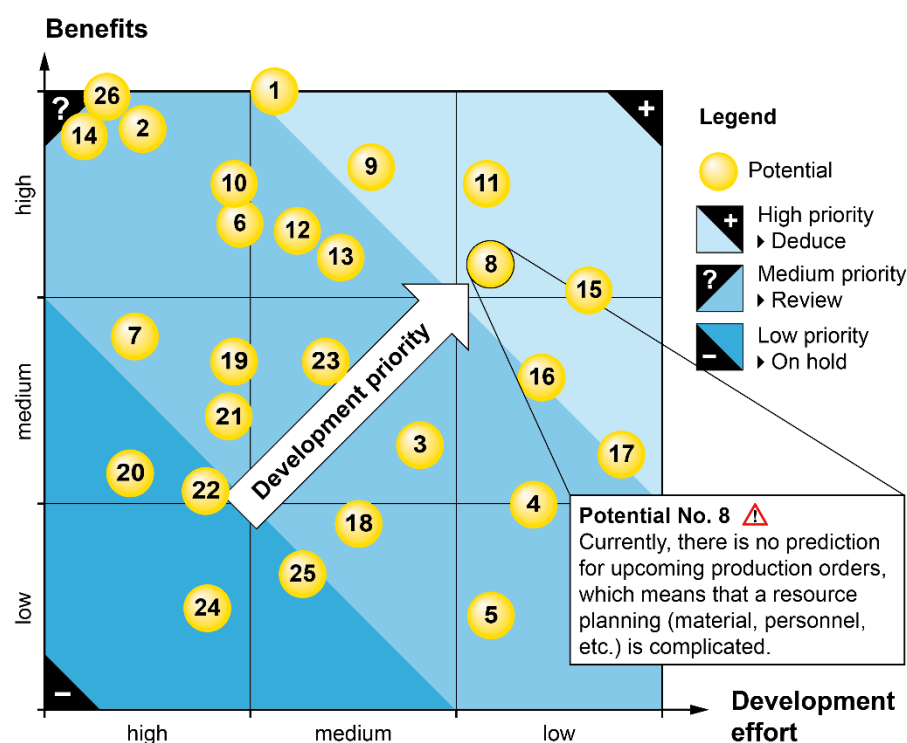


Figure 2. Example of a derived field of action from the Quick Check criteria [20].

**Industry 4.0 in-depth analysis:** A toolbox of methods is provided for the in-depth analysis of the selected fields of action. It includes both, already established methods and specifically developed methods, which are used during workshops. Experts from different disciplines and management levels should be involved to obtain the most comprehensive discussions possible. The toolbox includes methods like OMEGA (method for business process modeling and analysis) [69] or a modeling language for value creation systems [39]. Applying the methods allows to identify concrete potentials for improvement in the context of Industry 4.0 (e.g., complicated resource planning due to lacking predictions for upcoming orders). This serves as the starting point for improving the performance. Generally, speaking from our experience, companies should invest three to six months for in-depth analysis. This results in many potential improvements, which are then prioritized with the help of a bubble chart (Figure 3). The chart considers the two evaluation dimensions benefit and development effort. Improvement potentials at the bottom left of the portfolio have a low benefit and at the same time require a high development effort. Hence, they should be neglected at first. Potentials in the middle of the portfolio should be reviewed on an individual basis to determine whether the potential should be exploited immediately or put on hold for the time being. Potentials at the top right of the portfolio should be given priority as they offer considerable benefits while requiring little effort. These so-called “low-hanging fruits” help to significantly boost the Industry 4.0 performance within a short period.



**Figure 3.** Evaluation portfolio with exemplary potentials derived from one case [20].

#### 4.3.2. Phase 2: Industry 4.0 Target Position

The aim of the second phase is the Industry 4.0 target position for the considered company. The target position is a strategic long-term commitment to change and, hence, must consider forging a fit [70]. The term fit in this case means the consistency of multiple contingencies and structural aspects [71], i.e., the fit of the target position to the future business environment. To ensure that, this phase involves three activities: (1) anticipate the future, (2) analyze the impact, and (3) set the target position.

**Anticipation of the future:** To anticipate the future of markets, technologies, and the business environment for Industry 4.0 two foresight methods are combined: trend analysis and scenario technique in combination allow for the envisioning of a medium and a long-term view.

The trend analysis (c.f., [58]) is suitable to anticipate medium-term developments (i.e., approx. five years into the future). A trend is a possible trajectory into the future that can be observed to a certain degree today. Trends can be identified by scanning relevant business-specific and global sources like studies and publications or conducting expert interviews. The trend identification should consider trends that influence the technology, business, and people dimensions of the firm. Identified trends are documented using trend profiles that include a first firm-specific analysis of the trend (i.e., chances and risks) as well as further information (e.g., drivers of the trend). This allows assessing the trends regarding their probability of occurrence and foreseeable impact strength. To communicate the results of the trend analysis, a trend radar is a suitable tool. Each trend is represented by a bubble on the radar. Trends with a high probability of occurrence are placed in the center and the bubble size indicates the impact strength of the trend. Furthermore, the trends can be sorted into one of the three socio-technical dimensions. Trends with a high impact and a high probability of occurrence should be considered in developing the Industry 4.0 strategy.

Scenarios describe possible situations in the future which are based upon a complex network of influence factors and a plausible explanation of the progress from today to that situation. The scenario technique is a suitable tool to develop these kinds of scenarios (c.f., [58]). The results of the scenario technique are multiple, internally consistent scenarios. For the development of the Industry 4.0 target position, one must be chosen as a reference



scenario that serves as an orientation. Usually, the scenario with the highest perceived combination of the probability of occurrence and relevance is chosen.

**Impact analysis:** The impact analysis delivers insights on the effect of future developments on the Industry 4.0 maturity. This allows for an assessment if a higher maturity might be achieved. For that, an influence matrix and an impact matrix are used. This is done on the one hand for the trends and on the other hand for the reference scenario. In the following, the procedure for the analysis of the trends is described. First, the influence matrix is filled out. It answers the question of how a trend (column) influences a criterion of the maturity model (row). For the assessment, five evaluations are possible ranging from −2 (trend hinders the performance improvement significantly) to +2 (trend benefits the performance improvement significantly). For example, the trend “market penetration of cyber-physical systems” benefits a performance improvement of the criterion “horizontal integration” and is, hence, evaluated with +2.

Building upon the influence matrix, the impact matrix is filled out. Here, the overall impact of a trend (row) on a maturity criterion (column) is assessed. That means, in addition to the influence matrix, the individual assessment of trends from the firms’ point of view is included. The impact of each trend is calculated by multiplying influence strength (InS), probability of occurrence (PO), and impact strength (ImS). Now, for each maturity criterion, the line sum is calculated. This allows the estimation of the influence of all identified trends on the considered criterion. Figure 4 shows the matrices and their relations.

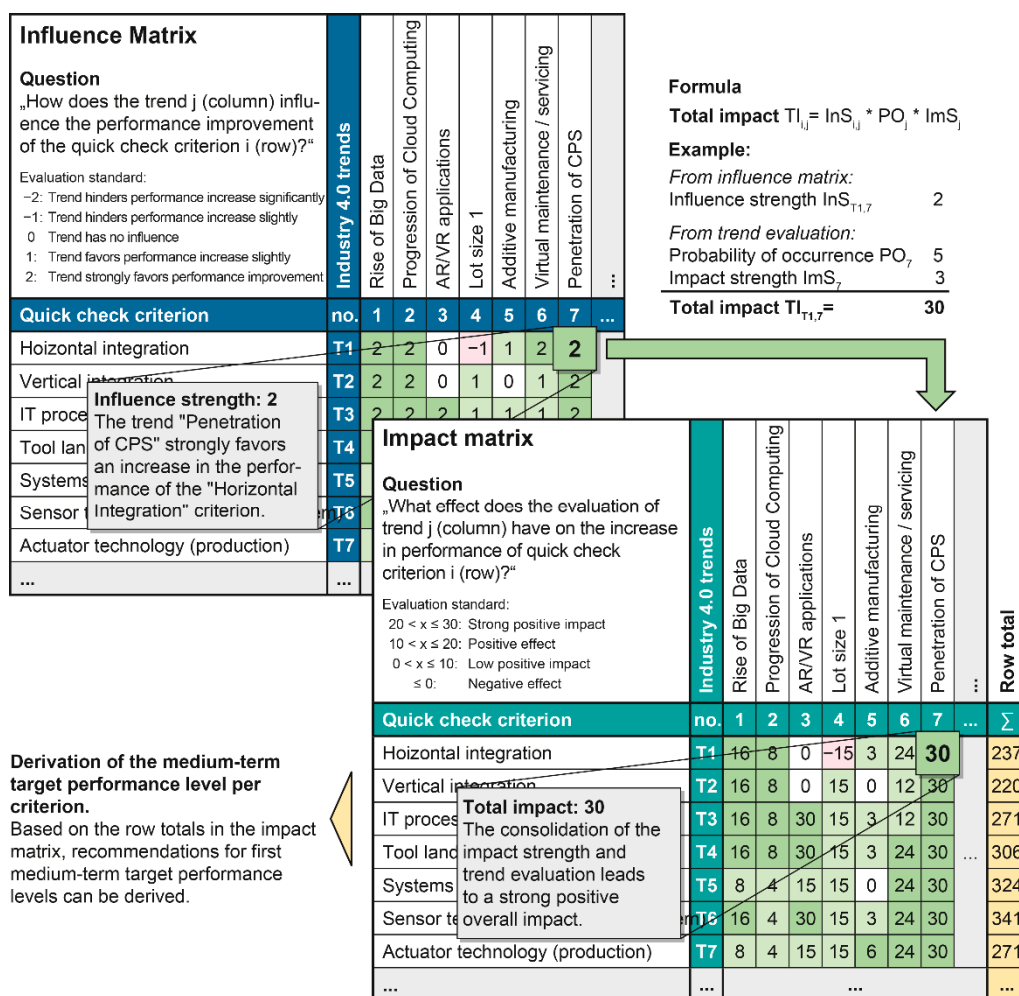


Figure 4. Influence and impact matrix [20,72].

Building on these insights, a recommendation for the medium-term target maturity level can be derived. This is done using an interval scale, which must be created depending on the considered trends. One possible solution might be to divide the criteria into quartiles according to the row total. A criterion that falls into the first quartile would then allow for an improvement of three levels, a criterion from the second quartile would allow for two levels, and so on. The medium-term target maturity level (e.g., level 2) can then be calculated by adding the current maturity level (e.g., level 1) for a criterion and the performance improvement possible through the Industry 4.0 trends (e.g., one level).

Finding the long-term target maturity level is conducted similarly. Instead of trends, here, the future projections of the descriptors within the reference scenario are considered in the influence and impact matrices.

**Target position definition:** The results from the impact analysis allow the creation of mid and long-term target profiles. The profiles summarize the results and show the necessity to act. Figure 5 shows the profiles from one of the case studies within the project. First measures and projects can be derived and structured, e.g., using a high-level road map. To detail the necessary transformation process, the target position has to be translated into an implementation plan.

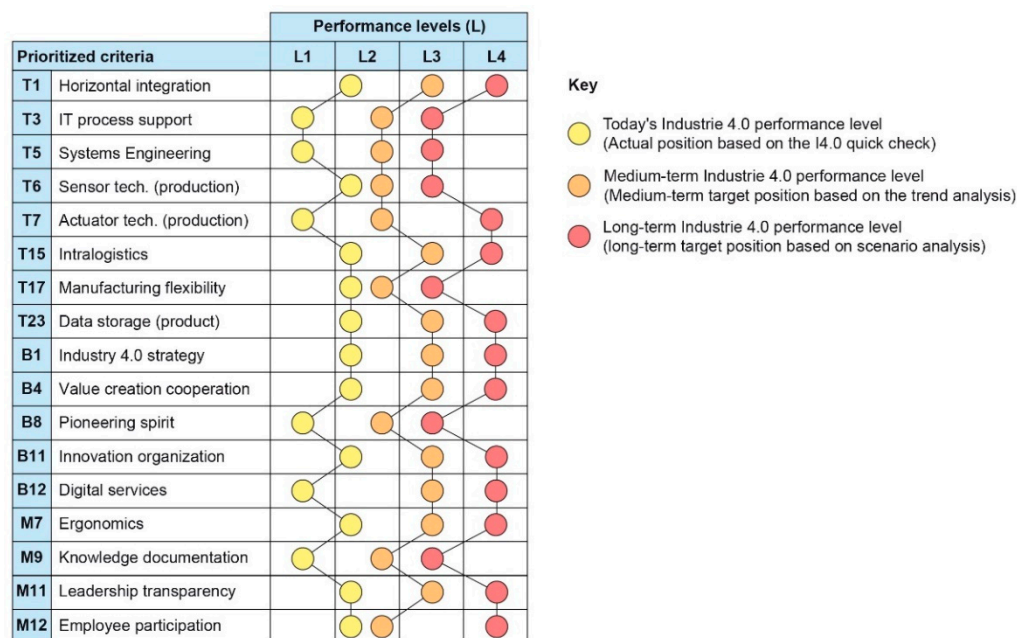
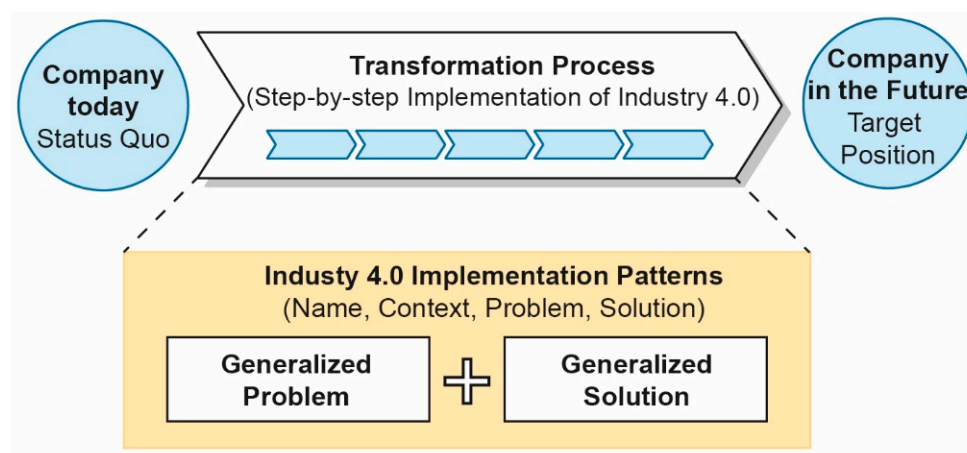


Figure 5. Mid- and long-term Industry 4.0 target profile [16,20].

#### 4.3.3. Phase 3: Industry 4.0 Implementation Planning

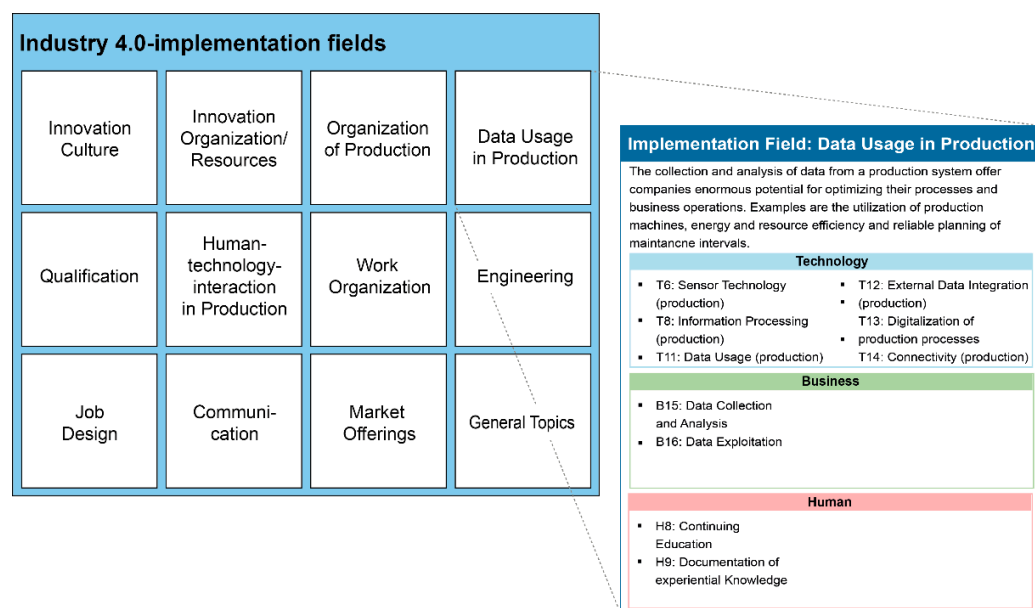
When the status quo and target position are known, the implementation of Industry 4.0 within the company can be planned. The goal of this phase is, hence, a suitable implementation path. Since this is a complex and challenging task, solution patterns are utilized to integrate existing knowledge about Industry 4.0 into the method. First, the patterns are described, then it is explained how they can be assessed, combined, and structured to drive Industry 4.0.

**Solution patterns for Industry 4.0 Implementation Planning:** There is already a large body of knowledge regarding options for action in the context of Industry 4.0 through pioneers. As argued, this knowledge can be made accessible for companies following the solution pattern approach. In our case, the term Industry 4.0 implementation pattern is used. The use and proficient combination of several Industry 4.0 implementation patterns enable the successive transformation of the company's status quo (maturity level) today to its desired target position (target maturity level) in the future (Figure 6).



**Figure 6.** Pattern-based transformation planning [20].

The patterns stem from different so-called implementation fields. An implementation field is composed of the criteria of the quick check and includes criteria from up to all three socio-technical dimensions. In this context, an implementation field represents a thematic alignment of options for action and company-specific goals. A short profile with a concise description and criteria for performance evaluation relevant to the implementation field supports the subsequent selection of relevant implementation fields. The number of criteria per dimension determines the direction of impact of the implementation field. A total of 12 implementation fields have been identified (Figure 7).



**Figure 7.** Industry 4.0 implementation fields [20].

Within 12 implementation fields, 83 Industry 4.0 implementation patterns were identified. This was done analyzing successful examples, i.e., best practices. In addition to this approach, there are two other widely acknowledged ways to identify patterns: observation and analysis of unsuccessful examples and the derivation of patterns based on abstract arguments [35]. For Industry 4.0, the best practice approach is best suitable since the field is still young, but old enough that many interesting solutions have been discovered. The analyzed knowledge base consisted of the following four sources:

1. **Practical project examples:** In the context of this study, best practices represent Industry 4.0 projects that have been successfully implemented by pioneers—mostly large companies. This allows identifying both, problems and associated solutions. A comprehensive list of projects is for example provided by the Industry 4.0 platform initiated by the German Federal Ministry of Education and Research as well as by acatech ([www.plattform-i40.de](http://www.plattform-i40.de) (accessed on 14 July 2020)).
2. **Studies:** Publications that deal with challenges and successfully implemented solutions or with future developments provide direct or indirect indications of potential implementation patterns. An example of this is the accompanying research for AUTONOMIK, an Industry 4.0 technology program carried out by the German Federal Ministry for Economic Affairs and Energy [19].
3. **It's OWL transfer projects:** Within the cluster of excellence it's OWL 171 so-called transfer projects were successfully carried out. Solutions for Industry 4.0 problems were developed in 8-to-10-month project collaborations between research institutes and SMEs on various cross-sectional topics such as self-optimization or systems engineering. Both the problems as well as the associated solutions represent a valuable source of knowledge [55].
4. **Industry 4.0 demonstrators:** Representations of prototypical solutions in smart factories (e.g., SmartFactoryOWL) internal, and external exhibition demonstrators also represent suitable sources for implementation patterns.

134 Best Practices were analyzed regarding repetitive problems and associated solutions to identify patterns. The resulting 83 implementation patterns were then visualized in the form of so-called pattern cards. They comprise a detailed description of the established components of a solution pattern—name, problem, solution, and context (Figure 8). Based on the implementation field, each implementation pattern is assigned to a direction of impact.

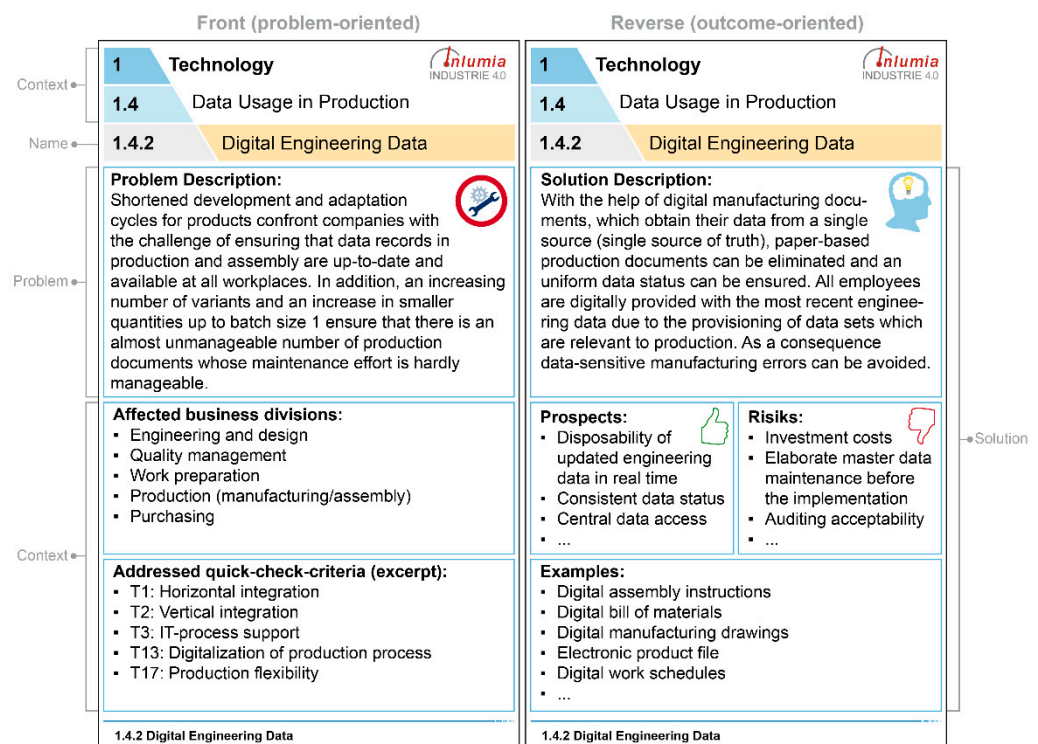
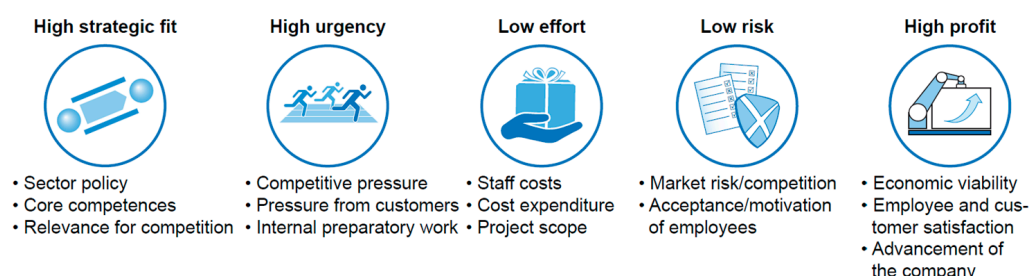


Figure 8. Example of a documented implementation pattern [20].

**Identification of relevant implementation fields:** To narrow the solution space, first, the relevant implementation fields are identified. This is done based on the current and target maturity levels. Because every implementation field is characterized by a bundle of criteria of the maturity model, the implementation fields can be ranked based on their contribution to bridging the gaps. In most of the considered case studies, this allowed to focus on three or four implementation fields, drastically reducing the number of patterns to be considered (to around 20), and, hence, allowing us to master the complexity.

**Assessment of Industry 4.0 implementation patterns:** The implementation patterns within the chosen implementation fields are then evaluated in a two-stage process. First, restrictions are examined regarding the feasibility of implementing the patterns in the respective company. Such restrictions are, e.g., the type of production (pure assembly), the market offerings, or the average age structure of the employees of a company. For example, a purely mechanical product is difficult to use for the introduction of data-based services. Second, the feasible implementation patterns are systematically evaluated. For this purpose, an utility analysis is applied. Five evaluation criteria are used for assessing the implementation patterns, they can be weighed individually for each company (Figure 9).



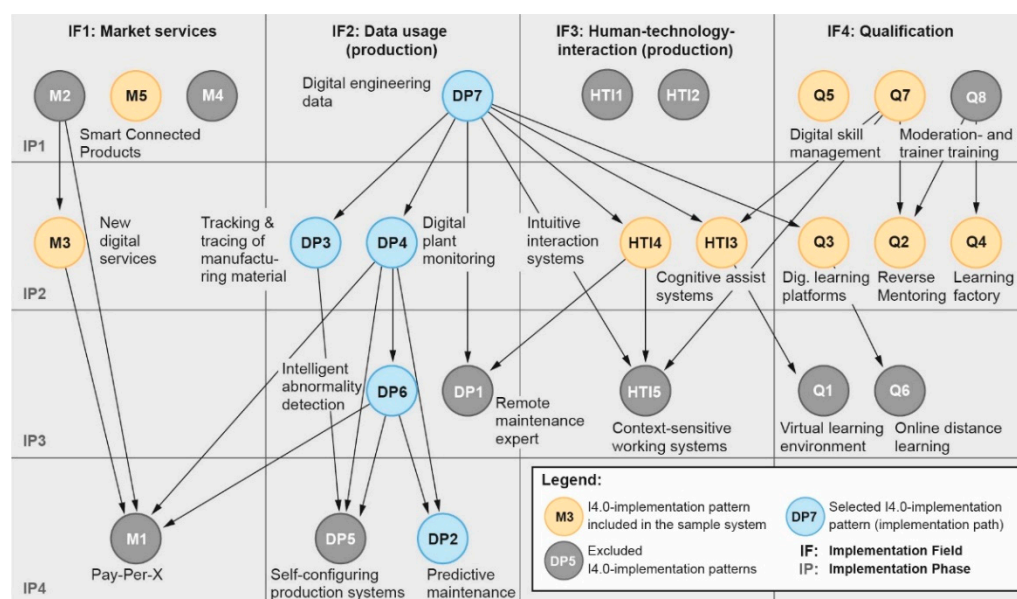
**Figure 9.** Evaluation criteria for the assessment of implementation patterns [20,73].

Following the assessment, the highest-rated implementation patterns are selected for further consideration.

**Combination analysis:** In the context of socio-technical systems theory, the three dimensions people, technology, and organization are to be considered as independent subsystems, but their mutual dependence and interaction always have to be taken into account [10]. In addition to the socio-technical dependencies, there are also dependencies between implementation patterns themselves. The application of a pattern usually leads to other patterns that have to be considered upstream or downstream. Therefore, when the Industry 4.0 implementation patterns are used, they must form a consistent whole and be put into a meaningful sequence. For this purpose, the implementation patterns are investigated with dependency and combination matrices. The matrices show, which patterns require other patterns as prerequisites, and which patterns can be combined for mutual benefit. Depending on the evaluations within the matrices and starting from an individual initial pattern (which resulted from the pattern assessment), an algorithm for topological sorting is applied and an individual pattern system is derived (Figure 10).

The pattern system maps the dependencies between the patterns and puts them in order. This results in multiple implementation phases, from which possible socio-technical implementation paths are generated.





**Figure 10.** Pattern system for Industry 4.0 Implementation [20].

#### 4.3.4. Industry 4.0 Transformation Setup

After the status quo is known, a target position is determined, and a desirable implementation path is derived, the concrete transformation must be planned. For that, measures are defined. Since the transformation is associated with many demanding changes, the risks of the transformation have to be taken into consideration as well. Only then, the transformation setup can be specified within a master plan of action.

**Definition of measures:** The general prescriptions documented in the chosen patterns must be concretized. Individual measures have to be derived, that are necessary to realize the patterns. Usually, this is done within a workshop setting. Here, the insights and documents from the in-depth analysis should be considered. The workshop results in a first concrete implementation roadmap.

**Risk assessment:** Various issues arise for companies, especially regarding the smooth introduction of the use cases. These are often less technical, but rather risks that are difficult to assess concerning the organization, e.g., economic viability, and in terms of people. Even if the installation of new technologies is successful (e.g., assembly assistance system), the beneficial operation depends to a large extent on investment costs, accurately fitting processes, adequate competencies, and employee acceptance. The resulting socio-technical risks and their interdependencies are difficult to manage and should be considered systematically at an early stage. For that, workshops for risk identification, analysis, and mitigation should be held. This results in a prioritized list of measures for the mitigation of risks.

**Masterplan of action:** Current maturity, target maturity, implementation paths, and measures and risk assessment are combined in a master plan of action. This is elaborated on and discussed in an interdisciplinary workshop. On the one side the master plan comprises the company's initial situation described by the fields of action from the maturity check. On the other side, the target situation is included in the form of the identified target profile. The iterative transformation process is documented connecting both. For this purpose, the intended use cases and critical risks are listed in accordance with the implementation path. Then, both, implementation activities and risk mitigations, are defined in the form of measures, after being differentiated into the socio-technical dimensions people, business, and technology. Existing activities should be considered, and synergy potentials should be exploited. The transformation setup summarizes all the results of the method and translates them into a gradual plan of action for the company. Furthermore, it serves as a transparent



means of communication within the entire company regarding digitalization efforts and as a basis for the capacity planning of subsequent pilot projects.

**Transformation controlling:** Since a transformation process is dynamic in nature, the master plan of action should be reviewed regularly in terms of the underlying premises and the progress made. For this purpose, it is first necessary to monitor the trends and scenarios to ensure the plausibility of the perception of the future. This review is necessary because changes in the assumptions about the future may lead to changes in the target maturity levels. Depending on the identified effects, the implementation controlling then checks whether the implementation is going according to plan or needs to be adjusted.

## 5. Discussion

This chapter will reflect on the results mentioned before. First, we shortly emphasize the main results and highlight peculiarities compared to literature. Then, we will provide insights from the application, show limitations, and elaborate on further research paths.

### 5.1. Main Results

In summary, our research delivers a comprehensive method for socio-technical performance improvement in the course of Industry 4.0. It combines a maturity model, future-oriented target definition, pattern-based implementation planning, and transformation setup to enable companies to plan their transformation from a socio-technical viewpoint and to realize their intended performance improvement. The method components provide consistent support for the companies, hence answering the research question “*How can companies identify and attain an individual and performance increasing Industry 4.0 target position?*”. The application within five use cases showed that the method is both useful and usable for companies.

### 5.2. Peculiarities Compared to Literature

Maturity models are nothing new as per se. According to research by De Bruin, for example, more than 150 different maturity models were already in place by 2005 [22]. Established Industry 4.0 specific approaches in practice include the acatech Maturity Index [14] or the VDMA Guideline [74]. Knowing the degree of one’s digitalization in comparison to the competition is an essential prerequisite for the successful digital transformation of a company [15]. However, the numerous existing maturity models are often very generic reference systems with only descriptive characters. Therefore, it is difficult to adapt them to the individual needs of companies, especially SMEs. Furthermore, the focus of most maturity models is on the technical perspective. The maturity level of digitalization is assessed based on the use of technology in the company. Especially, aspects of business in the sense of socio-technical perspective are often neglected. The method presented in this paper solves these challenges and hence extends the existing knowledge base. In addition to this, our method is—to the best of our knowledge—the first to combine a maturity model with foresight approaches. Since the transformation towards Industry 4.0 is a long-term endeavor, this seems appropriate and promising. Additionally, there is a lack of prescriptive solution proposals for achieving a targeted maturity level. Deriving knowledge about concrete solutions associated with a problem is therefore very difficult [75]. Hence, our method offers significant added value compared to the state of the art. At last, our method integrates first risk management aspects into the transformation towards Industry 4.0 extending the perspective.

### 5.3. Insights from Application

In the course of validating the instrument, it was possible to gain further insights into Industry 4.0. Besides the application within the case studies, the quick check was made accessible online, which allowed identifying commonalities between companies, particularly with regard to the performance assessment. The online quick check resulted in a database that includes a sample of over 250 companies that can be used for comparisons

between companies. A cross-company evaluation yields the following exemplary findings in the socio-technical dimensions as of 2020 [20]:

In the dimension *technology*, it can be recorded that digitalization is not yet far advanced. For most companies (54%), the exchange of information is aggravated by media breaks. Only a small amount of information is digitally available. Horizontal integration across different IT systems is a major challenge for companies. A total of 75% of companies state that there is no or only partial networking of the IT systems of individual value-creation steps within the company (e.g., production and logistics). After all, 51% of respondents state that so far only selected data is stored. However, in 39% of the cases, there is no further processing and use of the data by upstream or downstream systems.

Investigating the *business* dimension, 59% of companies pay attention to Industry 4.0 during the strategy process, but a concrete strategy has not yet been formulated. Challenges lie in the transformation of the entire organization to form more flexible and open structures. Most of the companies surveyed maintain long-term, contractually bound (“rigid”) relationships (26%) or short-term adaptable (“flexible”) business relationships with a few selected partners (45%). In most companies, there are no clear (24%) or clear but rigid responsibilities within the company for incremental and radical innovations, as well as rigid innovation processes that are independent of projects (41%). In addition, business model development within the company is also often unstructured (38%).

For the *people* dimension, rigid structures still prevail among employees. Only 8% decide completely independently on the design of their activities or the planning of their work schedule, and only 10% have irregular daily schedules with ever-changing requirements. This impression is also confirmed regarding the flexibility of working hours, even though this might have significantly improved in the course of the Corona pandemic. Most respondents have clearly defined attendance and break times for employees (31%) or flextime with flexibly scheduled breaks (35%). Overall, digitalization and people are not yet ideally synced. Still, 26% of the companies surveyed state that the disruptions regularly lead to delays because people and technology are waiting for each other.

A further fuzzy-set qualitative comparative analysis of the data from the quick check by Schneider and colleagues (2022) revealed two success paths for technological maturity: intensive training and strong worker participation combined with strong entrepreneurial culture or with strong customer-oriented innovation in larger firms [76].

The results presented here show the commonalities among companies in Germany about the status quo of Industry 4.0. However, even if many share the same problems, the respective target positions and the solutions depend on their individual requirements and contingencies. To validate that our method is suitable to help companies define and reach those, the method was conducted with the five early adopters from our case studies.

In our case studies, the initial situations and the relevant problems regarding Industry 4.0 were quite similar. Topics included eliminating analog documents, reducing media breaks, and increasing the competencies of employees. However, while the topics were similar, the concrete solutions created were quite different since the contingencies of the companies had to be taken into account. The strive to eliminate analog documents, for example, led one company to digitalize their order documents in the production, while another company focused on machine documents and the use of data from machines. This shows that companies must focus on what is specifically necessary and not on what is fundamentally possible. Despite the generalized content of the solution patterns, it was possible to tailor them individually to the different companies.

#### 5.4. Limitations

Although our results stem from a comprehensive consortium research project, there remain some limitations. First, qualitative research per se is limited in terms of generalizability. We applied the method in multiple cases in practice, but further studies on the application of the method are necessary to further prove the validity. Furthermore, in our work, we focus on the intellectual perspective of the transformation process without

addressing the social dimension. The people participating in the application of the method and their relations are not considered in detail (c.f., [77]). The third limitation is a temporal one: Our results reflect the insights on Industry 4.0 as of today. Hence, our method should be continuously reflected on, and new insights must be integrated. At last, regarding the insights from the quick check, it must be stated, that the companies participating through the online tool are not a representative sample because they were not randomly selected but participated because of their interest.

### 5.5. Future Research

Research on Industry 4.0 is not exhausted yet; there are still myriads of open questions. Especially driven by the socio-political discourse, sustainability is becoming more important for Industry 4.0. Research should emphasize an integrative view. The socio-technical dimensions technology, people, and organization/business of Industry 4.0 should be aligned to the social, ecological, and economic views of sustainability. Implementing Industry 4.0 in a company is also associated with risks. Our method delivers a first approach to deal with these risks that suits the scope of the method, but further research into this topic seems promising and necessary (c.f., [44,78]). Future research should focus on methods and approaches, that support these tasks.

## 6. Conclusions

Our study investigates how companies can adopt an individual, suitable approach to Industry 4.0 to increase their firm performance. The resulting method was developed and validated within a consortium research project of three years employing design science research and method engineering. The method comprises four phases: (1) Industry 4.0 maturity check, (2) Industry 4.0 target definition, (3) Industry 4.0 implementation planning, and (4) Industry 4.0 transformation setup. The first phase helps companies to determine their current performance level regarding Industry 4.0 using a socio-technical maturity model. Relevant fields of action are analyzed using a set of distinct methods. The second phase allows companies to determine their target position utilizing corporate foresight techniques. During the third phase, the implementation of the target position is planned by building combinations of established solution patterns. The last phase transfers the implementation path into a transformation setup comprising a gradual plan of action. The findings contribute both to theory and practice. For practitioners, we deliver a method they can use for the transformation of their own company. At the same time, however, we advise using the support of consultants in this regard. Comprehensive data regarding the performance level of other companies, that participated through the online tool, give them orientation regarding their peer group. For the scientific community, we provide one of the few socio-technical approaches to Industry 4.0 maturity models and the first approach to combine maturity models with foresight and extensive prescriptive knowledge for the transformation process.

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