

Resolving the productivity paradox of digitalised production

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Abstract: Although Industry 4.0 and other initiatives predict widespread adoption of digitalised technology on the factory floor, few companies use new digitalised production technology holistically in their ecosystems; in practical implementation, companies often decide against digitalisation for financial reasons. This is due to a paradox (akin to the so called “productivity paradox”) caused by the complexity of value creation and value delivery within digitalised production. This article analyses and synthesises cross-disciplinary research using a grounded theory model, thus offering valuable insights for businesses considering investing in digitalised production. A qualitative model and an associated toolbox (complete with tools for practical application by business leaders and decision-makers) are presented to address organisational uncertainty and leadership disconnect that often contribute to the paradoxical gap between digital strategy and operational implementation.

Key words: digitalised production, digital transformation, industry 4.0, Industrie 4.0, value creation, value capture, manufacturing strategy.

1. Introduction

Digitalisation is expected to deliver wide ranging value to almost all areas of society and the business world. The German initiative “Industrie 4.0” (Kagermann et al., 2011) is the most prominent example of international initiatives to drive investments towards a “fourth industrial revolution” that will utilise cyber-physical systems (CPS), cyber-physical production systems (CPPS), horizontal integration of the value chain, and vertical integration of production systems (Kagermann et al., 2013, p. 39) to unlock new added value for industrial production. High economical value is expected from applied digitalised technology. For example, additional revenue of 110 billion € and productivity gains of up to 18 % were predicted by PwC in 2014 (Geissbauer et al., 2014, p. 10f). However, Lerch et al. (2017, p. 6) underlines that only 15 % of German manufacturing companies show advanced

“Industry 4.0 readiness,” while over 50 % continue to rely on conventional – not digitalised - production processes. Actatech, the German national academy of science and engineering, therefore, assumes the importance to follow through the process to mature in competences related to digital capabilities in their “Industrie 4.0 Maturity Index” (Schuh et al., 2020). Further a production planning focussed taxonomy of design principles proposed by Cañas et al. (2021) becomes essential to get the concept of Industry 4.0 better defined.

This discrepancy between predicted benefit and real implementation is rooted in the lack of corporate experience with respect to purposeful and successful Industry 4.0 implementation (Veile et al., 2019, p. 2), as well in uncertainty caused by the complexity of a new technological landscape (Magruk 2016, p. 278) and novel digital dimensions (Fleisch et al., 2014, p. 816). Digitalisation, however, is not pursued

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for the sake of digitalisation. Digitalisation offers competitive advantage by delivering new products and cost benefits (Porter and Heppelmann 2014). New business models for data-based value creation play an essential role in providing these benefits (Arnold et al., 2017, p. 371) and challenge traditional business processes, as producing industries are more conservative than internet-based businesses. To encourage a wider scale of investment in new technology for production lines, a transition or extension of these companies' understanding of value proposition, value network, and value architecture has to be at centre stage. The transformation of the corporation's strategic necessity to go digital is creating an increasing "digital gap" from traditional operational reality. From technology perspective many companies appear well prepared but fall short in necessary structural adjustments (Gürdür et al., 2019). This results in a paradoxical situation where companies must evaluate the possibility of digitalised production while profitability criteria remain unclear (Kiel et al., 2017, p. 25). Al-Debei and Avison (2010, p. 371) show that this "digital gap" can be understood and managed by applying business models that hold the notion of value at centre stage. This approach is in line with Chesbrough and Rosenbloom (2002, p. 532), who understand business models as "mediating construct[s] between technology and economic value".

Industrial productivity is strongly related to measures for improving overall equipment efficiency (OEE) (Koch 2016, p. 49). The potential for flexibility and connectivity to improve productivity mandates that companies consider standardising communication within and between production equipment (Sauer 2014, p. 295). OPC-UA is identified as key enabler for the Industrial Internet of Things and the related factory of the future (Palm et al., 2014). Further, in most industrialised countries, initiatives to drive digitalisation of manufacturing offer alliances and funding programs (Kagermann et al., 2016). The digital gap is influenced by all these different dimensions related to digitalisation and production. To develop a practical model for investments in digitalised production, it is mandatory to create a holistic theory that covers all related disciplines of research. Scholars typically work within their research domain and identify cross themes as new area for research. Investment towards digitalised production often falls within these cross-disciplinary areas as it combines four scientific disciplines to understand the relations.

The wide-ranging dependencies amongst these research disciplines forms the research question, how necessary investments in digitalization can be assessed in terms of their contribution to value generation within a manufacturing value chain. The scientific aim of the study is therefore to research and surface the underlying structural constructs and interrelations determine the digital transformation processes of industrial production infrastructure. These results contribute to a holistic view on the novel research field of digital transformation of manufacturing companies. In practical terms, the empirical findings are furnished into an innovative toolbox supporting necessary assessment and validation that business enterprises undergo within their digital transformation processes.

An intensive review of the research literature from these four disciplines offers a rich data source for understanding questions related to digitalised production. A grounded theory can be established through a qualitative study of the phenomena identified in the literature data (Strauss and Corbin 2010, p. 54; Charmaz 2014, p. 45ff) combined with complementary expert interviews. The final coded grounded theory is elaborated upon to deliver a toolbox for gathering and processing conditions to then determine investment patterns. The paper presents the process for creating a suitable toolbox for production companies to manage paradox of digital investment. The first section presents an analysis of the relevant scientific disciplines to create a holistic model for the field of digitalised production. The second section explains the theoretical model of investment behaviour that bridges the gap of digitalised production. In the third section the toolbox is developed, based on the finding of the grounded theoretical model. Finally, conclusions and recommendation for further research are outlined.

2. Interrelation of research disciplines

As is often the case, existing research around digitalised production is focused and narrow, following the specific interests of individual disciplines. For example, publications related to digitisation initiatives—like Industry 4.0, IVI, or IIC (Kagermann et al., 2011; Industrial Value Chain Initiative 2018; Lin et al., 2017)—are concept-oriented and focus on technology needs. Technology-centric publications, on the other hand, take advantage of new development trends such as

OPC-UA, MQTT, big data, or artificial intelligence, as the core of their research. Business model research considers business issues with external partners, i.e., B2B, B2C and the aspects related to the “office floor.” In the same fashion, the work resulting from research related to production is dedicated to investigative tools for continuous productivity increases on the “shop floor.” Since digitalised production touches all these disciplines, there is value in combining their individual results to generate a holistic view to guide company investment perspectives. Figure 1 illustrates the four research disciplines that relate to investments towards digitalised production.

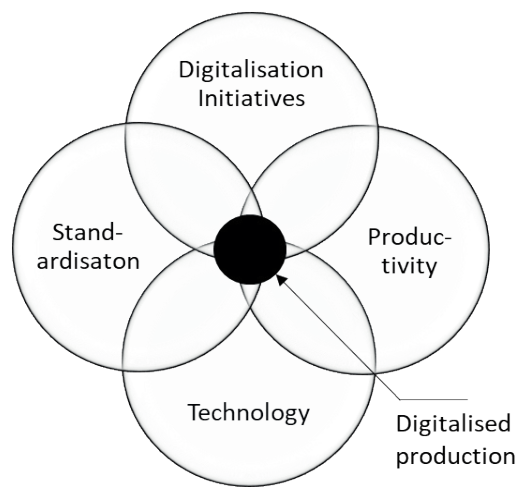


Figure 1. Four research disciplines related to digitalised production (Author’s illustration).

Currently, there is a lack of studies bridging these related disciplines, although the demand is often recognised and identified as area of further research (Obermaier and Schweikl 2019, p. 558). In most existing publications, cross-discipline aspects are mentioned superficially or remain fuzzy. To leverage our collective knowledge to inform investment decisions, a holistic model that incorporates all relevant insights from the scholars of these four disciplines is required. A search of the literature available on EBSCOhost, Emerald and Google Scholar delivered 15,450 matches with keywords related to the domain of digitalised production within these four disciplines. Table 1 contains the most relevant keywords and references. After deep review of the resulting keywords, abstracts, and full studies, 121 sources in total were identified as relevant to deliver data for a qualitative analysis, further described in section 4.

Table 1. Leading keywords and references (Author’s illustration).

Keywords and Boolean conditions	References (excerpt)
Automation AND Data	Arnold and Voight 2017; Sauer 2014
Business model	Osterwalder 2004; Al-Debei and Avison 2010; Zott et al., 2011
Digital transformation	Berghaus 2018; Schuh et al., 2020; Obermaier 2019
Digitalization	Rachinger et al., 2019; Bouwman et al., 2018
Industry 4.0 OR Industrie 4.0	Schuh et al., 2015; Magruk 2016; Kagermann et al., 2013; 2016 2016Kagermann et al., 2013
Internet of Things OR IOT	Jesse 2016; Imtiaz and Jasperneite 2013; Zuehlke 2010
Overall Equipment Efficiency OR OEE	Ylipää et al., 2017; Gibbons and Burgess 2010
Productivity AND manufacturing	Hopp and Spearman 2004; Schmenner 2015
Standardization	Cottyn et al., 2008; Dorst 2016; Eruvankai et al., 2017
Value proposition	Osterwalder and Pigneur 2010; Rese et al., 2013
Willingness to invest	Grebe et al., 2019; Skilton et al., 2010

3. The paradox of digitalised production

Throughout history, technological innovation has often caused paradoxical situations. In the 1980’s, for example, business and society at large entered the era of computerisation. Robert Solow (1987) observed then that “You [could] see the computer age everywhere but in the productivity statistics.” This was Solow’s paradox, also known as the “productivity paradox;” that in spite of rapid technological growth in every sector, productivity was down. Since the Solow Paradox, we have observed increasing values of computer usage that additional benefits being generated with latency, over time. Obermaier and Schweikl (2019, p. 540ff) researched the relevance of the Solow Paradox in relation to Germany’s Industry 4.0 initiative. They demonstrated that several phenomena of the “fourth industrial revolution” appear to follow same patterns as observed in the “computer revolution.” The paradox of digitalised production is grounded in the ultimate need of a business to evaluate potential technology

investments, a process that many companies are ill-prepared for (Porter 2010, 150,250ff). Traditional investments can be evaluated by weighing the value generated by improvements within the horizontal value stream (Porter 2010, p. 226). However, within the sphere of digital business, traditional judgment methods are challenged by complexity and uncertainty. Figure 2 visualises how the digital gap emerges from insufficient knowledge of digital technology combined with a higher level of risks and dynamics of the digital business environment.

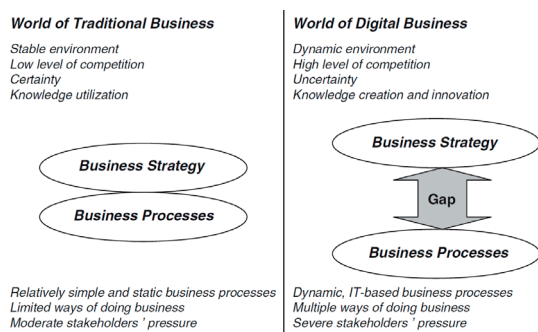


Figure 2. Comparison between the world of traditional and digital business (source: Al-Debei and Avison, 2010, p. 369).

This gap between process and strategy related to digital production equipment originates from the interaction between horizontal integration (Dorst 2016, p. 19) of the value stream and the related demand for vertical integration (Dorst 2016, p. 28) of data and information. In order to optimise the value stream of a produced item, information acquired from devices in the production process—like machine cells, fixtures, motors, robots, vision systems, a single sensor, or a power supply—must be aggregated and analysed. Consequently, to realise vertical integration, a heavy investment in hardware

and infrastructure is borne on the factory floor. The monetizable value, however, is captured from the usage within the horizontal integration of the value chain. Digital transformation requires either an explicitly defined digital business model or the implicit expectation that the company will benefit from digitalised technology. The ultimate need to ensure that an investment delivers a sufficient return and competitive advantage relates to the underlying assumptions of a digital business model.

As a consequence of organisational allocation of funds to install the value architecture, the assumed value proposition, and the mechanism to capture value, an effect of decoupling can be observed. Figure 3 visualises this phenomenon of decoupled costs and value and illustrates the underlying effects that create the digital gap related to investments into digitalised production.

The increasing complexity of digital transformation mandates new processes and criteria to evaluate return on investment. The decoupling of cost and value capture forms a gap between digital strategy and operational implementation in digitalised production. This gap hinders or biases traditional business decisions, especially in regard to digital-driven investments.

Al-Debei and Avison propose to overcome such a gap using business models as a conceptual tool for “alignment” between corporate strategy and business processes (Al-Debei and Avison, 2010, p. 371).

Figure 4 shows how business models intersect with digital business strategy and digital business processes. A business model can be understood as a “mediating construct between technology and economic value” (Chesbrough and Rosenbloom

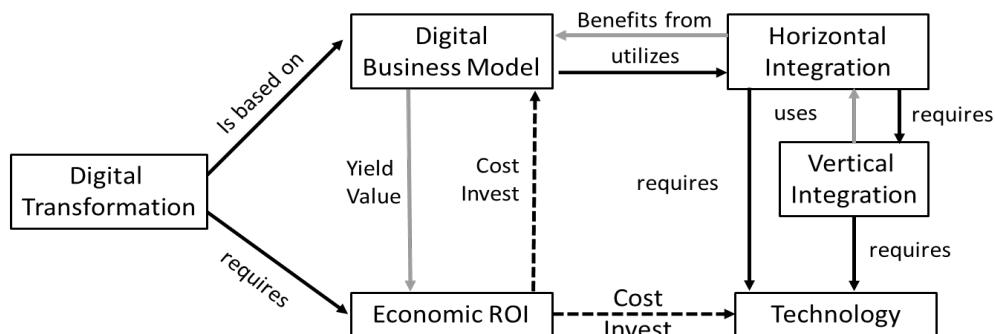


Figure 3. Instances of an Industry 4.0 transformation and their relations (source: Dold, 2020, p. 18).

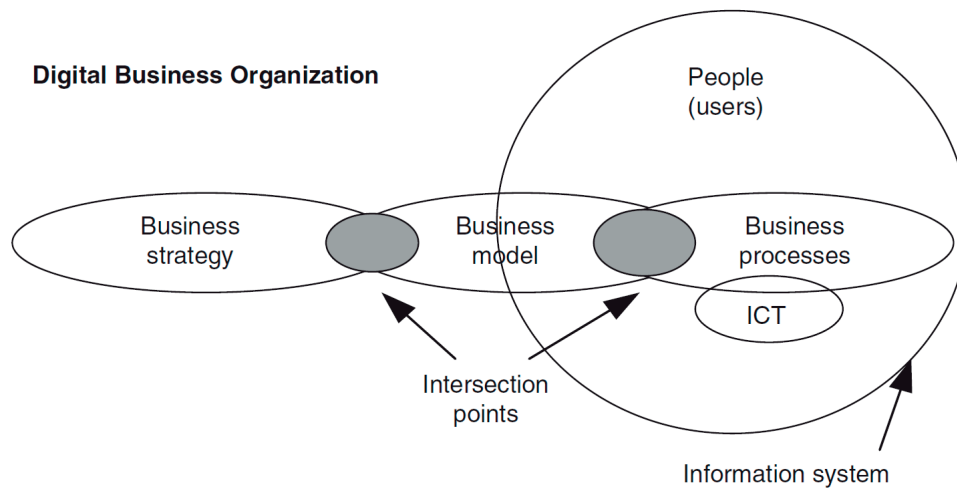


Figure 4. Business model intersection points (source: Al-Debei and Avison, 2010, p. 370).

2002, p. 532). Thus, business models and their value-oriented approach offer a path for reducing the identified digital gap and for managing the paradoxical conundrum facing decisions about investing into digitalised production.

4. Grounded Theory

The literature produced by scholars within the disciplines, technology, standardisation, productivity, and Digitalisation initiatives, is a rich source of data for analysing the phenomena related to digitalised production, though the data cannot be easily compared as it is rooted in such disparate disciplines. To make use of such heterogeneous sources within a grounded theory analysis model, Charmaz (2014, p. 45) explicitly recognises the value of data that is drawn from all aspects of the literature; phenomena can be identified not only in the content of the research studies, but also in their target audiences, the backgrounds of the authors, and in the presentation of the text. Drawing on this observation, a paradigmatic coding process was used to create a grounded theory model based on the identified literature sources. The applied paradigm was based on the work of Strauss and Corbin (2010) and delivers 76 phenomena from the process of open coding (Strauss and Corbin, 2010, p. 54). To understand the relationships between and the meaning of the observed phenomena, ten high-level categories have been defined to structure the coding results (Table 2).

Table 2. Results of the open coding process (source: Dold 2020 p.78).

Discipline	Category (open coding)	Phenomena
Business model	Utilization of business models	No. 1 to 7
	Layers of strategic decisions	No. 8 to 14
	Impact of business model	No. 15 to 20
Business	Commercial value	No. 21 to 26
	Determinants of investment	No. 27 to 33
	Strategy and Transformation	No. 34 to 42
Productivity	Maturity levels	No. 43 to 49
	Lean Production	No. 50 to 57
Technology	technological - economical relation	No. 58 to 66
	Data-integration	No. 67 to 76

Digitalised production is a new research domain; hence the analysed literature derives from surrounding disciplines only and may not reflect the latest status of the practical application of digitalisation. To cover this possible bias, the research design integrates qualitative expert interviews (Mayring 2008; Jüttemann 1989; Witzel 2000; Döring and Bortz 2016) to ensure applicable expert data is available to develop the theoretical model. The phenomena outlined in Table 2 were evaluated by four experienced industry experts to define the path diagram visualised in Figure 5. The path diagram utilises the causal and intervening conditions identified via axial coding (Strauss and Corbin, 2010, p. 75), thus fully incorporating data from literature and qualitative interviews. It shows that decision making is influenced by multiple phenomena centred around “maturity of company resources” and “digital penetration.” Further, the prominent representation of value elements originating from business models confirms the moderation of value.

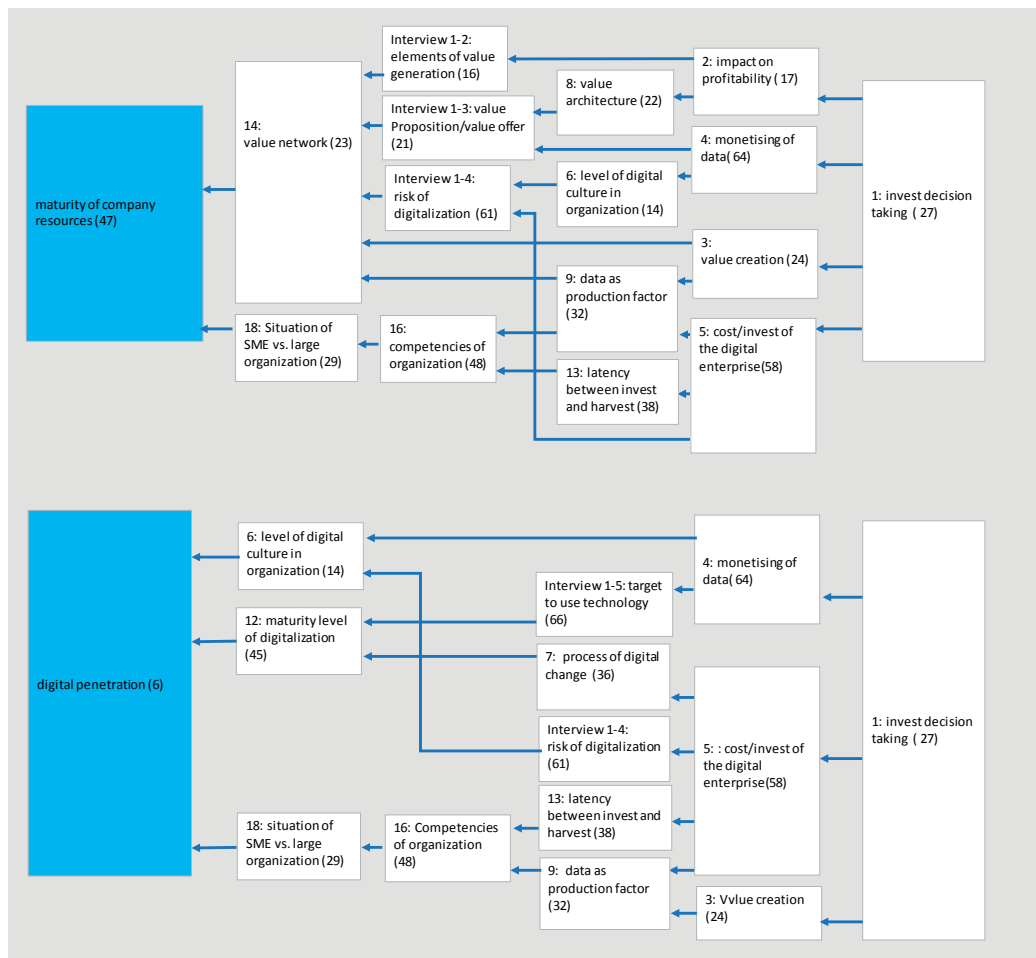


Figure 5. Path model of analysed relations amongst phenomena (source: Dold 2020, p. 101).

The process of selective coding (Strauss and Corbin 2010, p. 94) integrates the identified phenomena and conditions to form the core category of the final grounded theory model. A single central phenomenon cannot directly be identified from the available results. Three phenomena demonstrate similar dominance. Further validation with the source data show that these three phenomena are interrelated in their influence over investment decisions. Together they form a latent phenomenon that is the core category of the theoretical model. The core category is composed of phenomena related to “risk,” “people,” and “value,” and is given the name “associated balance” (see Figure 6). This core category enables evaluation of the conditions, context, actions, interactions, and strategies that consequently determine investment patterns in digitalised production. The process of paradigmatic transition (Strauss and Corbin 2010, p. 101) is outlined in Figure 7 and incorporates all available data and analysis results from the preceding steps.

The characteristics of the core category are defined by the conditions of “risk awareness,” “consideration of persons,” “networks,” and “value proposition.”

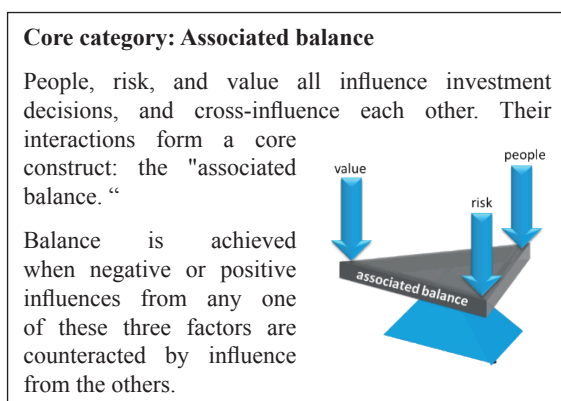


Figure 6. Core category “associated balance” (source: Dold 2020, p. 127).

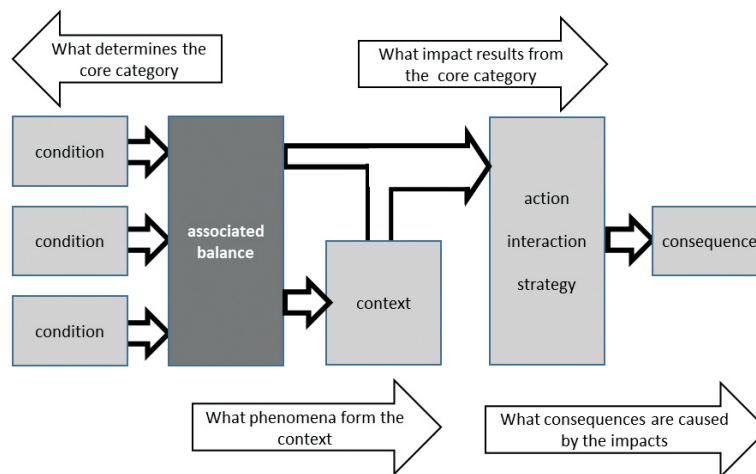


Figure 7. Paradigmatic transition (source: Dold 2020, p. 129).

Risk awareness is based on the uncertainties and risks connected with digitisation. Across companies and individual decision makers, understanding and considerations of related risks vary (Magruk 2016, p. 284). The deeper the understanding of risks, the clearer the risk level can be assessed and taken into account within a balanced investment evaluation.

Consideration of persons is the acknowledgment that people are responsible for successful implementation of and value generation through digital transformation. Involving people is indispensable (Burggräf et al., 2017, 2463). Considerations of the range of the people involved, as well in their hierarchical and department roles, contribute to determining the balance and influence of this factor.

Networks consider that value is created by a coordination of activities. This effect requires wide-reaching networking between functions and partners, both internally and externally (Al-Debei and Avison, 2010, p. 367). The more completely these networks are established, the more effectively risks and values can be balanced.

Value proposition for desired additional values from digitisation can manifest differently. A value proposition defines the benefit that is to be achieved or that has been achieved (Al-Debei and Avison, 2010, p. 365). The strength of the additional values constitutes an opposite pole to compensate evaluated risks.

Thus, determined from the four conditions of risk awareness, consideration of persons, networks, and

value proposition, the “associated balance” reflects a balanced understanding of the total situation, providing a basis from which to take actions, define strategies, and implement further interaction. The phenomenon of the associated balance (AB) is distinct in four states. If the interrelations between persons, risk and value are well balanced, a **secured AB** is considered. In case some, when discrepancies within the determining factors remain but the total effect is positive, an **optimistic AB** exists. A **critical AB** exists if, despite some positive influence, majority negative parameters predict instability. In the case when all conditions are shaped negative, a **disrupted AB** emerges.

The status of the AB works in conjunction with the specific context of the project being evaluated, which encompasses “digital business model,” “digital culture,” “data usage as production factor,” and the “competitive situation” as conditions.

Each company’s **digital business model** utilises digitisation differently, with variations ranging from the use of simple digital tools for a conventional business model, to a holistic digitisation of the value chain (Burmeister et al., 2016, p. 146). Presence of a digital business model supports a well-developed transition towards action and decision for digitisation in production.

Digital culture addresses the possibility that significant digitisation may not be realised due to weak anchoring in the corporate culture (Schuh et al., 2020, p. 11). Readiness for change within the workforce, and the necessary communication of social aspects, are fundamental prerequisites for

developing and implementing digital strategies. Insufficient willingness within a company's personnel counteracts a positive effect from AB.

Data usage as production factor covers the potential for additional value capture or monetization via data collection in production (Maier and Weber 2013, 17,38). If the contribution of data to capture value is not considered, an inhibiting effect on the formation of strategies is considered (Legrenzi, 2017, p. 36). If the potential is recognised and included in the assessment of value, the implementation of digitised production technology will be supported (Tantik and Anderl, 2016).

Actions towards digitisation are influenced by a company's specific **competitive situation**. Small and medium enterprises usually have fewer available funds or resources to implement comprehensive measures (Leyh and Bley 2016; Andulkar et al., 2018). This deficiency has a limiting influence on the effects of the status of the AB.

The aggregate composed of the status of the AB and the contextual conditions impacts a variety of factors to establish an overarching attitude towards digital investments. These factors include leadership initiatives around digital transformation and developing the competence of people and organisations; the strategic management of latency of investments as well digital standardisation strategies; and the manifestation of value capture.

Value capture incorporates the creation of value by digitisation as is amplified through means of networked activities (Arnold and Voight, 2017, p. 100). Increase in efficiency and or the use of

synergies (Zott et al., 2011, p. 1029) are simplified by networked communication to coordinate and capture value creation. The more the AB is balanced, the more a value-oriented decision on investments is enabled.

There is a time lag between the realisation of value and execution of the investments necessitating that a **latency of investment** to be recognised during the decisions-making process. The strategy for dealing with this latency (Maklan et al., 2015, p. 583) is formed by the AB and the given context as well as the understanding that production works as an overall process (see Industrial Value Chain Initiative 2018, p. 18).

Standardisation aims to cope with the increasing complexity of digitalised production through new and specific standards (Henssen and Schleipen 2014, p. 302). Combined with an overall positive context and AB, strategic orientation towards full standardisation can be expected (Buchholz et al., 2017, p. 32).

With **digital transformation leadership**, the need to understand the process of digital transformation is counted in. The leadership style is determined by the level of digital maturity (Berghaus et al., 2017, p. 22) which is reflected in observable behaviours.

The **development of people and organisational competences** is necessary to expand value and to bridge uncertainties around adopting new technology (Magruk, 2016, p. 279). In order to achieve economy of scale and synergy, broad digital skills are required throughout an organisation (Remane et al., 2017, p. 7).

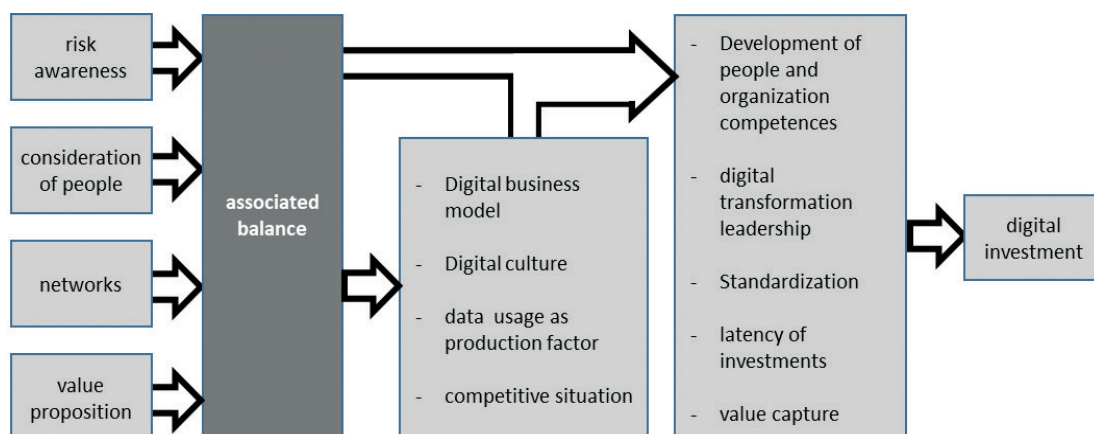


Figure 8. Grounded theory model after paradigmatic transition (source: Dold, 2020, p. 136).

These impact items underpin a behaviour toward investment decisions as they represent the measures taken to create value via innovation of technology (Chesbrough, 2010, p. 359). The question of what investment is the most attractive (Zennaro et al., 2018, p. 7) consequently follows from an attitude that ranges from being reluctant to being proactively entrepreneurial. The paradigmatic transition builds a grounded theory model as visualised in Figure 8 incorporating all considerations and phenomena outlined in the qualitative analysis. This model enables structured evaluation of individual projects and enterprises with regards to planning and execution of investments in digitalised production.

5. The digital investment toolbox

The transformation of conventional production processes towards a digitalised production paradigm promises to unlock further value generation and gains in competitiveness. However, many businesses struggle to start or scale up from their first light tower projects. This difficulty is due to the multiplicity of investment projects and technical innovations on the one hand, and uncertainty and a lack of best practices on the other. Businesses would benefit from guidance and tools to facilitate solidified decisions on investment priorities, and to map the transformation process.

In constructing the grounded theory model presented in the preceding sections, extensive analysis of the rich data and insights gleaned from the existing body of literature, plus expert interviews, was conducted. This analysis also enables the creation of a practical toolbox. The formative model, as outlined in Figure 8, delivers relevant elements to assess the condition of a business in regard to digitalised investment conditions, context, action, strategy, interaction, and consequent investment patterns. This assessment enables a validation of the desired “to be” condition from companies’ strategic considerations and identifies areas to change from “as is.”.

Based on the model and data insights, a toolbox to assess and validate the determinants of digitalised production can be developed. This Digital-Investment-Toolbox (DIT) enables enterprises to analyse and navigate their digital transformation process by efficiently managing the aforementioned digital investment paradox. Technically the logical connections are coded into Excel documents and the relations, queries and evaluations are realized

by VBA-scripts. The DIT (Figure 9) offers four tools based on the paradigmatic elements developed within the selective coding process. The “associated balance check” (ABC) is the first tool, and retrieves the observed status of the exogenous characteristics to determine the state of the AB. The second tool subsumes the contextual conditions and assigns a specific context pattern. This tool has been given the name “context compass” (CC). The output of the ABC-tool and the CC-tool are preconditions for the third tool to provide guidance about related impacts. This “impact guide” (IG) provides a set of “to be” conditions based on the observed conditions and context. These “to be” conditions are compared with the “as is” situation within the organisation to visualise the potential gap within the business. The fourth tool, the “investment validator” (IV), given the gap identified with the IG-tool, delivers recommendations for corrective actions, interaction, and strategy to realise the desired transition to digital investments.

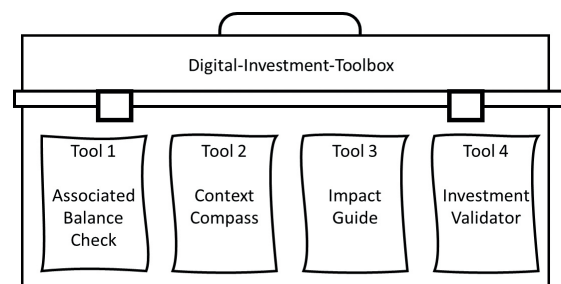


Figure 9. The Digital-Investment-Toolbox (source: Dold 2021, p. 92).

5.1. Associate Balance Check (ABC) – Tool 1

The ABC aims to determine the aggregated status of the relevant exogenous variables that form investment decisions for digitalised production. The variables consist of two-dimensional characteristics for each of the AB conditions identified within the qualitative model (risk level, networking, consideration of people, and value delivery). A numeric value can be assigned by taking into account the effect of both dimensional characteristics. The values are normalised within a range of +1 to -1 and correspond to a value related to the underlying results from the grounded theory process.

To calculate the AB value, eight characteristics have to be qualitatively evaluated and ranked as high or low, minor or complete, and isolated or holistic. For ease of use, four-field diagrams depicting the

corresponding value of each variable are determined, and finally the average of all four values is taken to define the state of the individual AB.

Figure 10 shows the ABC calculation card to be utilised in workshops and practical investment evaluation. The ABC-tool delivers an early prediction for business deciders regarding the solidity of the underlying variables as they relate to successful digitalised investment. Further, this easy tool enables identification of areas to address if the AB result turns out to be lower than 0.5 (critical or disrupted).

5.2. Context Compass (CC) – Tool 2

The specific context of the business to be digitalised has a significant impact on the actions, strategies and interactions to be established and considered. The context related to digitalised production is composed out of five variables; competitive pressure, resources, digital culture and digital business model, as outlined in section 4. The dimensional characteristics of these variables are more sophisticated than in the AB, and the constitution of the individual context is not based on a deterministic balance as is used to calculate the AB; there are a total of forty-eight possible combinations of the variables. However, based on the theoretical results, the number of different scenarios can be reduced to eighteen contexts. A headline has been defined for each identified context to describe the expected qualitative influence on digitalised investments. These headlines range from “missing

substance” to “high risk in digital transformation,” and from “digital laggard” to “digital specialist” and “digital leader.”

The CC-tool aims to underline the implications that may result from a business’s specific context, in which the intended investments are situated. Table 3 summarises the composed contexts in a simplified format. The CC-tool offers a full selection table as well a detailed explanation of each context, outlining the theoretically based implications and opportunities.

The CC-tool is uniquely valuable in its ability to offer evaluation of external factors which are rarely considered in traditional investment evaluation. The influence of the contextual elements on leverage of digitalisation can be highly supportive (e.g., contexts 7, 12, 16, 17 and 18) or obstructing (e.g., contexts 1, 3, 8 and 13). Once this contextual influence is understood, the CC also provides reflective insights to help identify blind spots and areas of improvement for the investment project.

5.3. Impact Guide (IG) – Tool 3

While the ABC and CC tools aim to assess exogenous elements and evaluate influences and possible blind spots within the decision-making process, the IG takes the related impacts into consideration and reveals potential gaps that may hinder the digitalised investment project. The first part of this tool surfaces

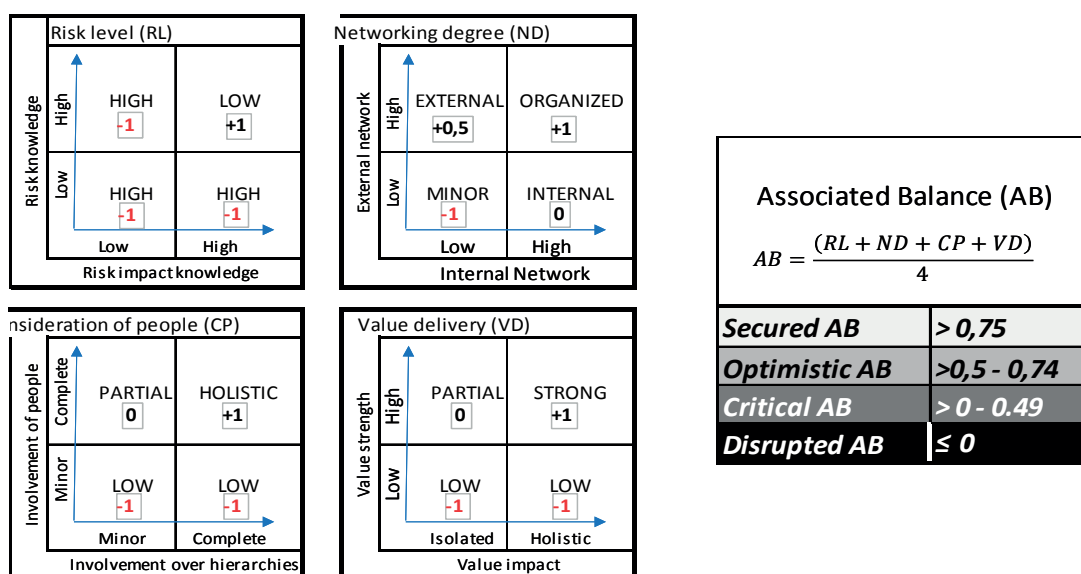


Figure 10. ABC-tool calculation card (Author’s illustration).

Table 3. The CC-tool with defined context combinations and related headlines (Author’s illustration).

Context number	Combined categories	Competitive pressure	Resources	Data usage	Digital Culture	Digital business model	Context headline
1	9	LOW	Low	Multiple combinations			Missing substance
2	3			Utilized	High	M. c.	Neutral readiness
3	6		Sufficient	No	Multiple combinations		Conservative basis
4	3			Utilized	Low	M. c.	Basis for digital beginners
5	1			Utilized	High	No	Basis for a digital start
6	1			Utilized	High	Partial	Digital fundament
7	1			Utilized	High	Holistic	Potential for digital leadership
8	6	High	Low	No	Multiple combinations		High risk in digital transformation
9	3			Utilized	Low	M. c.	Digital laggard
10	1			Utilized	High	No	Digital set up with limited resources
11	1		Utilized	High	Partial	Digital extension with limited resources	
12	1		Utilized	High	Holistic	Digital optimum with limited resources	
13	3		Sufficient	No	Low	M. c.	Neglected digital chance
14	3			No	High	M. c.	Ready for digital kick start
15	3			Utilized	Low	M. c.	Ready for digital leadership
16	1			Utilized	High	No	Digital kick-starter
17	1			Utilized	High	Partial	Digital specialist
18	1		Utilized	High	Holistic	Digital leader	

the required “to be” in the areas of strategy, action, and interaction, as indicated by the results of ABC and CC. The second part is a self-assessment of the “as is” situation. The final part compares the “to be” with the “as is” to visualise deficits and to prioritise corrective actions. Figure 11 illustrate the structure and rational of the IG-tool. The “to be” evaluation utilises a table of impact requirements based on theory. This impact table indicates clearly applicable impacts from the AB and the business context. If the evaluation results in a “non-applicable” judgement, the underlying theoretical conditions do not recommend proceeding with a digital investment until the AB or context improves or changes.

For the “as is” status evaluation, the dimensional characteristics based on the paradigmatic transitions are surveyed, as described below.

The interaction of value capture is judged as “High” or “Low” based on the additional expected value that can be gathered from three streams of value. First, the intermediate value resulting from direct savings in cost or proven improvements or productivity measures. Second, the mediate value delivered by improvements identified in the pre- and post-processes. Third, the value that is expected to be delivered with time delay. In relation to the two strategical impacts, the perceived “as is” paradigm must be judged. The paradigm related to latency of investments is rated as either “conventional,” “clearly defined,” or “entrepreneurial.” Similarly, the practical usage of standardisation is rated as “not defined,” “partial,” or “complete.” Paradigms of leadership and competence development are the basis of the action-based impact items, in which digital transformation leadership style is categorised

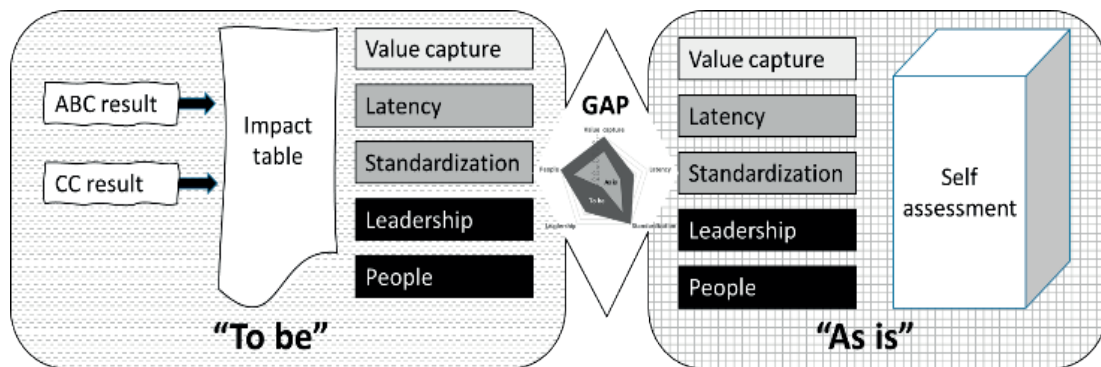


Figure 11. The Impact guide tool (Author’s illustration).

as “top-down,” “bottom-up,” “specialised,” or “innovative.” Activities to develop people’s and the organisation’s competences are rated as “Ad-hoc,” “project based,” or “holistic.”

A gap analysis collates the values in a radar chart to provide the IG-tool output. The IG is therefore the central tool within the DIT as it harnesses the theoretical results from grounded theory into a structural thought process that generates a practical gap analysis. The IG will clarify whether the intended digital investment considerations have theoretical stability or will identify the need for corrective measures that should be taken before wide-ranging investments in digitalisation are considered.

5.4. Investment Validator (IV) – Tool 4

While the three former tools offer guidance and clarity for operationally involved people up to the middle management, the IV-tool targets senior leadership, who sponsor the investment projects. Recall that the digital gap identified by Al-Debei and Avison (Figure 2) exists between the strategic considerations made by senior management and on-the-ground operations. The IV-tool aims to bridge the strategic agenda by identifying corrective actions to close the potential gap identified by the IG.

First, the IV-tool requires senior management to reflect on investment paradigms that are necessary to

best achieve the outlined digital transformation strategic targets. The tool describes the patterns of the investment paradigms, ranging from “cautious,” and “ROI-oriented,” to “innovative” and “entrepreneurial,” as compiled in Table 4.

The impact table used within the IG-tool correlates investment patterns to both the “to be” requirements (to support the given AB-status and context), as well as to the “as is” pattern (resulting from the operational assessment). In Figure 12, all three investment patterns are put into perspective and potential deviations with the strategic expectation of senior management are identified.

The IV-tool delivers the fundamental understanding about whether the digital gap exists—and if so, how wide it is—as well as pointing to where the limitations of the digital paradox may restrict necessary strategic implementations to capture value via digitalising production. As the findings of the IV-tool are based on insights generated from the IG, ABC and CC tools, this tool presents the overall digital awareness and capability to manage the effect of the decoupling of cost and value (presented in section 3).

The IV-tool further delivers transparency on corrective measures to senior management, provides understanding about how the value architecture of the business is composed, and how to capture the value from digitalisation via a holistic view.

Table 4. Understanding the strategic investment patterns within the IV-tool (Author’s illustration)

Investment pattern	Description
	The EIP is clearly looking ahead and acts in an open, innovation-friendly manner.
Entrepreneurial (EIP)	The paradigm is characterised by tangible entrepreneurial courage in the business. The characteristics of the EIP are an innovative approach to the digital transformation, the entrepreneurial wide horizon of expectations for ROI in future and the commitment to comprehensive standardisation amongst value chains and data streams.
	An IIP is characterised by the clear orientation towards technological benefits.
Innovative (IIP)	The commitment towards a full implemented standardisation is characteristic. The prevailing management style is either bottom-up or specialised. ROI orientation is considered but is handled flexible if the technological innovation promises to deliver a latent value.
	RIP is characterised by its clear orientation towards a defined ROI.
ROI-oriented (RIP)	RIP-based decisions require tangible timewise assessment, whereby the latency must be considered either conventionally or with clearly defined hedging. The leadership stick to conventional judgement and investment criteria as top-down or specialised approach. The immediate direct value creation is the dominating evaluation criteria within the RIP.
	CIP describes the cautious way of dealing with funds.
Cautious (CIP)	The willingness to invest for RIP, IIP and EIP is clearly recognisable by their specific characteristics and can be assigned as consequence of expected or proven value capture of digitalised investments. Conversely, it can be concluded that in consequence, if there is dominating uncertainty to decide for the three other patterns the cautious investment pattern apply.

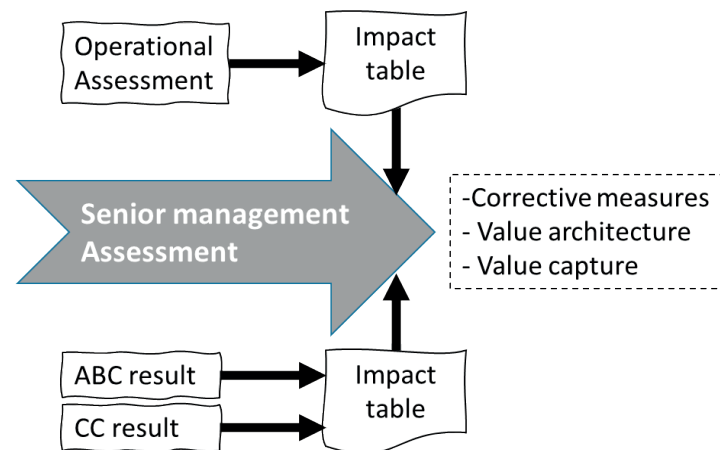


Figure 12. Investment validator process to point towards corrective measures (Auto’s illustration).

6. Conclusion and Discussion

Similar to other areas of technological innovation, the digital transformation of production presents companies and people with new challenges.

Though a majority of publications are focused on the new technology that comes with Industry 4.0, a digital gap between strategy and operational reality has created a paradoxical situation. This article promotes a holistic, cross-disciplinary perspective to resolve this decoupling between cost and value capture related to digitalised production. Senior management, middle managers, and operational contributors need to understand the relationship between these core elements of a digitalised business.

The researched grounded theory model delivers a solid understanding based on data from scholars and experts. The digital investment toolbox provides a method for applying this analysis to practical projects and is designed to offer a straight-forward assessment of the relevant parameters. This assessment enables organisations to understand where and how to tackle deficits and blind spots. The successful leveraging of digital investments will require sufficient maturity and full support from all layers. The toolbox is designed to indicate if digital maturity or leadership commitment appears insufficient. The parties involved, however, must heed these indications in order to benefit from a successful digital enterprise

and in order to make the necessary paradigm shifts away from practices that have been internalised over years of traditional business. The ultimate exercise outlined in the IV-tool carries potential to open eyes and promote change towards new entrepreneurial spirit and innovation.

7. Limitations and outlook towards further research

The research described in this article integrates data from heterogenous scientific disciplines. Since then, the impact of Covid-19 is supposed to have significant impact in the described transformation processes. As the proposed toolbox is based on pre-Covid data, a verification with post-Covid data is recommended once societies do return to a new normal paradigm. The qualitative analysis demonstrates the value of more frequent border crossing between disciplines for further research into the topic of digitalisation. The value-centric view will help practitioners to build bridges between technology, productivity, and business aspects. Other disciplines maybe be included within further research and expand the scope given by the limitations originated from selected disciplines. While the grounded theory delivers a formative model, further research is recommended to refine the relations and phenomena. The qualitative model delivers a solid base to combine a quantitative analysis for a mixed-methods-study.

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