

Article

Strategies for Knowledge Generation, Decision Support, and Overcoming Digital Hurdles in the Context of Industry 4.0 and Industry 5.0

Sebastian Trojahn ^{1,*} , Norge I. Coello-Machado ², Pia-Marie Kolbe ¹  and Elke Glistau ³

¹ Department Economics, Anhalt University of Applied Sciences, Strenzfelder Allee 28, 06406 Bernburg, Germany; pia-marie.kolbe@hs-anhalt.de

² Mechanical Engineering, Universidad Central “Marta Abreu” de Las Villas, Santa Clara 50100, Cuba; norgec@uclv.edu.cu

³ Institute for Engineering of Products and Systems, Otto von Guericke University Magdeburg, Universitätsplatz 2, 39106 Magdeburg, Germany; elke.glistau@ovgu.de

* Correspondence: sebastian.trojahn@hs-anhalt.de; Tel.: +49-(0)34713551369

Abstract: Traditional academic discourse has long prioritized published sources—such as monographs, peer-reviewed journal articles, conference proceedings, and legal or regulatory documents—as the sole authoritative references for scientific inquiry. While these sources undoubtedly provide a validated foundation of disciplinary knowledge, they also represent the codification of past insights and often lag behind emerging developments. This paper critically examines the limitations of this conventional epistemic framework and argues for its deliberate extension. In an era characterized by rapid information dissemination and knowledge creation across diverse platforms, a significant proportion of relevant expertise now resides outside the boundaries of traditional literature. Insights from domain experts, practitioners, real-time media (e.g., news reports, podcasts, video content), original data collection, experimental inquiry, and scholarly dialog increasingly constitute valuable sources of scientific knowledge. Drawing a parallel to data-driven disciplines, where historical records are complemented by real-time analytics and user-derived insights, this article outlines the categories of such contemporary knowledge that warrant academic recognition and proposes rigorous methodologies for their systematic integration into scholarly work.

Keywords: knowledge generation; Industry 4.0; Industry 5.0; digital hurdles; trustworthy public data



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1. Introduction

Digitalization and increasing connectivity are not only reshaping industrial practices but also creating new avenues for scientific research to access previously untapped sources of knowledge and experiential insights. Prevailing academic conventions continue to restrict references predominantly to publicly available written scientific sources, such as books, peer-reviewed journal articles, conference proceedings, abstracts, posters, and legal or regulatory documents. Nevertheless, a review of current research highlights a considerable gap between theoretical potential and practical application.

The aim of this article is to explore and propose strategies for effectively generating knowledge, providing decision support, and overcoming digital hurdles in the contexts of Industry 4.0 and Industry 5.0. By examining both theoretical frameworks and practical applications, the paper seeks to bridge the gap between emerging digital technologies and

their implementation in industrial settings. Ultimately, the goal is to equip practitioners with actionable insights and methodologies to enhance digital transformation efforts.

This article begins with an overview of the current landscape of digital transformation within Industry 4.0 and 5.0, highlighting the need for integrating diverse knowledge sources. Following this, the methodology section outlines the mixed methods approach used in the research. The subsequent sections discuss key strategies for overcoming digital hurdles, with detailed presentations of findings supported by tables and figures. The article concludes with actionable recommendations for practitioners and further research directions.

2. Methodology

This study employs a mixed-methods approach to explore the strategies for knowledge generation, decision support, and overcoming digital hurdles within the contexts of Industry 4.0 and Industry 5.0.

A literature review was conducted to identify existing research and theoretical frameworks concerning Industry 4.0 and 5.0. This involved analyzing peer-reviewed journal articles, conference proceedings, industry reports, and other scholarly publications to build a foundational understanding of the subject matter and identify gaps in current knowledge.

To supplement the literature review, semi-structured interviews were conducted with industry experts, including consultants, software developers, project managers, and corporate controllers. These interviews provided insights into the practical challenges and opportunities associated with digital transformation efforts. The expert interviews were critical for gathering non-academic perspectives and bridging the gap between theory and practice. In contrast to old approaches, we are now including expert interviews in the analysis and are applying our own methodology as outlined in Figure 1.

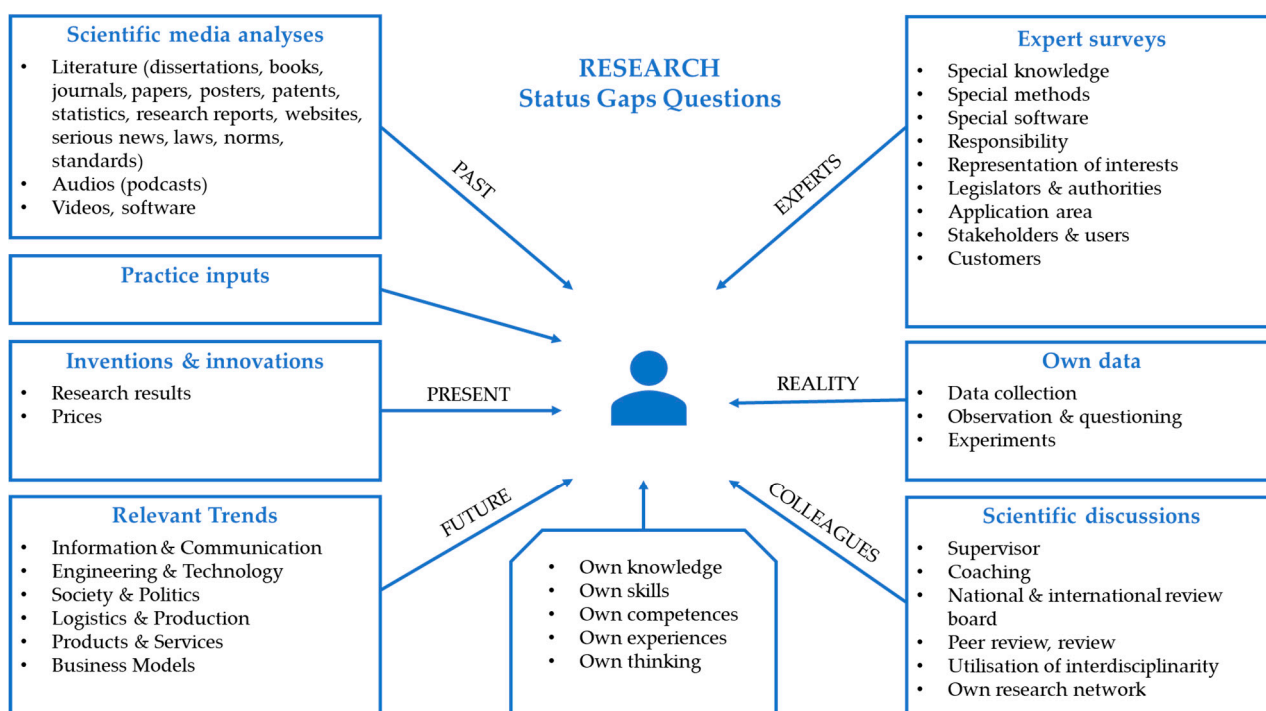


Figure 1. Holistic research data sources.

This research also includes case studies of select companies actively engaged in implementing Industry 4.0 and 5.0 technologies. These case studies provide real-world examples of strategies employed to overcome digital hurdles and highlight best practices.

The qualitative data collected from expert interviews and case studies were analyzed using thematic analysis. This approach involves coding the data to identify recurring themes, patterns, and insights regarding strategies for overcoming digital hurdles. Thematic analysis provided a nuanced understanding of the practical implications of digital transformation.

The findings were integrated to develop a comprehensive set of recommendations for knowledge generation, decision support, and overcoming digital hurdles in Industry 4.0 and 5.0 settings. This holistic approach ensures that the research addresses both the theoretical and practical dimensions of digital transformation.

The methodology and findings were validated through peer review and expert feedback. Feedback from these external sources helped refine the recommendations and ensure their applicability across different industrial contexts.

This methodology lays the groundwork for systematically exploring and addressing the digital hurdles faced in Industry 4.0 and 5.0, providing actionable insights that industry practitioners can implement to enhance their digital transformation initiatives.

3. New Recommendations

3.1. Recommendation 1: Expand the Knowledge Base

A broader range of reliable sources of knowledge and data is urgently required!

The integration of broader and more diverse sources of knowledge, experience, and data is essential for advancing scientific inquiry. In addition to traditional academic sources, valuable insights can be derived from fieldwork. This includes expert interviews, timely reports on innovations and technological developments (even those emerging from adjacent fields), and scholarly discussions. Many professionals with deep technical expertise, such as consultants, IT specialists, project managers, quality specialists, and corporate controllers, typically do not contribute to academic literature [1].

Current academic conventions, however, lack the mechanisms to adequately capture and systematically document the expertise of these groups. As a result, integrating the actual developmental status of Industry 4.0 and 5.0 remains incomplete as their practical knowledge cannot be fully incorporated or effectively communicated within the prevailing scientific frameworks. For example, motion mining can evaluate and improve manual processes from a lean perspective [2].

This gap places researchers in a challenging position. Non-academic, non-written knowledge is often excluded from formal documentation and referencing. In strict methodological terms, it may constitute an omission of relevant knowledge and a deviation from the principles of scientific integrity. These practitioners, however, are essential contributors to the development of optimal solutions. They possess in-depth understanding of infrastructural requirements, common operational pitfalls, and the economic limitations faced by enterprises, particularly small- and medium-sized enterprises (SMEs). They often find it difficult to absorb the fixed costs of digital transformation without jeopardizing their competitiveness.

Moreover, the inclusion of interdisciplinary perspectives has been shown to enhance the quality of solutions. Alongside conceptual research, expert dialogs and scholarly debates represent pivotal methods of knowledge acquisition. In this context, Trojahn et al. [1] have identified key sources of scientific knowledge, which the authors regard as a transformative development in the technical sciences (see Figure 1). The figure presents a framework illustrating how various sources contribute to the development of research questions, identification of gaps, and understanding of the current status in a given field. At the center is the researcher, surrounded by the following key input categories: scientific media analyses, practice inputs, inventions and innovations, relevant trends, expert sur-

veys, own data, scientific discussions, and literature reviews. These diverse sources interact to inform and shape the research process, ensuring that it is grounded in both theoretical knowledge and practical relevance [3].

A substantiated assessment of the current state of knowledge is essential for the further development of logistics systems. Table 1 shows the key components of a holistic analysis that systematically incorporates different sources of information. These include scientific media, market analyses, expert interviews, and current research findings, as well as our own observations and operational data. The aim is to capture relevant knowledge in a structured way—from theoretical principles and practical applications to real-world metrics and trends—to provide a reliable basis for strategic decisions.

Table 1. Examples of holistic analyses of the state of knowledge.

Components of a Holistic Analysis of the State of Knowledge in Logistics [3]	Relevant Knowledge
Scientific media analysis • Literature, E-books, • Audios, Videos.	• Terms, Definition/s, • Systematization, procedures, methods, • Application recommendations, • Laws, rules and standards, • Solution space, • Documented applications (national and international), • Selection algorithm, • Trends and goals.
Market analysis for • Software, • Technology (Internet, trade fairs).	• Software offered for the selection and operation of the provision, • Offered technology with characteristics) for the operation of the provision.
Expert interviews	• Work experience, • Qualification requirements, • Needs for support, • First experiences, • Real problems, • Input through interdisciplinarity and review board.
Current research (News, Headlines, Reports, and Events)	• Inventions, • Innovations.
Viewing, own observation	• Deviations from the target, • Interfaces in the flows, • Realization errors.
Utilization of operating data	• Real costs, • Real KPIs in relation to the identified targets, • Real capacity utilization (technology, personnel, space), • Real times, • Real distances, • Real stocks.
Scientific discussions	• Interdisciplinary work.

3.2. Recommendation 2: Implementation and Manual Processes!

Two distinct solutions are required: one for standard cases and another for exceptional scenarios where no digitalization is available.

In the era of digitalization and ubiquitous networking, manual processes continue to play a significant role. Certain processes inherently favor manual execution, including the following:

- Unique or unpredicted processes,
- Critical processes,
- Novel processes requiring initial testing prior to automation,
- Processes mandated by legal or regulatory frameworks to involve manual intervention,
- Inventive processes that derive value from human ingenuity (see more in [1]).

These scenarios demand not only the continued use but also the potential development of manual process variants. Moreover, the process landscape extends beyond a simple dichotomy of manual versus digital operations. Manual processes are often highly flexible manufacturing processes. Digital assistance systems make sense. These use a wide variety of sensor technology [4]. Hybrid approaches frequently deliver superior outcomes—for example, integrating FAQs, chatbots, and human interaction to enhance the quality of customer information services (see Table 2).

Table 2. Comparison of manual and digital processes.

	Manual	Hybrid	Digitizes	Networked
• Duration, • Effort, • Error rate, • Safety.				Reduced
• Actuality, • Accuracy, • Decision quality, • Transparency, • Traceability.				Higher
• Total costs + responsibility + consideration.				
• Empathy, • Flexibility, • Individuality, • Reliability, • Emergency reserve.	Higher			

Additionally, the rising frequency of disruptions affecting digital solutions cannot be overlooked. Notable examples include the following:

- Unauthorized publication of sensitive data,
- Disruption of administrative systems through cyberattacks,
- Incidents involving data manipulation,
- Power or Internet outages (e.g., the case of Cuba, Spain).

Not only do such events enflame fear and a heightened sense of vulnerability, but they also force decision-makers to take significant action. Guaranteeing the resilience of digital solutions requires flexibility, such as the integration of redundancy, alongside agility for swift responses in times of disruption.

These scenarios underscore the urgent need for robust solutions that complement conventional digital processes. Both industrialized and developing nations stand to benefit from mutual learning and collaboration in developing intelligent offline solutions. But is universal digitalization truly necessary? Not in all cases. When thinking about cost-effectiveness, how often a process repeats, its importance, and what we have learned from

experience, it becomes clear that not every process should be digitalized without careful consideration. Figure 2 presents a decision-making framework to guide through this process.

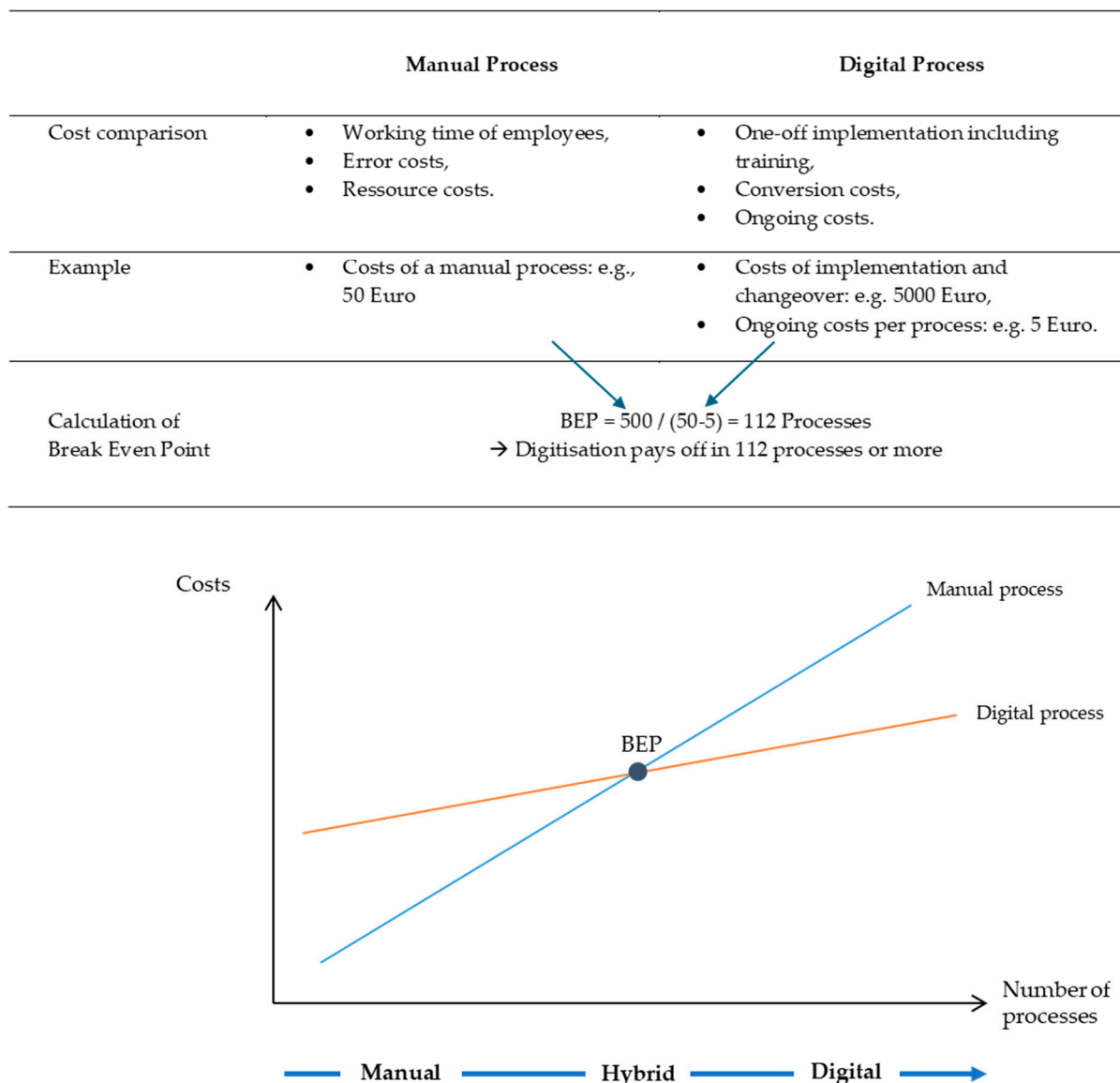


Figure 2. Determination the level of information automation in processes: manual, hybrid, and digital.

In addition, the effects of switching to digital processes can be taken into account when making decisions. Digital processes significantly reduce time- and cost-intensive factors such as working time, susceptibility to errors, resource consumption, and the rework process. At the same time, the use of digital solutions noticeably increases key performance indicators such as speed, efficiency, scalability, and competitiveness. Digital tools can simplify and speed up manual processes [5]. Manual workstations continue to play an important role. AI-supported assistance systems are necessary [6].

Digital processes are especially appropriate for the following:

- Standardized and routine processes,
- Processes requiring statistical analysis,
- Processes historically plagued by high error rates and extensive processing work,
- Complex processes with many participants.

Manual processes are especially appropriate for the following:

- Sporadic and flexible processes,
- Processes with a need for human interaction,
- Ethical processes.

Manual processes act as a safety net for high-risks processes, tasks with small failure tolerance, and newly implemented processes. They offer a fallback option, ensuring continuity in situations characterized by high risk or inherent unpredictability.

3.3. Recommendation 3: Remove Difficulties

High costs, a lack of qualified employees, and security concerns delay the widespread digitalization and networking efforts in SMEs!

Table 3 presents our step-by-step approach designed to address obstacles to digitalization within the research process. This visual representation clarifies the sequential method used to identify and overcome barriers, thereby aiding in a smoother transition to digital solutions.

Table 3. Procedure to remove obstacles.

STEP 1	Open list of barriers for digitalization in production, logistics, trade, and agriculture	• Literature analysis on summarizing studies, • Expert interviews, • Own expertise.
STEP 2	Open list of measures to specifically reduce barriers for digitalization	• Literature analysis on recommended measures for the individual barriers, • Expert interviews, • Own expertise, • ‘Expert discussion’ with AI chatbots [7].
STEP 3	Selection and assignment of particularly suitable literature references for scientific referencing	• Selection and assignment of particularly suitable literature references for scientific referencing.
STEP 4	Compilation of the results as a guideline for action (table)	• Own conceptual work.

Table 3 outlines a structured process for addressing digitalization barriers across various sectors such as production, logistics, trade, and agriculture. It begins with the identification of barriers (Step 1) and progresses to defining measures aimed at mitigating these barriers (Step 2). The process continues with the selection and alignment of relevant literature for scientific referencing (Step 3), culminating in the compilation of findings into an actionable guideline (Step 4).

Building on the identification of barriers and strategies, Table 4 presents specific obstacles in digitalization along with measures to overcome them.

In strategy and leadership, common issues include the lack of a digitization strategy and undefined goals. Organizations are advised to outline clear objectives, create precise plans, and prioritize projects, especially when resources are tight. Data protection and security are major challenges due to high requirements. Measures include appointing a data protection officer, providing regular employee training, and conducting external audits to ensure compliance with security standards. Costs pose significant barriers, with high initial investments and maintenance expenses. Recommendations include identifying funding programs, focusing on ROI, and exploring open-source software for cost-effective solutions. Human resource challenges, such as a lack of skilled personnel and technological know-how, are addressed by encouraging regular training, collaborating with universities, and involving employees early in digital initiatives. Poor internet connectivity is highlighted as

an infrastructure issue. The table suggests modernizing IT infrastructure and using cloud technologies to support digital operations more effectively.

The previous tables have provided a detailed look at the specific barriers to digitalization and offered actionable measures to address them. Building on this foundation, the next table compiles insights from extensive literature reviews and expert interviews to reveal common obstacles across various studies. This literature-based analysis enhances our understanding of systemic challenges and underscores the need for comprehensive strategies to overcome them.

Table 4. Barriers to digitalization and strategies for eliminating the barriers [8–14].

	Obstacle	Measures
Strategy and leadership	• No digitization strategy, • Undefined goals, • Lack of prioritization.	• Outline the objectives to be achieved through digital transformation in the organization, • Use the objectives to create a precise plan and set milestones, • Prioritize projects with limited financial resources, • Use of modern methods.
	• Lack of management.	• Presentations or workshops that convince the management level itself, • Integrate digitalization goals for manager.
	• Necessary revision of many internal processes.	• Automation of routine tasks.
Data protection and data security	• High requirements for data protection and data security.	• Appointment of a data protection officer and temporary deployment of external IT security experts in the processing of sensitive data, • Ensure and monitor compliance with defined safety standards, such as ISO 27001, • Regular training of employees in IT security and secure working methods, • Conduct external audits to identify and close security gaps, • Consideration of security certificates (e.g., B. ISO 27001) when selecting software vendors.
	• Legal uncertainty regarding the use of different digital tools.	• Obtain legal advice, • Use standard solutions from other companies.

Table 4. Cont.

	Obstacle	Measures
Costs	Financing problem (investments in new technologies and systems cause high initial costs).	Identify and use funding programs.
	High total costs: - Very cost-intensive to purchase, - Maintenance (servicing), - Training costs for existing staff, - Updates.	- Prioritization with a focus on ROI, - Open-Source software, - Open-source information material, - Open-source alternatives, - Efficient cloud solutions, - Maintenance contracts with providers including real-time monitoring.
	Particularly high fixed costs	Use funding programs: - Carry out a cost–benefit analysis, - Gradual implementation instead of a complete changeover at once.
	Opportunity costs due to implementation or conversion of IT systems	Introduce targeted measures to reduce opportunity costs.
Resources, knowledge, and personnel	Lack of know-how.	- Regular training courses, - E-learning platform for flexible learning.
	Opportunities not recognized due to ignorance.	- Clear communication and presentation of the benefits of digitalization and networking, - Involve employees right from the start, - Introduce digital communication systems such as Teams, - Involve all departments in digitalization, - Organize information events.

Table 4. Cont.

	Obstacle	Measures
Resources, knowledge, and personnel		• Clear differentiation between three levels of expertise: (1) General workforce (must be able to handle the systems provided), (2) IT specialists (have to work directly with the IT systems, implement and maintain them), (3) Highly experienced IT specialists (responsible for the future planning and implementation of IT systems as decision-makers). • Cooperation with external IT service providers, • Cooperation with universities, • Ongoing recruitment of new, young employees, • Retraining of own employees • Cooperation with other companies ○ Gain know-how and perhaps also generate new solutions (including companies from abroad). • Careful partner selection and transparent agreements, • Introduce training programs.
	• Lack of skilled workers and associated IT expertise,	
	• Lack of technological knowledge.	
	• Change itself.	• Involving employees right from the start
	• Lack of resources.	• Step-by-step introduction
Infra-structure	• Time pressure in daily business.	• Optimize time management, automate routine tasks, and provide resources for innovation projects
	• Poor quality of the Internet connection,	• Investments in modern IT infrastructure,
	• No continuous fiber optic network.	• Collaboration with technology providers, • Inventory and prioritization, • Use of the cloud.

Table 4. Cont.

	Obstacle	Measures
Data	Digitization of existing data.	Structured, low-effort approach.
	Incomplete data.	- Clean-up, sort, and structure data, - Standardize data storage.
	Storage of data in isolated systems.	- Modernization of the IT system structure, - Integration of legacy systems.

The following Table 5 offers a synthesis of key obstacles identified in the literature, ranging from IT security and data protection to the lack of qualified personnel and digital infrastructure. It highlights recurring themes such as high administrative burdens, uncertain economic benefits, and legal uncertainties.

Table 5. Main findings from current studies on the topic of ‘Obstacles to digitalization’.

Literature	Main Findings
[3]	- IT security and data privacy, - Significant administrative workload, - Limited availability of qualified personnel, - Insufficient digital infrastructure.
[4]	- Lack of resources and/or expertise, - Unclear advantages, - Cautious about of new technological innovations.
[5]	- Lack of resources and/or expertise, - Unclear advantages.
[6]	- High costs, - Incompatibility of digital technologies, - High system complexity, - Lack of knowledge about the systems.
[7]	- Question about profit, - Cautious about of new technological innovations.
[8]	- IT security and data privacy, - Significant administrative workload, - Limited availability of qualified personnel, - Insufficient digital infrastructure, - Lack of financing.
[9]	- Legal obstacles, - Process-related barriers, - Unclear advantages.

By presenting these insights, the table emphasizes the importance of addressing both technological and organizational hurdles in digitalization efforts. It serves as a valuable reference, guiding future research and practical implementations aimed at overcoming these persistent challenges.

The following obstacles are consistently observed in both our own analyses and the findings from the literature:

- Budget constraints,

- Data security,
- Shortage of staff.

Tables 6–8 show examples of how to promote digitalization processes in companies. Table 6 shows various internal measures to reduce fixed costs in the context of digitization. It clearly demonstrates how fixed costs can be reduced through targeted technological and organizational approaches and how digitalization can be designed to be economical.

Table 6. Key example 1: reduction in fixed costs.

Budget Constraints	
Within your own organization	With partners or through partners
Use software:	
• Use of free, standardized, or open-source software.	Partnerships with IT companies.
Software development:	
• Re-evaluation of software acquisitions and development	Outsourcing development teams.

Table 7. Key example 2: increasing data security.

Increasing Data Security	
Within your own organization	With partners or through partners
• Applying data encryption, • Data backup and disaster recovery strategies.	• Security audits, • Penetration tests.
Persons:	
• Assign access rights according to absolute necessity, • Strong password guidelines and implementation of multi-factor authentication, • Regular training.	Cooperation: • Cooperation with external security consultants.

Table 8. Key example 3: availability of qualified personnel.

Shortage of Staff	
Within your own organization	With partners or through partners
• Attractive employer branding, • Promoting an innovative working environment.	• Partnerships with universities and educational institutions, • Cooperation with HR Agencies.
Recruitment:	External personnel:
• Innovative recruiting, • Competitive salaries and benefits.	• Involve external consultants and self-employed individuals.

Table 7 provides an overview of the most important measures that can be taken to improve data security within the organization. Both internal technical and organizational approaches as well as external audits and collaborations are presented. The measures range from data encryption and security guidelines to penetration tests and cooperation with external security experts.

Table 8 shows an overview of key measures for recruiting, retaining, and developing qualified personnel both within the company and through external partnerships. In

addition to strategies such as attractive employer branding, flexible working models and targeted personnel development, partnerships with educational institutions, external consultants, and innovative recruitment approaches also play an important role.

In contrast to the past, the focus should not only be on one-off training, but on regular training and testing at the latest level. The organization of basic and advanced training for first responders, for example, serves as a model, renewing, expanding, and regularly training knowledge and skills through refresher courses and training sessions.

As online and self-learning will become more important in the future, this area must also be actively developed with digitalization. A company will only be successful in the long term if it keeps its own staff up to date and trained.

Table 9 lists some important formats in the relevant area of further education and training and at the same time offers scope for your own additions and activities in the future. The aim here is not to be exhaustive, but to provide suggestions for diversifying this area.

Table 9. Examples of typical formats for further education and training.

Formats of Further and Advanced Training:			
Events: • Conference, • Panel discussion, • Lecture, • Seminar, • Course (with/without certificate), • Training (with/without certificate), • Workshop, • Course, • Module, • Course of study.	Practice: • Case study, • Tour, • Excursion, • On-site meeting, • Best practice, • Best practice forum, • Trade fair, • Exchange of experience, • Job rotation, • Triad discussion.	Online: • Webinar, • Online course, • Distance learning, • Exam, • Special podcasts, • Video.	Self-study: • Own, self-organized knowledge acquisition via, e.g., audio, videos, web, • Learning teams, • Learning tandems, • Self-initiated exchange among colleagues, • Exchange with chatbots.
Evaluation: • Internal audit, • External audit, • Review, • Accreditation.			

4. Conclusions

This article addresses three key guiding concepts for digital transformation within the contexts of Industry 4.0 and Industry 5.0. The first concept underscores the necessity of comprehensive data collection that extends far beyond traditional literature reviews. The goal is to enable a robust scientific analysis that will allow for the targeted advancement of digital processes. For further details, the authors refer to their previous works [1,2]. The second concept highlights the critical importance of having non-digital fallback solutions. Offline strategies are vital to maintaining operational continuity in the event of disruptions or system failures. This section explores areas where digital processes provide substantial efficiency gains and identifies situations where manual processes remain justified. Hybrid solutions, particularly those leveraging artificial intelligence, present a promising avenue for further enhancement. The third concept addresses the obstacles hindering digitalization, such as high fixed costs, concerns regarding data integrity, and the scarcity of qualified personnel. Rather than simply documenting these challenges, the article advocates for

their active and incremental removal. To this end, specific actionable recommendations are provided that organizations can adopt independently to overcome these barriers.

Each of the three concepts is accompanied by tailored recommendations to guide companies in advancing their digital transformation efforts in a structured and successful manner.

In conclusion, this paper has addressed the multifaceted challenges and opportunities presented by digital transformation in Industry 4.0 and Industry 5.0. By examining both traditional and contemporary sources of knowledge, we have identified strategies that can enhance decision-making and effectively mitigate digital hurdles. The integration of expert insights, combined with robust methodology, has provided a clearer understanding of how industries can navigate the complexities of digitalization. We recommend that future research continues to explore the dynamic interplay between emerging technologies and industry practices, ensuring that businesses can not only adapt but thrive in this evolving landscape. Through the collaborative efforts of academia, industry practitioners, and policymakers, the potential of digital transformation can be fully realized, driving innovation and efficiency across sectors.

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