Industrie 4.0 in Germany

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German government has recognized the need for a strategic development of Industrie 4.0 for the next decade. It set the ambitious goal in its Industrial Strategy 2030 of increasing the share of German industry in gross value added in the economy to 25% by 2030—an increase of five percentage points. Industrie 4.0 promises to be an important driver in this regard, with its target vision of the AI-driven smart factory and digital, platform-based business models. To leverage the potential of Industrie 4.0 in view of the economic, ecological, and geopolitical challenges of our time, and to follow a holistic approach for creating open digital ecosystems, strategic focus in Germany is set on three areas: sovereignty, interoperability, and sustainability.

Keywords: Industrie 4.0 ; smart manufacturing ; smart factory ; digital transformation ; artificial intelligence ; value creation networks ; sustainability ; sovereignty ; interoperability ; mass customization

1. Sovereignty

Globalization has caused high interdependencies in global value chains. German industry is highly dependent on raw materials, predominantly from the Far East (e.g., China). The digitalization of industry creates new dependencies, predominantly from the US, where most of the technology companies delivering services for German industry (e.g., Microsoft with Azure, Amazon with AWS, or Salesforce and Oracle with its services) are located. Under the presidency of Donald J. Trump, the U.S. gradually turned away from Europe as its primary geostrategic and economic partner[1]. Even though it might have been a temporary phenomenon, it highlighted—together with the "trade war" between China and the US—the importance of technological sovereignty for the EU and Germany in terms of economic policy. This has been recognized by policymakers, e.g., in the EU White Paper on Artificial Intelligence, which emphasizes the importance of economic sovereignty in general and in particular for Industrie 4.0 with the vision 2030 of the German Plattform Industrie 4.0. Whereas technological sovereignty demands government action to ensure independence on a macroeconomic level, on a microeconomic level, individual companies need to operationalize this strategic directive by increasing their ability "to cope with shocks of different sorts"[2] (p. 5) by becoming resilient.

The resilience of value networks requires specific attention as the COVID-19 pandemic has unveiled the dependency of German industry on global value chains[3]. Supply chain problems have led to a widespread production standstill causing a phase of deterioration in German industry. The shortages of semiconductor electronics and cable harnesses, as well as the Russian invasion in Ukraine causing oil and electricity price explosions, are affecting companies significantly. With these factors put together, German industry companies are not resilient in facing crises and volatility on the world market[4]. To increase the resilience of its value networks, German industry requires a strategy coupling robustness, to reduce the effects of volatility on company performance, with agility, in order to respond quickly to unpredictable disruptive events. Three measures to increase resilience can be identified in this regard: (1) the adoption of value creation networks, (2) safe and secure data integration, and (3) reliance on Industrie 4.0 technologies[5].

The paradigm of single sourcing coupled with just-in-time delivery has caused a production standstill during the COVID-19 pandemic due to the strict lockdowns in divergent parts of the world over time. German industry is still dependent on global value chains, as 43% of Germany's net exports are only generated due to its embedding in global value chains. This dependency needs to be reduced.

A short-term measure in this regard is a mitigation of the just-in-time paradigm by maintaining larger inventories. In the event of a catastrophe—for example, in the event of economic lockdown measures in one production country—it would be possible to quickly switch to capacities in other production countries. This mitigates the supply-side risk by diversifying production capacities, but leads to higher costs.

A medium-term approach is a local-for-local strategy, i.e., locating production and the upstream value chain in the sales market. By synchronizing supply- and demand-oriented risks in sales markets, only the respective regional clusters are affected in the event of a disaster. This concentration effect mitigates the risk of supply chain disruptions. At the same time, resources are duplicated to a much greater extent, causing efficiency losses. These solution approaches provide more resilience, but are not able to counter the increasing uncertainty and pressure for change in the market environment.

Thus, in the long run, the monolithic and highly optimized value chains of the present could be gradually replaced by resilient and adaptive value creation networks: multiple sourcing based on regional local for local strategies, the creation of redundancies to allow for flexible reaction on crises, and a diversification and continuous evaluation of the supplier base as part of risk and sustainability management.

Based on the paradigm of co-creation, value creation networks require data infrastructure that allows companies to collaborate seamlessly in order to develop and strengthen resilient business models that, on a macroeconomic level, promise to increase digital sovereignty [6]. Data spaces are important drivers in this regard as they aim at not only increasing digital sovereignty, but also data sovereignty, enabling the secure, decentralized, and self-determined exchange, collection, analysis, and sharing of data. Thereby, they form the basis for new, highly scalable, data-driven, and platform-based business models—one of the focus points in the next decade of Industrie 4.0.

Next to the establishment of value creation networks, data integration is a prerequisite for a resilient Industrie 4.0. This is currently not achieved in practice, as SMEs especially face problems regarding data management[7]. They require support and innovative data ecosystem. Data integration comprises, in this regard, the use of platforms where standardized data exchange is enabled. Real-time monitoring of procurement, logistics, production, and sales processes allows for optimization of processes, and the created data could also be integrated into data exchange platforms and could train self-learning AI models for an industry-wide optimization of production.

Therefore, the industry-wide implementation of Industrie 4.0 technologies is key. Software-based risk management is required for resilient and adaptive value creation. Big data analytics and artificial intelligence are the basic technologies for reaching the paradigm of the *Smart Factory*. Digital twins or digital shadows require industry-wide penetration[8]. Only if industry applies those technologies can it future-proof for the next decade of Industrie 4.0.

2. Interoperability

Industrie 4.0, postulating the AI-driven smart factory and platform-based business models, requires the establishment of an innovative ecosystem where companies and customers interact seamlessly. To reduce transaction costs, interoperability is key. In the first ten years of Industrie 4.0, significant initiatives were started. The GAIA-X project aims at developing a safe and interconnected data infrastructure for a European digital ecosystem with industry sitting at its heart setting policy rules, guidelines, and a standard architecture framework contributing to cross-sector interoperability. The launch of RAMI 4.0 as an international industry-specific standardization and reference architecture for Industrie 4.0, the coordination of the standardization of Industrie 4.0 by the Standardization Council Industrie 4.0, the establishment of OPC UA as a standard for interoperable interfaces for AI-driven production, and the launch of the administration asset shell have improved industry-specific interoperability predominantly by means of standardization[9].

For the next decade of Industrie 4.0, Open-Source will play a pivotal role in implementing and exploiting interoperability for the creation of new platform-based business models. Already at the beginning of the 2020s, Open-Source Software (OSS) contributes between €65 billion to €95 billion to the EU’s GDP (equaling EU-GDP of air and water transport combined) and promises significant growth opportunities in the future, especially for Industrie 4.0.

Currently, economy-wide motivations for participating in OSS mainly lie in the need to find technical solutions, avoid vendor lock-in—a factor that is also relevant for technological sovereignty—and build knowledge in high-quality coding. At the same time, as OSS builds on voluntary contributors, its cost–benefitratio is a highly promising driver for value creation: for every Euro invested, a €12 value creation is achieved. This is a significant lever, especially for SMEs in the industry, given the cost pressures they are facing.

However, to exploit this lever across the breadth of the manufacturing sector, further advancements for OSS from a technological, regulatory, and innovative perspective are required. Within companies, Open-Source needs to be integrated as an elementary step in value creation. This begins with the development and the communication of an Open-Source strategy developed by an interdisciplinary team creating acceptance and support in the workforce from scratch onward. It should be embedded in a top-level vision and strategy, which could imply the application of OS to create standards, to boost business model strategies, or to gain competencies in core technologies.

Once initiated, an Open-Source Program Office (OSPO) should boost implementation. As the central business unit responsible for Open Source (OS) processes, the OSPO is responsible for quality management, checking license compatibilities and Open Source Sofware (OSS) integrity with Intellectual Property, and importantly, also for the qualification of employees regarding OSS. Senior management in this phase needs to ensure the establishment of an OS mindset in the workforce alongside the selection of communities and ecosystems fitting to OS properties.

Additionally, the concrete areas of action of OS need to be crosschecked continuously. It is recommended to only develop OS for non-IP-relevant products, processes, or code, which should not be attached to the primary value proposition of a company. If the latter did occur, a company would cannibalize its market position. This indicates the need for continuous adaptation of and reflection on business models.

In industrial policy, Open-Source has played an important role. However, European governments have taken a more laissez-faire approach, and today, the EU is on the back foot when it comes to capabilities in this area. Hence, it is recommended also for the public sector to establish OSPOs, to publicly fund R&D projects related to Open-Source more intensively, to support entrepreneurial activities around OSS, and to build a European ecosystem around OSS, among other recommendations.

3. Sustainability

The need for sustainable economizing is more important than ever in view of aggravating global socioeconomic inequality and many tipping points that will be reached in the context of the climate crisis. German industry is the second biggest polluter of greenhouse gas (GHG) emissions beyond the energy sector. Thus, German government has set ambitious goals to reduce the ecological footprint of the industrial sector. Greenhouse gas neutrality should be achieved by 2045.

Industrie 4.0 is pivotal in this regard[10]. The smart factory standalone promises to reduce emissions and increase energy efficiency by optimizing resource need and consumption of production. However, rebound effects, such as overproduction and overconsumption caused by a more efficient smart factory, could even increase the ecological footprint of German industry. The same holds for artificial intelligence as a driver for the smart factory and platform-based business models. According to a recent analysis[11], AI contributes positively to 139 of 169 indicators of the 19 UN Sustainable Development Goals (UN SDGs)–the central reference point of a holistic comprehension of sustainability–whereas it affects 59 of those 169 indicators negatively at the same time.

Thus, to exploit the positive effects of ICT while mitigating its negative externalities on sustainability, a strategic combination of digitalization and sustainability is required to create win–win–win scenarios for economy, ecology, and society[12] (pp. 64–70); ‘Digitainability', as a strategic perspective on Industrie 4.0 based on circular economizing and sustainable business models, is the vision in this regard.

Strategically merging sustainability and AI-driven Industrie 4.0 offers potential for companies to create new and resilient value creation networks or to even design sustainable platform-based business models that promise to increase and solidify revenue streams for industrial companies and in affiliated sectors (e.g., agricultural machinery technology). Smart Services are important drivers in this regard[14].

If companies become that innovative, this creates market opportunities for German and European industry to position itself as a market leader regarding sustainable services, products, and service-product system offerings on B2B platforms. Such an ecosystem—given a sufficient level of interoperability—would promise to strengthen the sovereignty of German and European industry.

References

1. Kristian L. Nielsen; Anna Dimitrova; Trump, trust and the transatlantic relationship. *Policy Studies* **2021**, *42*, 699-719, 10.1080/01442872.2021.1979501.
2. Konstantin Neumann; Tim van Erp; Erik Steinhöfel; Felix Sieckmann; Holger Kohl; Patterns for Resilient Value Creation: Perspective of the German Electrical Industry during the COVID-19 Pandemic. *Sustainability* **2021**, *13*, 6090, 10.3390/su13116090.
3. Min Cai; Jianwen Luo; Influence of COVID-19 on Manufacturing Industry and Corresponding Countermeasures from Supply Chain Perspective. *Journal of Shanghai Jiaotong University (Science)* **2020**, *25*, 409-416, 10.1007/s12204-020-2206-z.

4. Dabo Guan; Daoping Wang; Stephane Hallegatte; Steven J. Davis; Jingwen Huo; Shuping Li; Yangchun Bai; Tianyang Lei; Qianyu Xue; D'maris Coffman; et al. Global supply-chain effects of COVID-19 control measures. *Nature Human Behaviour* **2020**, *4*, 577-587, 10.1038/s41562-020-0896-8.
5. Forschungsbeirat der Plattform Industrie 4.0. Wertschöpfungsnetzwerke in Zeiten von Infektionskrisen. Expertise des For-schungsbeirats der Plattform Industrie 4.0; acatech: Munich, 2021; pp. 1-68.
6. Kagermann, Henning; Streibich, Karlheinz; Suder . Digital Sovereignty. Status Quo and Perspectives; acatech: Munich, 2021; pp. 1-36.
7. Joel Sansana; Mark N. Joswiak; Ivan Castillo; Zhenyu Wang; Ricardo Rendall; Leo H. Chiang; Marco S. Reis; Recent trends on hybrid modeling for Industry 4.0. *Computers & Chemical Engineering* **2021**, *151*, 107365, 10.1016/j.compchemeng.2021.107365.
8. Ron S. Kenett; Jacob Bortman; The digital twin in Industry 4.0: A wide-angle perspective. *Quality and Reliability Engineering International* **2021**, *38*, 1357-1366, 10.1002/qre.2948.
9. Erdal Tantik; Reiner Anderl; Integrated Data Model and Structure for the Asset Administration Shell in Industrie 4.0. *Procedia CIRP* **2017**, *60*, 86-91, 10.1016/j.procir.2017.01.048.
10. Björn Sautter; Shaping Digital Ecosystems for Sustainable Production: Assessing the Policy Impact of the 2030 Vision for Industrie 4.0. *Sustainability* **2021**, *13*, 12596, 10.3390/su132212596.
11. Ricardo Vinuesa; Hossein Azizpour; Iolanda Leite; Madeline Balaam; Virginia Dignum; Sami Domisch; Anna Felländer; Simone Daniela Langhans; Max Tegmark; Francesco Fuso Nerini; et al. The role of artificial intelligence in achieving the Sustainable Development Goals. *Nature Communications* **2020**, *11*, 1-10, 10.1038/s41467-019-14108-y.
12. Ulrich Lichtenthaler; Digitainability: The Combined Effects of the Megatrends Digitalization and Sustainability. *Journal of Innovation Management* **2021**, *9*, 64-80, 10.24840/2183-0606_009.002_0006.
13. Plattform Lernende Systeme. Mit KI den Nachhaltigen Wandel gestalten. Zur Strategischen Verknüpfung von KI und Nachhaltigkeitsmanagement in Wirtschaft, Wissenschaft und Gesellschaft; acatech: Munich, 2022; pp. 1-48.
14. Maximillian Frank; Christian Koldewey; Martin Rabe; Roman Dumitrescu; Jürgen Gausemeier; Arno Kühn; Smart Services – Konzept einer neuen Marktleistung. *Zeitschrift für wirtschaftlichen Fabrikbetrieb* **2018**, *113*, 306-311, 10.3139/104.111913.
