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A STRATEGY GUIDANCE MODEL TO REALIZE INDUSTRIAL DIGITALIZATION IN PRODUCTION COMPANIES

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ABSTRACT
The realization of digitalization in production companies – currently also referred to as Industry 4.0 – aims for reduction of internal value creation costs as well as costs for intercompany collaboration and plays a key role in their current strategy development. However, related strategy research still lacks to provide operationalized digitalization methods and tools to practitioners with scientific rigor as well as real-world relevance. To challenge this status quo, we present a scientifically grounded 14-step procedure model including 11 practically tested tools, developed specifically for real-world application. The model leads practitioners from their first contact with industrial digitalization, through the maturity assessment of 143 digitalization items, until the implementation of a KPI-monitoring system and a continuous improvement process. We applied and re-worked the procedure model during three years of application. Validation and Feedback from practitioners and scholars indicate, that the model drives strategy development towards objective and data-based decision making and increases stakeholder engagement in organizations considerably.

KEYWORDS
Industry 4.0, industrial production systems, strategy development, digitalization, automation.

Introduction and problem definition

Increasing digitalization of data, thus information, as well as the automation of formerly manual processes, had a decisive influence on the development of society and economy in the last decades [1, 2]. For example, a country's degree of digitalization [3] correlates positively with the prosperity and life satisfaction of its inhabitants [4]. Or in the economic sector, the use of digitalizing technologies and the automation of processes have a positive effect on the company's performance [5–8]. In this paper we build on these positive effects of Industrial Digitalization (ID). However, we acknowledge, that the digital transformation of companies holds various challenges and that pre-conditions such as educated workforce, broadband internet or supporting laws have to exist to manifest these positive effects.

By focusing ID on the industrial enterprise sector, for which the EU aims at a target value of 20% of the total value added to secure prosperity, the concepts of ID are currently summarized within the industry 4.0-approach. Which pro-claims the *Fourth Industrial Revolution* by pursuing three target states [9, 10]:

1) horizontal integration via value creation networks;
2) digital consistency of engineering across the value chain;
3) vertical integration and networked production systems.

The fundamental goals of production companies in the era of Industry 4.0 does not differ compared to goals defined during traditional production- optimization approaches, such as increased productivity through efficiency and flexibility as well as reduced costs and complexity [11, 12]. However, our own re-

search and project experience in the field of Industry 4.0 [13–15], as well as expert interviews of the last four years lead to the definition of two main challenges during implementation:

- the abstraction level of Industry 4.0 is too high for operational implementation;
- guidance to operationally implement Industry 4.0 is missing.

As a result, Industry 4.0-concepts lack transfer into industrial companies, thus the intended competitive advantage cannot be claimed. The basic motivation of this paper therefore lies in the reduction of the abstraction level of Industry 4.0-strategy tools. We aim to reduce abstraction via the development of more easily understandable strategy tools of ID that operationalize abstract Industry 4.0-tools.
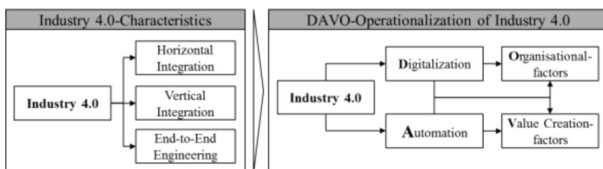

Fig. 1. Industry 4.0-operationalization through DAVO.

At this stage, we state some working definitions to transfer developments to an operational level. Firstly, we present our interpretation of Industry 4.0 composed by an integrated framework of digitalization and automation applied on organizational and value creation factors – short DAVO [16].

Following this framework, we argue that all concepts related to Industry 4.0 such as smart factories or smart objects, and subsequently smart processes can be composed of integrated digitalization and automation elements (Table 1).

Table 1
Working definitions for Digitization, Digitalization and Automation [17].

Digitization	Digitalization	Automation
Describes the conversion of continuous analog, noisy and smoothly varying information into clear bits of 1s and 0s.	Describes the social implications of increased computer-assistance, new media and communication platforms for economy, society and culture and working environments.	Describes the implementation of technology, software and programs to accomplish a procedural outcome with little or no human interference.

Although these concepts are distinct, yet in practice they manifest in combined and integrated manners to realize modern production paradigms – such as Industry 4.0. In the following, we refer to the utilization of these concepts in a combined manner as

Industrial Digitalization (ID). The concept of ID receives increased scientific attention as research contributions e.g. in the scientific database *Science Direct* show a 300%-increase between 2015 and 2019 or results in the scientific search engine *Google Scholar* show a 2100%-increase during the same time. However, we conclude that regarding strategic guidance research related to ID, two fundamental research issues remain:

- frameworks, methods and models are developed on a generic level with a lack of operationalization;
- a lack of holistic metrics to measure the implementation of ID in real production environments.

Moreover, interviews with practitioners revealed:

- a lack of tools that allow for evaluation of the own operational ID development status in the company;
- missing operationally relevant approaches for systematic strategic planning of the implementation of ID.

Based on these problems, we define two research goals:

1) development of a practically applicable and holistic strategic guidance tool towards ID;
2) development of an ID-assessment tool on an operational level using quantitative measurement metrics.

In order to define our research requirements and build on the current state of the art, we carry out an extensive literature research and review relevant findings critically.

Strategic guidance – literature and status quo

Our literature observations over the last years show, that publications in the area of strategic guidance towards ID divides into two basic streams – firstly various readiness and maturity assessment models and second works that suggest strategic phase models or procedure models towards realization of ID.

In regard to readiness and maturity models, the authors reviewed a wide number of scientific works in prior research [14, 15]. Thereby, works mostly focus on Industry 4.0 realization on a generic level. Therefore, the goal of this literature research was to find maturity approaches on a more operational level of ID. In regard to strategic phase or procedure models towards ID, the author's prior literature research [13] revealed various works that aim for providing general suggestions, however no publications that offer practically relevant methods directly applicable by industrial practitioners. Therefore, it was evalu-

ated if the current state of the art provides operationalized, comprehensive and practically applicable strategy-tools towards ID.

To assess literature findings, the authors define the following scientific and practical quality criteria:
1) Scientific criteria:
   SC1.1 Scientific relevance: topic relevance, degree of innovation, citations, journal and conference level
   SC1.2 Scientific rigor: methodology, validation, development transparency
2) Practical criteria:
   PC2.1 Practical relevance: operationalized content, method-ability to create practical results
   PC2.2 Practical usability: transfer media towards industry, accessibility for practitioners

To evaluate the findings, a quality fulfillment rating is defined using a Likert-Scale reaching from 1 until 5 (1 – no fulfillment until 5 – comprehensive fulfill-ment) and cross-evaluation is carried out in the research team to increase objectivity.

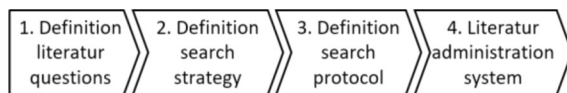To collect relevant research, a systematic approach in four steps as shown in Fig. 2.

Fig. 2. Approach literature research.

In Step 1, four questions narrow the search area such as "What scientific and non-scientific models exist to assess the degree of digitalization in industrial companies?". In Step 2, seven databases and search engines are determined for the search (Scientific databases: *Web of Knowledge, Taylor and Francis, Science Direct, Springer Link, Emerald Insight*; Non-scientific: *Google Scholar, Google*). Moreover 15

search terms and five search limitations and inclusion criteria such as topic-relevance, peer-review or publication-date are defined. Step 3 includes the documentation of all search activities to enable replication and Step 4 the local categorization and further screening of all findings.

Overall, after a first online screening of 3462 findings, the authors assessed 105 publications as potentially relevant. Next, cross-evaluations of all publications between three researchers was carried out. Thereby all articles were rated regarding two criteria (1. adds to the existing body of knowledge, 2. shows same or higher scientific value than existing articles). If both criteria were rated positively by at least two researchers, the article was considered further. As a result, 11 findings are considered for critical review and assessment. In the following, the authors assess these findings, consisting of maturity models and relevant strategy tools using the quality criteria SC1-1 until PC2.2. Thereby, two literature streams of assessment models (A) and phase or procedure approaches (B) – are divided in Table 2.

Rating these findings regarding scientific (SC) and practical criteria (PC), results in the following degree of quality-fulfillment over all 11 publications – see Fig. 3.

- **SC1.1 (3,3/5,0):** All findings show high scientific topic relevance and a high degree of innovation, however deficits in the quality of publication-channels and the number of citations.
- **SC1.2 (2,9/5,0):** The level of scientific rigor scatters widely over all findings. Whilst some show high transparency and a systematic development approach, others lack development-insights or validation and present resulting models and applications directly without scientific validation.

Table 2
Assessment quality fulfilment of literature.

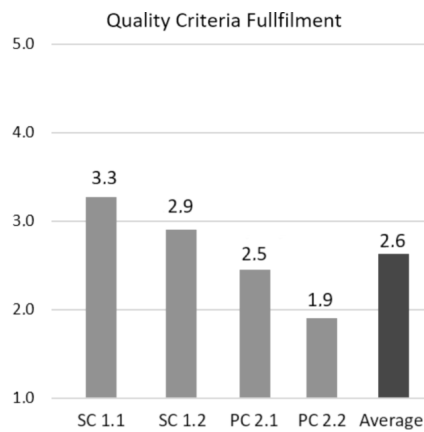| Author and year	Approach	Fulfillment quality criteria (1–5)				
		SC 1.1	SC 1.2	PC 2.1	PC 2.2	Average
Fast et al. (2008) [19]	A	2	3	2	2	**2,3**
Katz and Koutroumpis (2013) [22]	A	2	4	2	1	**2,3**
Lichtblau et al. (2015) [20]	A,B	3	1	4	3	**2,8**
Bogner et al. (2016) [18]	A	2	4	2	1	**2,3**
Ganzarain and Errasti (2016) [24]	B	3	1	2	2	**2,0**
Erol et al. (2016) [13]	B	3	3	2	2	**2,5**
Jung et al. (2017) [21]	A	3	3	2	1	**2,3**
De Carolis et al. (2017) [23]	A,B	5	2	4	3	**3,5**
Lenka et al. (2017) [25]	A,B	3	3	2	1	**2,3**
Santos et al. (2017) [26]	B	5	4	1	1	**2,8**
Ghobakhloo (2018) [27]	B	5	4	4	4	**4,3**
Average	–	**3,3**	**2,9**	**2,5**	**1,9**	**2,6**

Fig. 3. Quality-fulfillment of reviewed literature

- **PC2.1 (2,5/5,0):** Nearly all findings focus generic Industry 4.0-concepts and do not use operationally relevant assessments or procedure models.
- **PC2.2 (1,9/5,0):** No finding offers a practically directly applicable model or method that industrial companies could follow to create results in self-sufficient manners.

The work from Ghobakhloo [27] proposing a strategic roadmap towards Industry 4.0 shows the highest rating (4,3/5,0). This results from high scientific rigor (journal publication, extensive literature review etc.) as well as the proposition of detailed development paths towards Industry 4.0 in six dimensions. Weaknesses can be found in a lack of operational elements relevant in real production environments, a missing guidance approach provided to practitioners, as well as no initial assessment to provide a development-starting point.

Based on the reviewed literature, the next chapter presents requirements to a holistic strategic guidance approach and the research methodology followed.

Research approach – development of the Industrial Digitalization Strategic Guidance Model (ID-SGM)

Building on the initially defined scientific and practical problems as well as reviewed literature, the authors define the following development requirements:
- development with high scientific rigor and transparency;
- development on an operational production and industry level;
- development from a practitioner's perspective.

In order to ensure high scientific rigor and transparency, we base our development on the proposed Design Science approach by Hevner et al. [28] that provides widely accepted guidelines for the development of artifacts and models. Moreover, the procedure model by Roseman and Du Bruin [29] leads through the development of the ID maturity model – the core element of this research effort. Additionally, the framework by Becker et al. [30] applies the Design Science-guidelines specifically to the development of maturity models. To ensure development on an operational level in production environments, the value stream-framework [31] in combination with nine operationalized characteristics of ID that were developed during a prior research project [16]. Finally, to consider the practitioners perspective, all guidance and assessment developments consider the organizational structure of real companies (departments, responsibilities etc.) and moreover eliminated abstract and unspecific wording (e.g. smart objects, big data, artificial intelligence etc.). Considering these development requirements, we define the following approach to develop the Industrial Digitalization-Strategic Guidance Model (ID-SGM) – see Fig. 4.
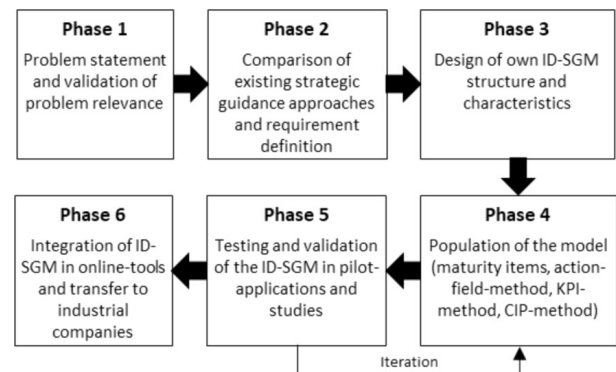

Fig. 4. Development approach ID-SGM.

In *Phase 1*, the development starts with the statement of initial research problems and the validation of their actual relevance. The authors derived the need for a scientifically rigor guidance model in prior research [13], where they proposed a three-stage procedure model towards Industry 4.0. However, a need for operational and specific guidance models was drawn as a conclusion of that research. From a practical point of view, the authors derived and specified the need for operational guidance towards ID from 20+ industrial research projects in the area of Industry 4.0 over the last four years as well as 18 expert-interviews [14, 15]. The content carried out in *Phase 2* is described in the literature section of this paper. Besides the assessment of quality criteria, the design and structure of all screened findings was captured as a basis for the new development. In *Phase 3*, the ID-SGM's structure and content is designed. There-

by aspects such as the number of guidance-steps, the results at each step, the company-dimensions covered, or the tools used to realize each step are defined. *Phase 4* requires the highest research intensity, as the specific content for each guidance-steps is inserted into the structure. Aspect such as the maturity-items for initial assessment, the logic for action-field derivation, the logic for KPI-monitoring, or the elements of the ID-Continuous Improvement Process (ID-CIP) are defined in detail. The testing of the ID-SGM in *Phase 5* is carried out several times on different development stages until the theoretically developed contents are creating useful results for industrial practitioners. Besides testing, this phase contains the theoretical and practical structure as well as performance validation following the validation square [32]. Finally, in *Phase 6* transfer media i.e. digital online-tools are implemented to make the ID-SGM accessible and available to a wide range of practitioners.

The development phases thereby aim to challenge the weaknesses of existing approaches (see literature review) that either focus on scientific rigor or practical accessibility and relevance. After carrying out the 6 development phases, the next section focuses on the resulting guidance model as well as content and characteristics.

Resulting ID-SGM

The resulting ID-SGM consists of two main guidance stages as well as 14 chronological and distinct steps. The first stage focuses the ID-Initialization and the second state the ID-Implementation within the company – see Table 3.

Table 3
Content of two stages of the ID-SGM.

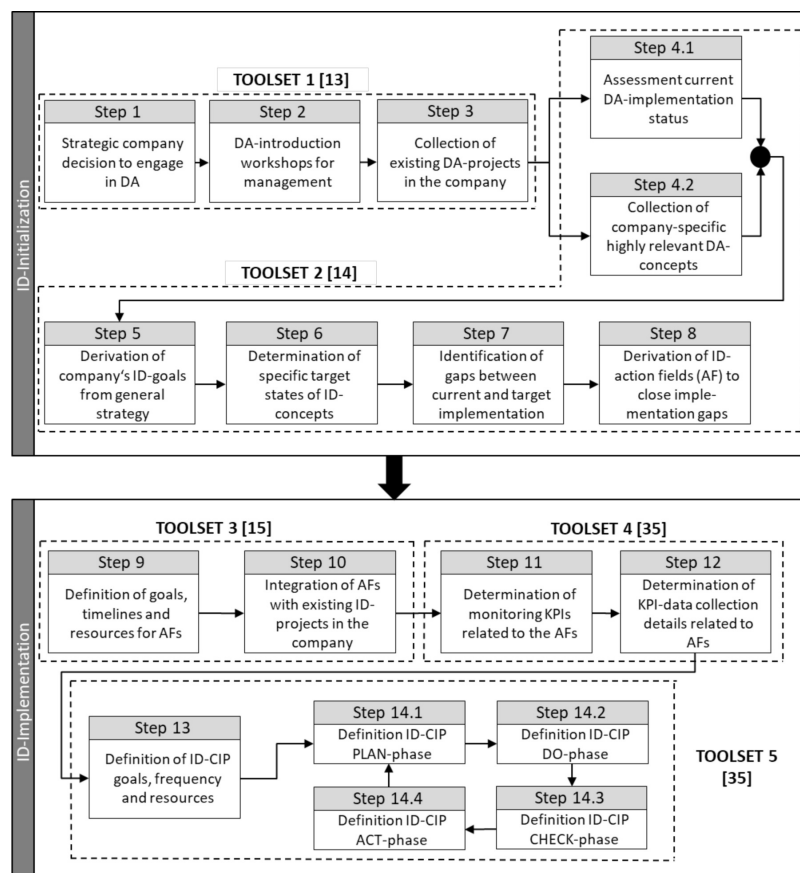| ID-Initialization	ID-Implementation
• Derivation ID-goals	• Detailling ID-AF-details
• Determination ID-target states	• Integration ID-AFs in company's ID-landscape
• Identification ID-development gaps	• Determination relevant ID-monitoring KPIs and collection
• Derivation ID-action fields (ID-AFs)	• Definition ID-Continous Improvement Process (ID-CIP)

Fig. 5. Approach development ID-SGM.

Table 4
Toolsets of the ID-SGM.

TOOLSET 1 (ID-SGM Step 1 – Step 3):
• Enabler-Creativity-Set consisting of 84 best-practises from real world ID-applications
• ID-Radar to collect current company-activites in 9 dimensions (dimensions see ID-maturity model
TOOLSET 2 (ID-SGM Step 4 – Step 8):
• ID-maturity model to assess current implementation in 9 dimensions using 143 maturity items
• Online survey-tool for digital maturity rating
• Online benchmarking-service to compare rating with other participants and receive a benchmarking report
TOOLSET 3 (ID-SGM Step 9 – Step 10):
• Framework for AF-organisation adjustable to company-structure during workshop series
•Template for ID-project relation matrix to align new and existing ID-projects
TOOLSET 4 (ID-SGM Step 11 – Step 12):
• ID-KPI-Collection of max. 143 KPIs using a 13-scale metric clustered into topic-related KPI-categories
• ID-KPI-monitoring manual
TOOLSET 5 (ID-SGM Step 13 – Step 14):
• ID-CIP circle including 13 CIP-activities in 4 phases
• ID-KPI-CIP manual

Initialization stage: leads a company from the first contact with ID until the derivation of individual action fields. Therefore, the authors developed a novel maturity assessment approach for ID that allows to assess the company's current maturity as well as the determination of specific target states for each defined maturity item – for details see following subchapter. Maturity-gap-analysis combined with practitioner's relevance ratings of all ID maturity items lead to the identification of development gaps and to related to ID-AFs.

Implementation stage: leads from the detailing of derived ID-AFs until der definition of a continuous improvement process designed to increase ID in sustainable manners. Thereby, the derived AFs are integrated into the companies ID-project landscape to avoid the creation of parallel projects thus inefficient implementations. To monitor implementation, out of all assessed maturity items that lead to defined AFs, relevant items are extracted and used as monitoring KPIs for the related AFs. Finally, the ID-CIP, derived from existing CIP-approaches from the area of Lean-Management [33], is defined. The resulting ID-SGM consisting of 14 steps is depicted in Fig. 5.

To lead companies through this procedure model, practical methods and tools are utilized at each Step summarized in TOOLSETS. Five TOOLSETS were defined that contain the following tools and methods – see Table 4.

Overall, 11 practically tested and validated tools and methods are integrated into to the ID-SGM, whereby in the following we present two important toolsets in detail.

Toolset 2 – ID-maturity assessment and action field derivation

In general, the term "maturity" refers to a "state of being complete, perfect, or ready" [34] and implies progress in the development of a system. Accordingly, maturing systems (e.g. biological, organizational or technological) increase their capabilities over time in regard to some desirable future state. In our case, we understand maturity in ID as the progressiveness of production companies to utilize digital enablers including all technological and social requirements along value creation and organizational processes. The developed ID maturity model measures ID-maturity in nine dimensions with 143 operational maturity items using quantitative assessment scales to ensure objective ratings [35]. The maturity dimensions thereby follow the main elements of value creation processes in industrial companies to consider the practitioners view as depicted in Fig. 6.
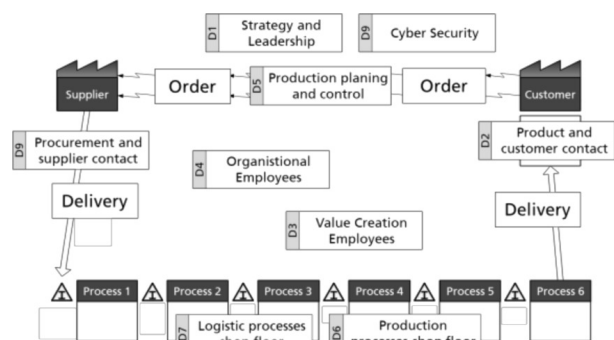

Fig. 6. Assessment dimensions ID-maturity model.

Item D9.15	Existence of replacement software services in the event of failure of software systems
Assessment question: For which proportion of the software systems in your company is replacement software provided to ensure task execution in the case of software-failure?	
Replacement software after failure: Use of internal replacement software or use of external software services to carry out the core tasks of office software, or of ERP, MES, CRM, SCM, etc.	
Example: Contractually secured insourcing of replacement software services from third parties for defined core functions of own software systems, which can be activated as required.	
Implementation of replacement software services not yet investigated	Concrete implementation of replacement software services planned
Replacement software available for <1% of own software systems	Replacement software available for 1-10% of own software systems
Replacement software available for 11-20% of own software systems	Replacement software available for 21-30% of own software systems
Replacement software available for 31-40% of own software systems	Replacement software available for 41-50% of own software systems
Replacement software available for 51-60% of own software systems	Replacement software available for 61-70% of own software systems
Replacement software available for 71-80% of own software systems	Replacement software available for 81-90% of own software systems
Replacement software available for 91-100% of own software systems	No (further) implementation due to negative benefit assessment carried out

Attribute very irrelevant for the company	Attribute rather irrelevant for the company	Attribute medium relevant for the company	Attribute rather relevant for the company	Attribute very relevant for the company

Fig. 7. Example ID-maturity item.

Each of the 9 dimensions consists of 14–18 maturity items that are all structured according to Fig. 7.

Besides maturity rating in 13 implementation levels (supports *Step 4.1 ID-SGM*), the relevance of the respective item is considered to derive additional information (supports *Step 4.2 ID-SGM*). The maturity assessment is carried out through an online- assessment tool and after statistical analysis, standardized maturity reports are created.

After evaluating the current maturity, strategy workshops (supports *Step 5 ID-SGM*) lead to the definition of the company's future development states which are then transferred into maturity levels for each item (supports *Step 6 ID-SGM*). To systematically derive action fields, a three-step approach is carried out, that mathematically builds on the assessment results – see Fig. 8.
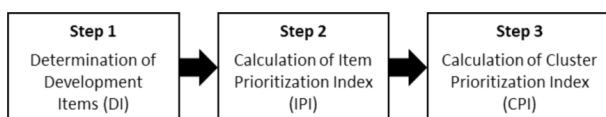

Fig. 8. Three-step approach AF-derivation

In Step 1, the current and the target-maturity for each ID-maturity item are used to evaluate, if the company states a need for development of the maturity item, thus the related ID-area (supports *Step 7 ID-SGM*)

$$\text{DI} \ \ \text{if} \ \ \sum_{i=1}^{n} M_{\text{ITi}} - \sum_{i=1}^{n} M_{\text{ISi}} \geq 3$$

DI... Development Item

n... Number of ratings   (1)

M_{IT} ... Maturity of item (target)

M_{IS} ... Maturity of item (current)

If the difference between the target (M_{ITi}) and current maturity (M_{ISi}) is equal or more than three maturity levels, the item is defined as a Development Item (DI) and therefore considered further for AF-derivation. The treshold of three maturity levels is dervied from previous maturity model applications [14] in which the goal was to define a sufficient treshhold for derivation of a practically relevant number of digitalization action fields. In Step 2, to insert the relevance dimension to the list of development items, the Item Prioritization Index (IPI) is calculated for each item

$$\text{IPI} = \frac{\sum_{i=1}^{n} R_{\text{DIi}} * (M_{\text{ITi}} - M_{\text{ISi}})}{n} \tag{2}$$

IPI... Item Prioritization Index

R_{DIi} ... Item Relevance Rating

n... Number of ratings

To calculate the average IPI, the relevance rating (R_{DIi}) for each item is multiplied with the difference between the target and current maturity. Finally, in Step 3 the Cluster Prioritization Index (CPI) is calculated to assess relevance of derived action fields. Item-clusters result from grouping topic-related maturity items which directly leads to the ID-action fields

$$\text{CPI} = \frac{\sum_{k=1}^{j} IPI_{\text{DIi}}}{j} \tag{3}$$

CPI... Cluster Prioritization Index

IPI_{DIi} ... Item Prioritization Index

j... Number DI-items in cluster

Thus, the Cluster Prioritization Index (CPI) results from the average Item Prioritization Index (IPI) over all items grouped into the cluster.

The result of this 3-step approach are clusters of maturity items with a requirement for development from a maturity point of view as well as from a relevance point of view. Therefore, we find the company's action fields towards their indended maturity in ID directly in these clusters (supports *Step 8 ID-SGM*). The next step after derivation of action fields is their detailling and integration with existing ID-project in the company.

Another core-Toolset of the ID-SGM is the implementation of an continuous improvement process, specifically designed for application towards ID-realization.

Toolset 5 – ID-Continuous improvement process (ID-CIP)

We derive our approach towards continuous improvement (CI) in ID from widely accepted methods in the area of Quality Management following ISO9001 and Lean Management [33]. Thereby CI is defined as the collection and implementation of employee driven improvement measures to reach sustainable development in small steps. The main building block we derive for our ID-Continuous Improve-

ment Process (ID-CIP) depicted in Fig. 9 is the Plan-Do-Check-Act-circle, which allows structuring of activities towards ID in an iterative manner following 4 phases (supports *Step 14.1-14.4 ID-SGM*):

- **Plan:** Determination, operationalization and project integration of defined ID-AFs.
- **Do:** Implementation and monitoring of ID-AFs, KPI-data collection for each AF.
- **Check:** Status-evaluation of AF, Evaluation of AF-KPIs, KPI-gap-analysis.
- **Act:** Adjustment of overall ID-goals, Adjustment of ID-maturity targets, Setting of new ID-standards in company.
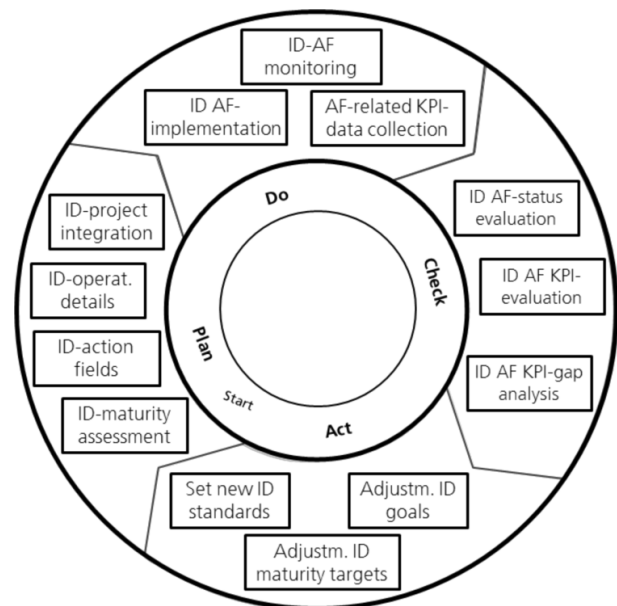

Fig. 9. PDCA-Circle for ID-CIP

The overall goal is to create new ID-standards within the company and to constantly adjust ID-goals and related maturity levels. The frequency the ID-CIP is carried out depends on the ID-project-size and must ensure an efficient DO-phase to allow for organizational change and measurable results. Activities during the Plan-Phase of the ID-CIP overlap with the step from the ID-SGM during the initial loop. The operation of the ID-CIP requires defined responsibilities and resources to collect status-reports, update KPIs for action fields and to organize ID-CIP-team meetings or go-and-see-approaches known from Lean Management (supports *Step 13 ID-SGM*).

After detailed explanations of two toolsets the ID-SGM contains, in the next chapter we present the highlights of a practical application.

Practical Application of the ID-SGM

We pilot tested the ID-SGM following *Phase 5* of the defined development approach (see Fig. 5) in an internationally operating industrial company in the area of heavy machine manufacturing with 3000+ employees. Following the 14 steps of the procedure model, the authors firstly carried out introductory management workshops (*ID-SGM Step 1-3*). Thereby we collected the following 4 goals in ID –see Fig. 10.
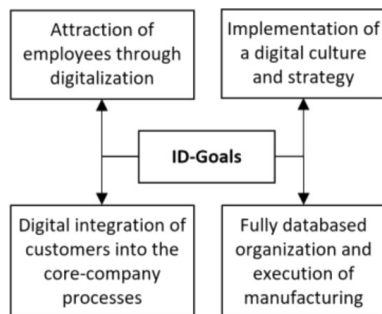

Fig. 10. Definition of four ID-Goals.

Next, (*ID-SGM Step 4-8*) the maturity assessment in nine dimension and 143 maturity items was carried out. Exemplary, we present the maturity assessment for Dimension D3 – Value Creation Employees in detail. The dimension contains the following 14 maturity items – see Table 5. Thereby, the acronym VC shortens the term Value Creation.

The assessment procedure required participants to internally collect data related to all 14 items and to assess each item with one of the 13 maturity levels. After carrying out the current maturity assessment, strategy workshops helped to define future target states for all 143 items. Depicted in Fig. 11 is the current as well as the target maturity rating for all items of Dimension 3.
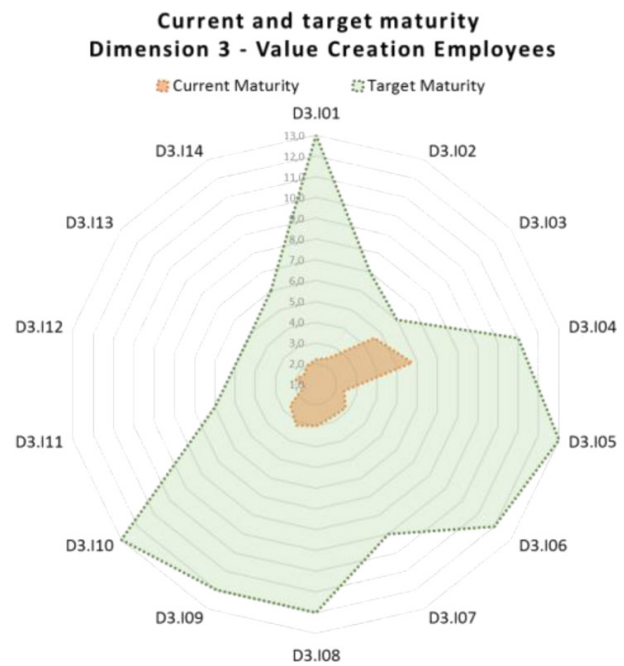

Fig. 11. Dimension 3 – Current and target maturity.

Table 5
Overview Maturity items Dimension 3.

Maturity Item Nr. and Title
• D3.01: KPI system for monitoring the digital exchange of information
• D3.02: Standards for the use of digital communication channels by VC empl.
• D3.03: Standard equipment of VC employees with ICT
• D3.04: Systematic survey of the digitalization employee competencies of VC employees
• D3.05: Digital collection and management of digitalization employee competencies of VC employees
• D3.06: Digitalization competence increase of VC employees
• D3.07: KPI system for monitoring the digitalization competence development
• D3.08: Definition of measurable annual targets to increase digitalization competencies
• D3.09: Data usage strategy for collected employee data of VC employees
• D3.10: Data collection about the physical load condition of VC empl. at the shop floor
• D3.11: Data collection about the employee location at the Shop Floor
• D3.12: Monitoring of ergonomic posture during work of VC employees
• D3.13: Physical support of VC employees via digitally controlled assistance systems
• D3.14: Automatic adaptation of Shop Floor workstations to the body size of VC employees

The aggregation of all 143 maturity items on a dimension-level leads to the overall current and target maturity over nine defined company dimensions – see Fig. 12.
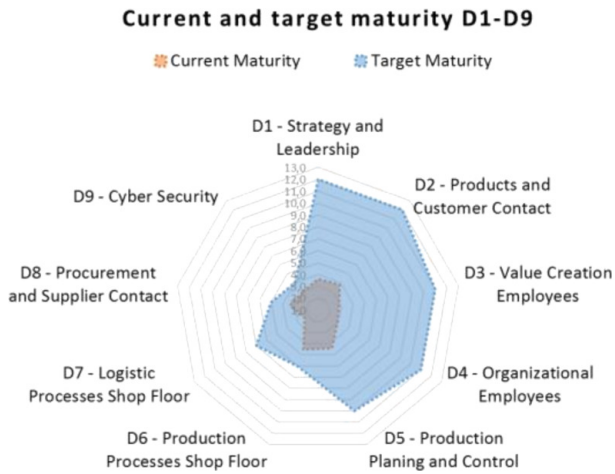

Fig. 12. PDCA-Circle for ID-CIP.

The current maturity in Fig. 12 shows levels reaching from 2,3 (D7 – Logistic Processes Shop Floor) until 4,4 (D4 – Production Processes Shop) out of the max. Implementation level of 13. The target-level distribution shows high consistency with the initially defined ID-Goals in Fig. 10. As a result, the dimensions D1-D5 show the highest maturity gaps, thus the most need for development. The dimensions D6-D9 also show need for development, however to a considerably lower extend due to lower target maturity ratings.

As a direct result from the maturity assessment 27 development items were clustered into 5 AFs (*ID-SGM Step 9-12*). Moreover, the AF-relevance was calculated following Formula (3), resulting in the following relevance ranking of AFs – see Table 6.

Table 6
Ranked Action Fields by CPI.

Action Field Name	Av. CPI out of max. 5
• AF1: Data-driven shop floor management	• 4,7
• AF2: Mangerial digitalization development	• 4,4
• AF3: Digital employee branding	• 4,4
• AF4: Digital customer integration	• 3,6
• AF5: Corporate cyber security	• 2,1

The action fields AF1-AF4 result directly from the maturity model and relevance ratings. Action Field AF5 however was defined during management workshops and is a result of an awareness process and therefore included into the development strategy. Therefore, AF5 shows a comparably low CPI-rating if viewed only from the maturity model results. The next steps following the ID-SGM were:

- Definition of five permanent action field-leaders.
- Relation and integration of 36 existing ID-projects within the company into the five5 AFs.
- Definition of the 27 related maturity items as relevant monitoring-KPIs for implementation monitoring and definition of 12 additional monitoring KPIs in alignment with the company's existing operational KPI-system.

Finally, the company's continuous improvement processes (ID-CIP) was defined (*ID-SGM Step 13-14*) by the determination of an ID-CIP responsible person in the company and the definition of an execution approach as follows:

1) **Execution on department level:** focusing on small ID-projects, ID-CIP-circle every two months;
2) **Execution on inter-department level:** focusing on medium ID-projects and small programs, DI-CIP-circle every six months;
3) **Execution on corporate level:** focusing on big ID-projects and programs, DI-CIP-circle every 12 months.

Moreover, details for the ID-CIP-elements were defined:

- **Plan:** Execution of full ID-maturity assessment at least every two years; Yearly alignment of defined ID-action fields with corporation strategy; Implementation of operational ID-realization dep-partment; Initialization of standard process for integration of bottom-up ID-projects into action fields
- **Do:** Budget allocation of 4% of revenue specifically to implementation of AFs each year; Monthly KPI-data collection and update in action field dashboards
- **Check:** Evaluation of action field status every month including KPI-evaluation and gap analysis;
- **Act:** Yearly alignment of four defined ID-company goals on board level; Adjustment of 27 related maturity targets on operational level; Creation of ID-company white paper including digital standards

The implementation of the ID-CIP marks the last of all 14 steps of the ID-SGM and should result in the long-term digital transformation of the company.

After presentation of our pilot-application, in the next chapter we summarize our findings, critically reflect our own approach in regard to our defined research problems, goals and criteria towards the state of the art. Moreover, we state required future research to close currently remaining gaps and our next steps to approach these.

Conclusions

In this paper we presented a novel approach to guide industrial companies from their first contact with ID until the creation and implementation of digital standards. Therefore, we developed a 14-step guidance model and integrated five Toolsets including 12 tools and methods targeted at practitioners. Our main goal thereby was reduce the abstraction of modern production paradigms such as Industry 4.0 to make their benefits accessible on an operational level.

Our research conclusion divides into two parts. First, we draw conclusion and engage in a critical reflection of our own research contribution and effects on identified research gaps. Second, we want to state future research requirements resulting from additional gaps we identified during our practical model applications.

Feedback we collected from several applications at different development stages indicate, that the ID-SGM clearly enables strategic guidance on a more operational level and with a high degree of usability. Practitioners find the main advantage in the systematic approach that shifts decisions of teams in strategy development from subjective and power-driven behavior towards a more objective and data-based approach. Moreover, especially the ID-maturity model applied in nine company areas ensures holistic development towards ID.

Taking a critical view on our own work, our indention during development was to create a strategy guidance model allowing companies to develop their digital agenda in independent and self-sufficient manners. Feedback and our observations during workshops however support prior observations that the moderation during all ID-SGM-steps carried out by external experts proofed to be an essential success-factor. Therefore, expert guidance and the inclusion of an external ID-view must be treated as an integrated Toolset over all application steps. Moreover, we found out that additional tools and toolsets will be required to be able to support a wider range of companies – e.g. through the development of an ID-maturity model focusing on industrial service companies.

Regarding future research requirements we see in the area of ID-strategy research, we state two main areas with a lack of scientific attention. Firstly, guidance models that focus the employees-perspective on an operational level, and second, scientifically rigor and practically accessible approaches to benchmark the own ID-development status against competitors. Benchmarking allows for the determination of target states based on external data additionally to internally defined ID-goals.

We close our conclusion section with these defined requirements.

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