ChemSkills

The Enabling Technologies for Digitalization in the Chemical Process Industry

Marcin Pietrasik, Anna Wilbik, and Paul Grefen

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Who are we?

- Marcin Pietrasik
    - Postdoctoral researcher in Data Fusion at Maastricht University
    - PhD in Electrical and Computer Engineering
- Anna Wilbik
    - Professor in Data Fusion at Maastricht University
    - PhD in Computer Science
- Paul Grefen
    - Professor in Information System Architecture at the Eindhoven University of Technology
    - Principal Architect at Eviden
    - PhD in Computer Science
- **Perspective:** computer science, digitalization, and business process experts

Our work

- The chemical process industry is facing several challenges:
  - A skills shortage in the labour market
  - Reaching its sustainability goals in the face of changing climate realities
  - Transitioning from existing feedstock and energy sources to alternative, more sustainable ones

- **Our work** focuses on investigating how digital solution can be leveraged to solve these problems

- Develop a **roadmap** for digitalization in the chemical process industry
  - In collaboration with the Brightsite initiative at Chemelot Campus in Geleen

- **First step:** identify the enabling technologies that make the digital transformation possible

Aims

- **Identify** and **categorize** the enabling technologies for digitalization, thereby providing **structure** to an otherwise loosely connected basket of technologies

- Identify the **problem domains** that characterize the chemical process industry and connect them to **development aspects** in the industry that lend themselves to digital solutions

- For each of these connections, **select** the technologies **most essential** to bridging the gap between problem and solution

- Provide **case studies** to cast a spotlight on the use of state-of-the-art technologies that offer great potential but are still underutilized in an industrial context

Enabling Technologies

- Leveraged the 11 enabling technologies identified by (Ortiz, 2020) an extension of the nine pillars put forth in earlier works (Rüßmann et al., 2015, Silvestri et al., 2020)

  - Big data and analytics
  - Autonomous robots
  - Simulation
  - Cloud computing
  - Additive manufacturing
  - Extended reality
  - Artificial intelligence
  - The industrial internet of things
  - Cybersecurity
  - 5G
  - Horizontal and vertical integration

Enabling Technologies

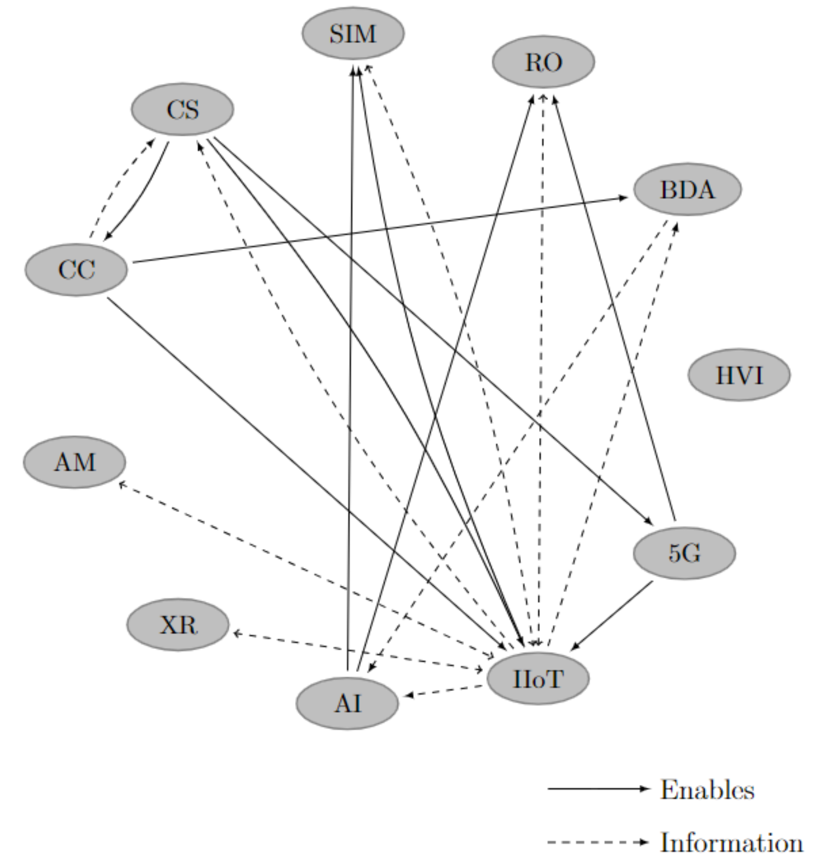


Figure 1: Graphical depiction of the relationships between enabling technologies. Solid lines represent an enabling dependency between technologies and dashed lines represent the directed flow of information between technologies. For instance, 5G → IIoT indicates that 5G enables the industrial internet of things whereas IIoT --→ SIM indicates that information flows from the industrial internet of things to simulation models of plant processes. We note that relations may be bidirectional such that IIoT ←-- SIM indicates that the simulation model also sends information back to the industrial internet of things.

Enabling Technologies

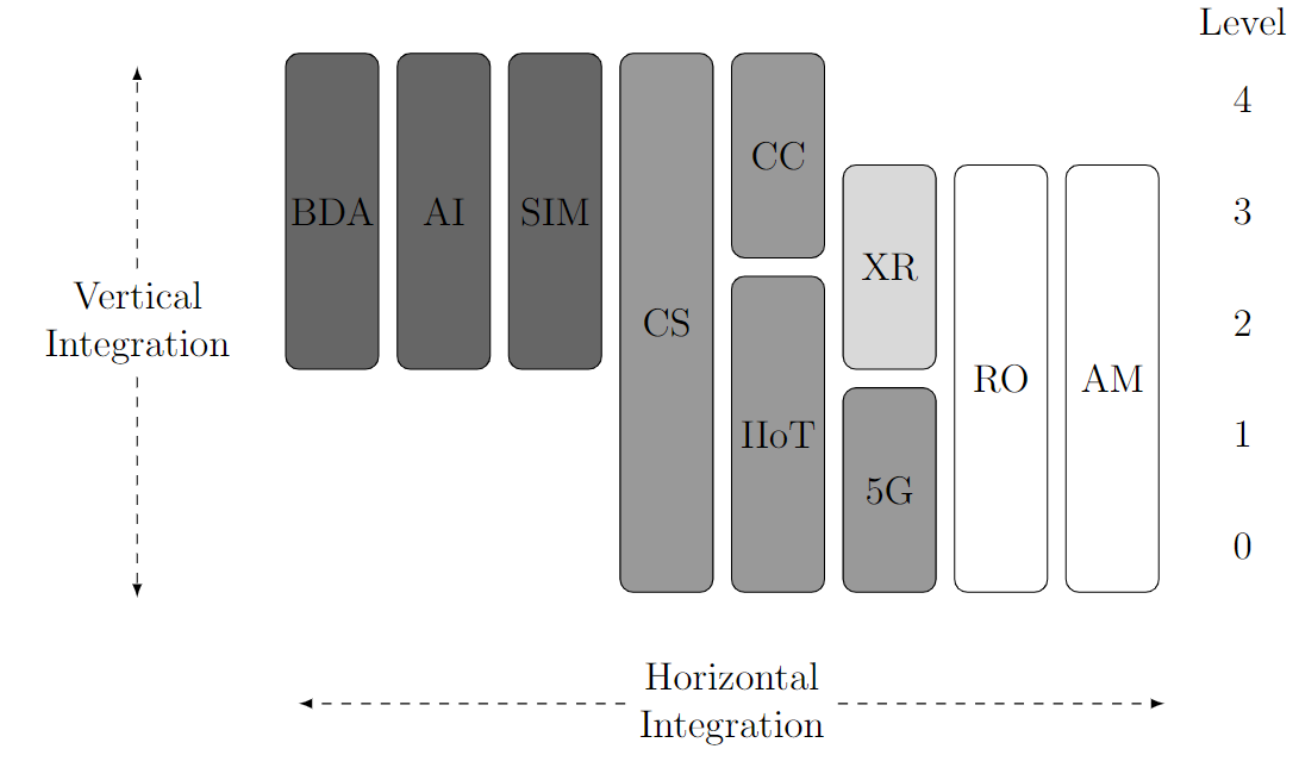
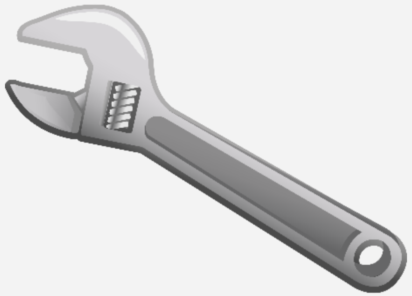


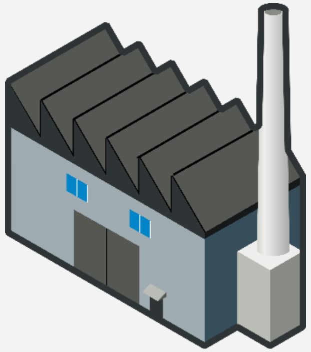
Figure 2: Graphical organization of the enabling technologies using ISA-95. Shading reflects technology clustering. Recall the ISA-95 levels from zero to four: (0) production, sensor, and actuator hardware; (1) sensor and actuator control; (2) work cell and reactor control; (3) production process and plant control; and (4) customer order management.

Problem Domains

Maintenance

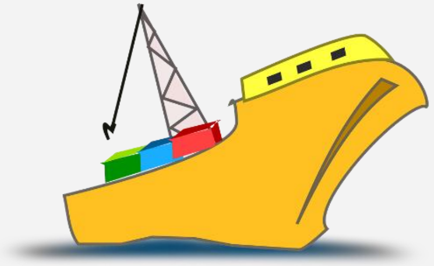


Production



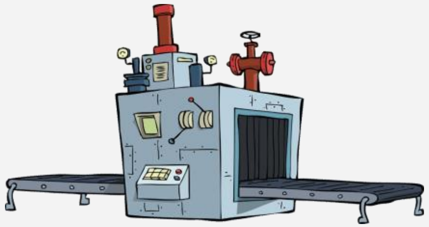
Safety
Management

Supply Chain
Management



Development Aspects

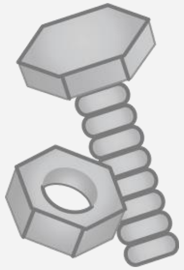
Assets



People

Feedstock

Energy



Spare Parts

Site

	Maintenance	Production	Safety	Supply Chain
Assets	√	√	√	√
People	√	√	√	
Feedstock		√		√
Energy		√		√
Spare Parts	√			
Site	√	√	√	√

Problem domain	Development aspect	BDA	RO	SIM	CC	AM	XR	AI	IIoT	CS	5G	HVI
Maintenance	Assets	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
	People	✓			✓		✓	✓		✓	✓	✓
	Spare Parts					✓						
	Site	✓	✓		✓		✓	✓		✓	✓	✓
Production	Assets	✓		✓	✓	✓		✓	✓	✓	✓	✓
	People	✓			✓		✓	✓		✓	✓	✓
	Feedstock	✓		✓				✓				
	Energy	✓		✓				✓				
	Site	✓	✓		✓			✓		✓	✓	✓
Safety	Assets	✓		✓	✓		✓	✓	✓	✓	✓	✓
	People				✓	✓	✓			✓	✓	
	Site	✓	✓		✓		✓	✓		✓	✓	✓
Supply Chain Management	Assets	✓		✓	✓			✓	✓	✓	✓	✓
	Feedstock	✓		✓				✓				
	Energy	✓		✓				✓				
	Site	✓			✓			✓	✓	✓		

Artificial Intelligence for Predictive Maintenance


Focus – Infographic

Digital industry

04 Focus Infographic

Infographic The digital transformation is making ever greater advances and permeating the value chains of industry. Here are some examples.

Predictive maintenance

In the steam cracker, where many important basic chemical building blocks for subsequent use in production at BASF are produced, several thousand sensors capture process data such as pressure and temperature around the clock. This information is evaluated by analysis software to predict the best time for maintenance work, avoiding unplanned downtime and operating the plant in the best possible way.

Digital logistics

Autonomous and automatically driven vehicles are directed around the plant site by transponders in the ground. This saves time. At BASF in Ludwigshafen, it currently takes around 22 hours for a conventional railway tank car to be delivered from the plant's train station to one of more than 150 loading stations. With autonomously driven, driverless vehicles, the delivery takes only an hour.

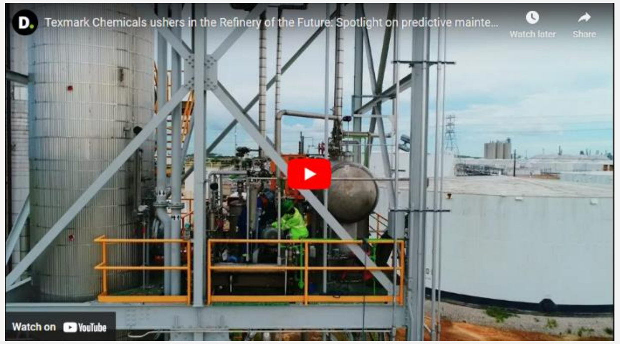
Information on the ground

At production plants, increasing use is being made of industry-specific tablets that make it possible to access information on-site in the plant (augmented reality). Operating instructions or measurements, among other things, are shown on the display. Employees are taught how to handle new digital technologies as part of their initial and continuing training.

18 – Creating Chemistry

Catalyzing digital transformation to build the Refinery of the Future

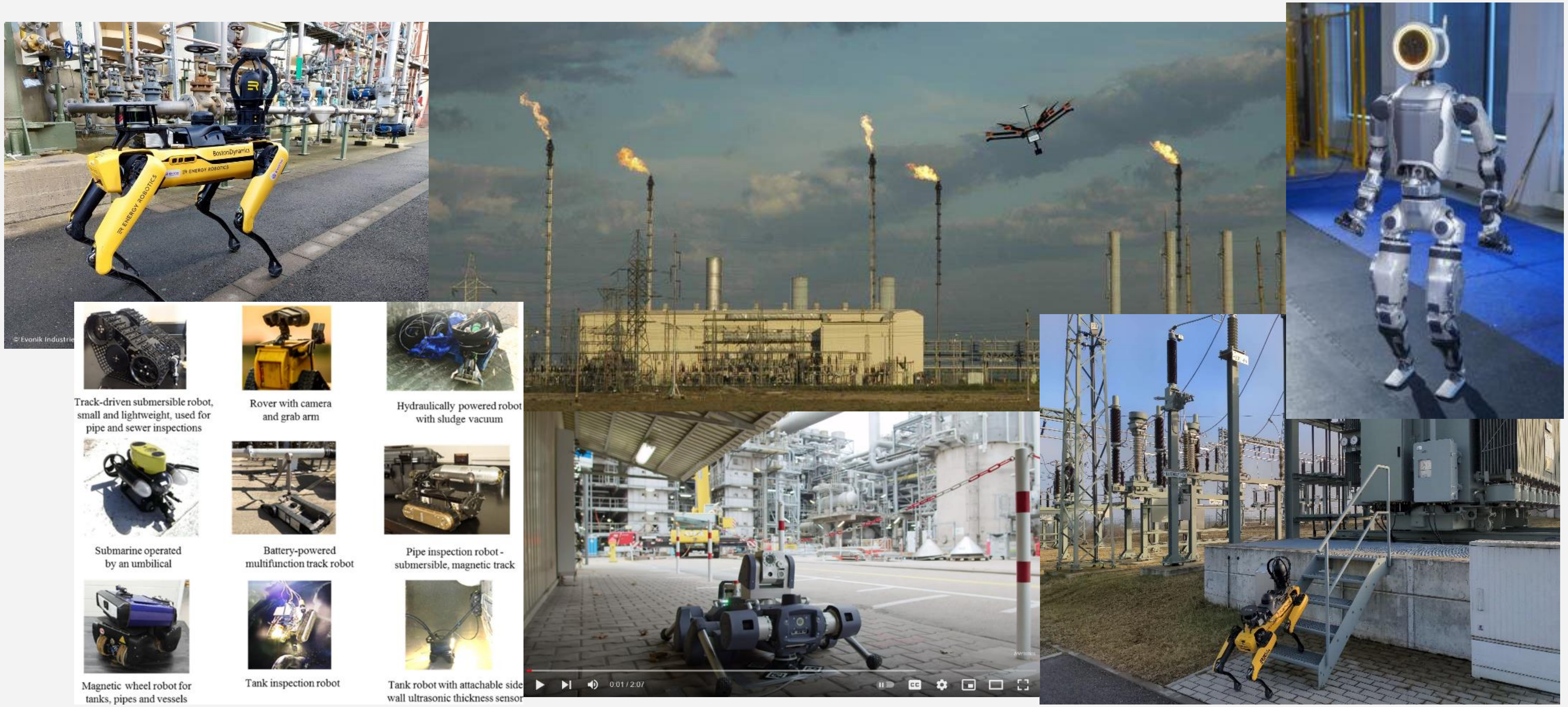
Using IoT technology, Deloitte helped Texmark Chemicals digitally transform their refinery operation. Now, they save time and money using predictive maintenance.



downtime. Predictive maintenance typically reduces machine downtime by 30 to 50 percent and increases machine life by 20 to 40 percent.

Internet of Things: Mapping the Value Beyond the Hype, suggested that manufacturers' savings from predictive maintenance could globally total between $240 and $630bn by 2025.

Autonomous Robots for Automated Asset Inspection



Extended Reality as Digital Aids to Human Performed Maintenance

Questionnaire

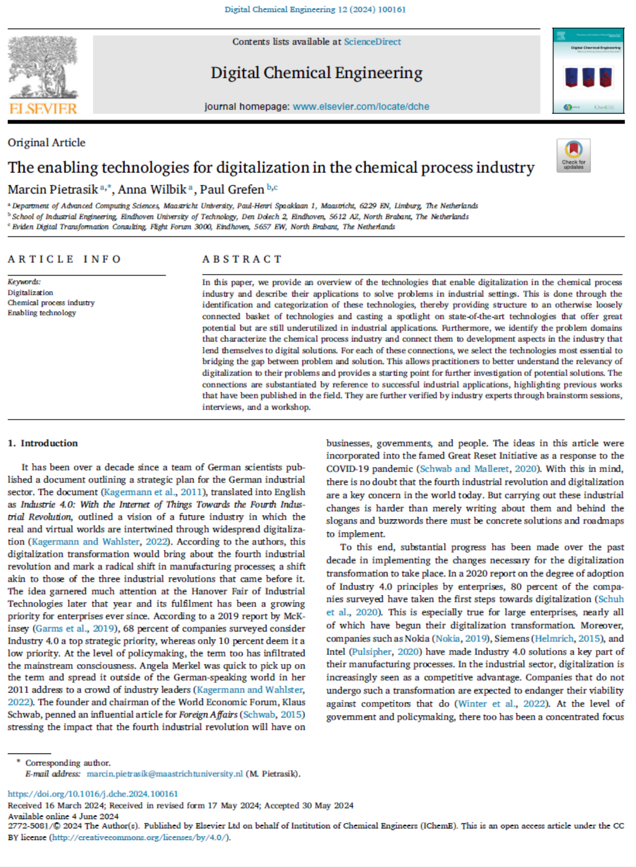
- Online questionnaire was sent to gauge acceptance of the enabling technologies by industry experts
- Questioning was performed using the Technology Acceptance Model to ensure or orthogonality in the questions. Specifically, the questions were:
  - Are you **confident** in answering questions related to [the enabling technology] in the chemical process industry?
  - Do you perceive [the enabling technology] as **useful** in your company?
  - Do you perceive [the enabling technology] as **easy to implement** at your company?
  - Do you **intend to use** [the enabling technology] in the future at your company?
  - Would you like to learn more about [the enabling technology] and how it relates to digitalization in the chemical process industry?

Key Insights

	Top 3	Bottom 3
Usefulness	Artificial Intelligence Simulation Big Data and Analytics	Additive Manufacturing Autonomous Robots Extended Reality
Ease of Implementation	Cloud Computing 5G Cybersecurity	Autonomous Robots Artificial Intelligence Extended Reality
Intent of Use	Simulation Big Data and Analytics Artificial Intelligence	Additive Manufacturing Autonomous Robots Extended Reality

Summary and Next Steps

- Published a **comprehensive overview** of the enabling technologies for digitalization in the chemical process industry
- Continue working alongside industry partners at Chemelot to bring about **digital solutions**
- Develop a **maturity model for digitalization** in the industry that will serve as the backbone of a digitalization roadmap



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Original Article

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ABSTRACT

In this paper, we provide an overview of the technologies that enable digitalization in the chemical process industry and describe their applications to solve problems in industrial settings. This is done through the identification and categorization of these technologies, thereby providing structure to an otherwise loosely connected basket of technologies and casting a spotlight on state-of-the-art technologies that offer great potential but are still underutilized in industrial applications. Furthermore, we identify the problem domains that characterize the chemical process industry and connect them to development aspects in the industry that lend themselves to digital solutions. For each of these connections, we select the technologies most essential to bridging the gap between problem and solution. This allows practitioners to better understand the relevancy of digitalization to their problems and provides a starting point for further investigation of potential solutions. The connections are substantiated by reference to successful industrial applications, highlighting previous works that have been published in the field. They are further verified by industry experts through brainstorm sessions, interviews, and a workshop.

1. Introduction

It has been over a decade since a team of German scientists published a document outlining a strategic plan for the German industrial sector. The document (Kagermann et al., 2011), translated into English as *Industrie 4.0: With the Internet of Things Towards the Fourth Industrial Revolution*, outlined a vision of a future industry in which the real and virtual worlds are intertwined through widespread digitalization (Kagermann and Wahlster, 2022). According to the authors, this digitalization transformation would bring about the fourth industrial revolution and mark a radical shift in manufacturing processes; a shift akin to those of the three industrial revolutions that came before it. The idea garnered much attention at the Hanover Fair of Industrial Technologies later that year and its fulfilment has been a growing priority for enterprises ever since. According to a 2019 report by McKinsey (Garms et al., 2019), 68 percent of companies surveyed consider Industry 4.0 a top strategic priority, whereas only 10 percent deem it a low priority. At the level of policymaking, the term too has infiltrated the mainstream consciousness. Angela Merkel was quick to pick up on the term and spread it outside of the German-speaking world in her 2011 address to a crowd of industry leaders (Kagermann and Wahlster, 2022). The founder and chairman of the World Economic Forum, Klaus Schwab, penned an influential article for *Foreign Affairs* (Schwab, 2015) stressing the impact that the fourth industrial revolution will have on businesses, governments, and people. The ideas in this article were incorporated into the famed Great Reset Initiative as a response to the COVID-19 pandemic (Schwab and Malleret, 2020). With this in mind, there is no doubt that the fourth industrial revolution and digitalization are a key concern in the world today. But carrying out these industrial changes is harder than merely writing about them and behind the slogans and buzzwords there must be concrete solutions and roadmaps to implement.

To this end, substantial progress has been made over the past decade in implementing the changes necessary for the digitalization transformation to take place. In a 2020 report on the degree of adoption of Industry 4.0 principles by enterprises, 80 percent of the companies surveyed have taken the first steps towards digitalization (Schuh et al., 2020). This is especially true for large enterprises, nearly all of which have begun their digitalization transformation. Moreover, companies such as Nokia (Nokia, 2019), Siemens (Helmrich, 2015), and Intel (Pulsipher, 2020) have made Industry 4.0 solutions a key part of their manufacturing processes. In the industrial sector, digitalization is increasingly seen as a competitive advantage. Companies that do not undergo such a transformation are expected to endanger their viability against competitors that do (Winter et al., 2022). At the level of government and policymaking, there too has been a concentrated focus

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