Article

JIM
ISSN: 2183-0606
(CC BY 3.0)
Vol. 11, 1 (2023)
p. 1-17
AM: Jan/2023
SM: Apr/2021

Business Model Innovation in the German Industry: Case Studies from the Railway, Manufacturing and Construction Sectors

Johannes Winter[1]

[1]L3S Research Center, Leibniz University of Hannover, Appelstr. 9a, 30167 Hannover, Germany | *winter@L3S.de*

Abstract

For a long time, the business activities of industrial companies in mechanical engineering, plant construction or the automotive industry focused on products and product-related services. Digital pioneers have refined these products, such as machinery, equipment, and devices with data-driven services, which they make available worldwide via digital platforms. This emerging trend influences existing and future business models of all companies. This transition from product-related, single-sided markets to platform markets is characteristic of the digital age. The speed at which business models must change continues to be underestimated by many market participants, especially when order books are well-filled and the pressure to change appears to be low. Industrial and service companies need to adapt to the changes induced by new market players to secure future business success and remain competitive in the digital age. The aim of this article is to intensify the debate on digital business models in the industry by providing practical examples of business model innovations in three industries.

Keywords: Digital Transformation, Business Model Innovation, Business Process Reengineering, Smart Data, Artificial Intelligence, Machine Learning, Manufacturing Industry, Railway Industry, Construction Industry.

Cite paper as: Winter, J., (2023). Business Model Innovation in the German Industry: Case Studies from the Railway, Manufacturing and Construction Sectors, *Journal of Innovation Management*, 11(1), 1-17.; DOI: https://doi.org/10.24840/2183-0606_011.001_0001

---

1 Introduction: Business model innovation in the digital age

Successful business models have long been stressed by increasing competitive and cost pressures, breaking down silos, and commoditization of products and services. In the digital age, this is compounded by new entrants offering entirely new value propositions that will be data-driven and disruptive (Christensen et al., 2015). This is because once developed, software platforms have process costs that tend toward zero. This makes it easy to aggregate massive amounts of data, learn from data with artificial intelligence (AI), and develop digital business models from it that can scale exponentially across domains and countries.

1.1 Single-sided markets, platform markets, innovation ecosystems

However, the business logic of traditional industry typically follows the linear value chain model (Porter et al., 2015, p. 98ff.). This affects sectors such as automotive industry, mechanical engineering, plant construction, chemical industry, and other manufacturing industries. Companies process goods in several stages to create higher-value end products and sell them to consumers.

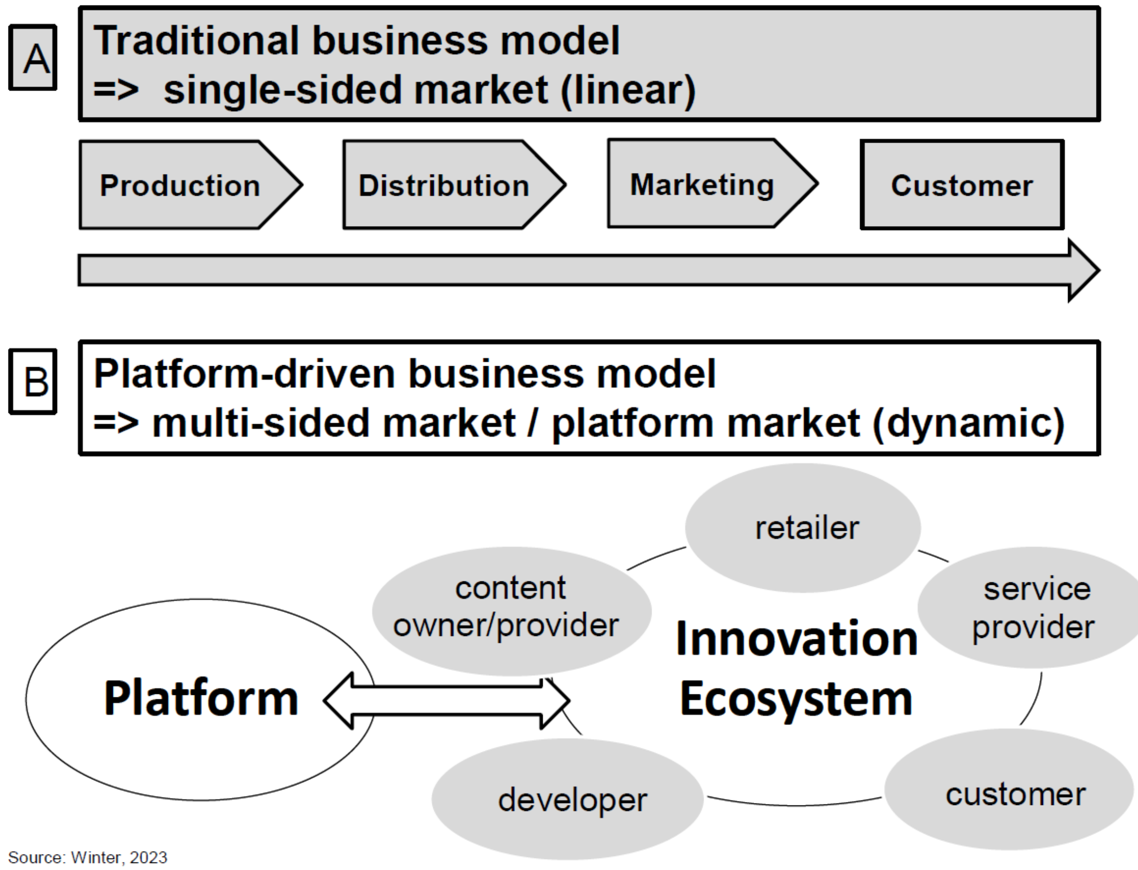


Figure 1. Single-sided markets, platform markets, innovation ecosystems (own illustration)

They generate value by managing the process of value creation activities that build on each other. Markets that function according to this principle are also referred to as single-sided, one-sided, or supply-driven markets (see figure 1). In contrast, platform markets are multi-sided markets characterized by the so-called network effect (Rochet et al., 2016, p. 645; Rysman, 2009, p. 125). Network effects arise when a product is valued according to the extent to which other market participants adopt or use the same product via the platform (Jullien et al., 2021, p. 2). This means that the more market participants of a certain group are on the platform, the more attractive a platform is for another group of market participants. However, once a critical mass is reached, a highly interconnected value creation system is formed, which significantly increases the opportunities for market transactions and significantly reduces transaction costs (Brynjolfsson et al., 2002).

1.2 Characteristics of digital platforms

Platforms are companies or services provided by companies that connect market participants and enable them to interact or transact via digital infrastructures (Jullien et al., 2021, p. 2). In contrast to single-sided markets, the platform (company) is not necessarily manufacturer and owner of the traded goods and services, but primarily owner and operator of the marketplace.

Platforms usually consist of two central technical components (Tiwana, 2013, p. 225): a platform core in terms of technical infrastructure with a business management layer. This platform core is controlled by the platform provider. The second part is the platform periphery, which sometimes combines several hundred thousand dependent service providers such as APP developers and e-commerce stores (see Figure 1). Amazon and Alibaba have perfected this model. APP developers use platform technology made available to them through APIs (application programming interface) or SDKs (software developer kits) (Winter, 2010, p. 147). From the periphery, they dock onto the platform core via programming interfaces, without the externals maintaining business relationships with each other in the process. They co-exist and usually compete (co-evolution). Together, they make up a digital business or innovation ecosystem: the more apps are offered to consumers, the more consumers will use the platform, and the more the individual developer benefits from the demand. A self-reinforcing growth occurs (Tiwana, 2013).

If a firm successfully positions itself as a platform provider and operates a platform business model, it can achieve a dominant position by acting as an intermediary between the producers and consumers of the market. This poses a serious risk for a lead firm in the value chain, such as an automotive manufacturer, as it may lose the direct interface with its customers (Cusumano et al., 2019, p. 75; Winter et al., 2022, p. 7).

1.3 Platform-based business models

Today, the traditional approach to business in industry is being disrupted by Internet giants and platform companies from primarily the United States, Korea, and China (Kagermann et al., 2018). As explained before, a digital platform is a marketplace that connects suppliers and consumers, as well as any other providers, via the Internet and enables value-creating interactions between them (Parker et al., 2016). This digital transformation of the marketplace and business model implies that a growing proportion of manufactured goods are now smart and refined through the collection, storage, analysis, and evaluation of data (Kagermann et al., 2017, p. 25). In the process, smart product-service bundles are changing the business logic of entire industries and markets by being based on digital platforms, enabling data-driven services, and creating digital innovation ecosystems through networked value creation by complementary market players. On this basis, completely new business models can emerge in the industry. The starting point for these new business models is a radical focus on the customer with his or her individual needs. Instead of selling a physical product such as a medical device, an agricultural machine or a machine tool, platform companies and digital pioneers aim to offer customers an adequate range of product-service systems at any time and any place.

The aim of this paper is to intensify the debate on digital business models in the industry by presenting and analysing case studies on business model innovations in three industrial sectors. The study consists of four main parts. The first and second parts deal with the problem definition and the methodological approach of the work. The third part highlights the rise of platform companies and the transformation of industry. Finally, some conclusions and an outlook follow.

2 Methodological approach, limitations, and target groups of the article

This paper provides a practical insight into the digital business model innovation in the German industry. The article is primarily designed for applied researchers and practitioners, as it offers a concrete insight into the strategic and implementation-orientated process of business transformation and digital business model innovation in various companies and industries. The article focuses on individual case studies from the German economy. Accordingly, it should be examined to what extent transferability to other geographical regions of the world is possible or whether regional differences could sometimes come into play.

In the following, three qualitative case studies are presented. The findings, results and implications of the case studies are not necessarily transferable to other companies, sectors and industries but offer a valuable orientation framework for applied corporate research and enable companies of varied sizes and orientations to gain direct insight into specific transformation processes.

The case studies presented in section 4 were based on qualitative interviews with industry executives and experts in Germany between September 2015 and March 2020. The data collection was conducted through exploratory semi-structured guided interviews based on existing studies, publications and projects on the relevant research and innovation areas in industry and services. The qualitative questionnaire and interview guide included guiding interview questions as well as quantitative elements.

The in-depth interviews were transcribed and analysed using 'Qualitative Content Analysis' (Glaeser et al., 2004). The article is based on results from two research and accompanying projects conducted at acatech - German Academy of Science and Engineering and funded by the German Federal Ministry for Economic Affairs and Energy (acatech, 2016) and the German Federal Ministry of Education and Research (acatech, 2023), respectively.

3 The digital transformation of industry

The interviews conducted with representatives from industry and the service sector overwhelmingly reinforce the assumption that digital technology platforms are increasingly becoming the dominant marketplace for new business models. Digital platforms have a productivity-enhancing effect by creating transparency and networking actors, capital, and resources more efficiently – and with almost unlimited reach via the Internet (Kagermann et al., 2018). The network effect ensures self-reinforcing growth of the platform. The more participants are connected via the platform, the more the participants benefit from using it and the more attractive the platform becomes for new customers, suppliers, and providers.

Based on the empirical findings obtained, five trends can be derived that represent an increase in the importance of digital offerings in the industry and strengthen the transformation of this key industry:

3.1 Big Data and artificial intelligence are driving the transformation of the industrial sector

All experts interviewed agreed that data is increasingly becoming an economic asset, has a value of its own and forms the basis of innovative and profitable business models. Intelligent products and machines are connected via the Internet even after they leave the factory and exchange massive amounts of data during their use. This Big Data is refined into Smart Data, which can then be used to control, maintain, or further develop and improve smart products and services. They generate the knowledge that forms the basis for new business models.

Advanced tools for data-based analysis and prediction such as artificial intelligence (AI) and machine learning have the potential to become a game changer and permanently change the rules of the global economy (Daugherty et al., 2018; McAfee et al., 2017). The beginnings of AI date back more than half a century. However, the big breakthrough came only a few years ago. The Internet and sensor technology brought unimaginable amounts of data that could be used to train learning, adaptive software systems and increasingly achieve hit accuracy (accuracy) and robustness in use. Exponential growth in the IT industry, with huge advances in computing and storage power, now made it possible to process and understand this data by machine, in near real-time. For example, AI helps with speech and pattern recognition, image processing, machine vision, or human and (cognitive) machine interaction. This is driving new data-driven product

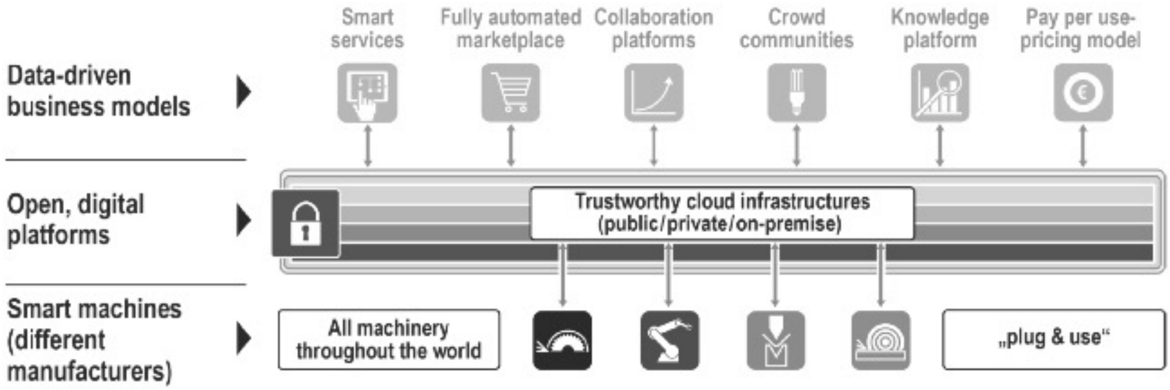


Figure 2. The architecture of data-driven business models (Source: acatech (2015), p. 12)

and service innovations in all industries. Examples include real-time, adaptive, and intelligent production (Industry 4.0; Winter, 2020, p. 10f.; acatech, 2016), or automated underwriting in the finance, legal and insurance industries.

Consolidation and refinement by mean of real-time analytics and AI usually takes place in data-intensive digital platforms, which, as explained at the beginning, are becoming the predominant marketplace. Industrial companies have already connected smart products to the Internet and started collecting and analysing data. However, many pilot projects do not yet make it from proof-of-concept to productive application and are rarely scalable (Falk et al., 2020). Ideally, platforms combine, for example, device management with connectivity, data storage systems and an app store with digital services provided by an open digital ecosystem. Crucial to the successful implementation of new data-driven business models is how good the digital innovation ecosystem is and how quickly it can be built (see Figure 2). In addition, various challenges regarding financing, reliability, data security, IPR (Intellectual Property Rights) protection and finally standardization must be answered.

3.2 Digital business models complement outdated product offerings.

Following the principle of the circular economy, digital sharing platforms can contribute to greater efficiency and sustainability along the entire product lifecycle by making better use of the capacities of cars, machines, and homes. Some platforms have the potential to influence established business models. Examples include online brokerage services for passenger transportation, accommodation, or streaming services for music and movies. The rapid and sustained growth of platforms is a decisive factor in their competitive success. In recent years, American and Chinese companies such as Amazon and Alibaba, Google, and Baidu, but also Facebook and Tencent, whose business models are based on digital platforms, have had enormous success in the B2C sector. Such platforms are now also emerging in the business-to-business (B2B) sector. With these platforms, the "winner takes all" principle is not equally inevitable, which is due to the importance of complexity and domain knowledge. In addition to the advantages mentioned, platform markets also have structural weaknesses, e.g., concentration tendencies toward monopolization due to scaling and networking effects, which pose problems for social networks such as Facebook. This also poses new challenges for competition law. If data power tends to reinforce existing market power, it must be clarified when the "abuse" of data power requires regulation.

3.3 Co-innovation in business

The interviews showed that no company has the necessary knowledge to be successful in the digital age in the long term. Through co-evolution and collaboration, companies can jointly offer complementary solutions to their customers and increase their competitiveness. When multiple innovators successfully collaborate in a platform environment, (co-)innovation ecosystems are created. Global competition will be transformed by novel co-innovation approaches and the emergence of digital business models and platforms: It will take place primarily between digital innovation ecosystems – no longer just between individual companies. This creates new market potential for small and medium-sized companies and start-ups by providing their highly specialized skills to these ecosystems without taking major entrepreneurial risks by setting up their own platforms.

The move toward hyperconnectivity, autonomy, and increased human-machine interaction is inspiring companies to make their core processes more efficient and to finish products and services digitally (Kagermann et al., 2018). This development will take an evolutionary course. Data-driven business models, platform markets and digital ecosystems, on the other hand, have a disruptive effect. Current business models can be cannibalized within a noticeably brief time, regardless of the industry. This new view of business is unfamiliar to many 'traditional' industrial companies (Cooper et al., 2020, p. 29ff.). Established business models and previously successful companies are being challenged by start-ups, but also by companies from outside the industry such as platform and internet companies.

3.4 From improved manufacturing processes to data-driven products and services

The boundaries between manufacturing industry, service companies and the internet sector are becoming increasingly blurred. Industrial companies need new skills and methods, for example in the areas of IT security, agile project, and process management methods and AI-driven data analysis. Even though many companies have already connected their "smart products" to the Internet – they also collect and evaluate relevant data. The speed and radicality with which current business models must change is often still underestimated.

Figure 3 shows what such a process from optimized production to data-driven business model innovations might look like.

Connectivity and real-time responses around the original product or service are followed by optimization and efficiency at the product and process level, including new after-sales services. Expanding the business model toward products as services and value-added services transforms the company into a service organization. Via the new digital business, the company develops into a platform company or participant in a digital ecosystem.

3.5 Transforming the product manufacturer into a product service provider

While the most powerful communication networks today have latency times of ten milliseconds, the upcoming 5G and 6G mobile communications standard will offer mobile Internet in real time. Data latency, the time that elapses between data retrieval and data provision, will be reduced to just one millisecond in the future. 5G is fast, latency-free, energy-efficient, and reliable – a basic requirement for the next generation of products and services.

The expert interviews showed that there is a clear trend towards autonomous systems in the industry, even if the Covid-19 pandemic has led to more cost discipline and new strategic thinking in terms of supply chain management and technological sovereignty. For instances, autonomous vehicles reach a given destination autonomously and according to the situation, without human control or defined action plans. The key components of autonomous systems are

	Connect & operate live	Optimise & supply efficiently	Expand & boost sales	Innovate & develop ecosystem
Business model	**Products & support services**	**Product services & after-sales services**	**Product-as-a-service & value-added service**	**Data-driven digital business model**
Business driver	Product sales	Process optimisation	Service growth	Expanded ecosystems
IoT capacities	Embedded systems, augmented reality	Analytics, machine learning, optimisation	Service management (portfolio, product management)	Ecosystem business development
Integration & technology	Vertical integration (OT-IT), machine connectivity	Horizontal integration (planning to delivery)	Services platform, SLA management	Open data platforms, business networks
Standards	Connectivity (e.g. OPC-UA)	Semantic standards	Service interoperability	Cross-sectoral standards
	Optimised production		**Smart services**	**Innovation business**

Figure 3. Transformation path from improved manufacturing processes to data-driven products and services (Kagermann et al., 2018).

sensors, self-regulation, and actuators. In this context, the self-regulation of autonomous systems is enabled by elements of perception and interpretation, planning and plan making, learning, and reasoning, and communication and collaboration (Nicholson et al., 2017, p. 5f.). As a result of tremendous advances in AI, it is now possible to extract valuable information and insights in real time from data collected by sensors. This data also serves as training material for self-learning and autonomous systems, which recognize the structure of their environment themselves and generate their own knowledge base that can be continuously updated during operation. Self-driving shuttles in public transportation, mobile service robots in rehabilitation centres and in nursing care, and smart home technologies are just a few examples of autonomous, adaptive systems that are taking on increasingly complex tasks in all areas of work and life.

The following section offers a direct insight into the transformation efforts of various companies in different industries in Germany. It becomes clear how processes and products can be digitally expanded and how business models can be expanded or rethought. In addition, technical, organizational, and business-related potentials, hurdles, and solution paths are analysed and explained.

4 A look into practice: Digital business model innovation in the Germany industry

What do productive examples of use by digital transformation pioneers look like, which companies can use as a guide in their transformation process? What are the success factors, where are the pitfalls, and what are the clear benefits of a specific business model innovation?

The following case studies have been compiled and prepared by the German AI platform ‘Lernende Systeme’ with partners from industry, the service sector and research (Platform Learning Systems, 2020). All examples have in common that they rely on advanced hardware and software solutions, powerful sensor systems, high-performance data analysis tools and advanced AI methods for process optimization and business model innovation. Fundamental changes to an organization's processes and products have a direct impact on the people who work with these systems (Werne et al., 2021, p. 44). Therefore, the introduction of novel digital methods and solutions also requires appropriate change management in the company. Workforces must be introduced to changes at an early stage, and they need comprehensive education and training programs so that the collaboration between people and machines can succeed.

The following three case studies come from three different sectors of the German economy to be able to show and analyse a certain variety of opportunities and challenges of digital business model innovation. Further analyses and studies should follow to enable transferability to several types of companies, company sizes, industries, and geographical regions.

4.1 Predictive Maintenance for critical infrastructure: reliability in railway transportation

The first case study shows how railway companies can improve their value proposition to customers. To achieve this, they rely on digitally supported predictive maintenance to identify potential disruptions in the operational process at an early stage and take preventive action. As a result, customers can be guaranteed higher punctuality rate or higher equipment availability. The changed value proposition based on the data-driven applications represents a business model innovation.

Starting point

In rail transportation, a failure of critical systems and infrastructure is associated with excessive costs and time expenditure for problem solving, customer dissatisfaction and a negative image of the operator. At the same time, it is very time-consuming to monitor around the clock a rail network that spans many thousands of kilometres. Smart sensor technology and learning systems have a decisive advantage here, as they are available twenty-four seven.

Data-based solution

The condition of the railway tracks can be monitored using a combination of autonomous Internet-of-Things (IoT) devices attached to the passenger coaches and freight wagons and an intelligent software solution, which maps the track route in a digital twin. A digital twin is a virtual, data-driven representation of the attributes and characteristics of the real physical train and its wagons. Statistical data on fine-grained vibration data and Global Positioning System (GPS) coordinates of train maintenance work enable track defects to be detected, classified, and communicated to the team together with historical data. The information obtained helps the customer to identify and evaluate problem areas on the route and to plan maintenance work.

Business model innovation / improved value proposition: Resilience in exceptional and ordinary situations

In exceptional situations, when the maintenance teams are only available on an emergency basis (e.g., during a pandemic), thanks to the digital twin, the railway network operator still has an overview of the condition of the railway network and can prioritize maintenance work. In general, the smart solution provided by the German Start-up incontext technologies improves the planning security for the maintenance of the track is increased (see Figure 4).

Unplanned infrastructure downtime is prevented and the risks of potential damage and increased maintenance costs for emergencies are significantly reduced. By detecting even small defects, critical areas can be observed before they become a problem. By knowing about problem areas and their nature and development over time, maintenance work can be optimized and even their quality can be checked.

4.2 APP store for smart factories in the industry

The second example shows how manufacturing companies can evolve into a service provider in a maturity logic. The focus is on an APP store that offers digital services that enable an efficient

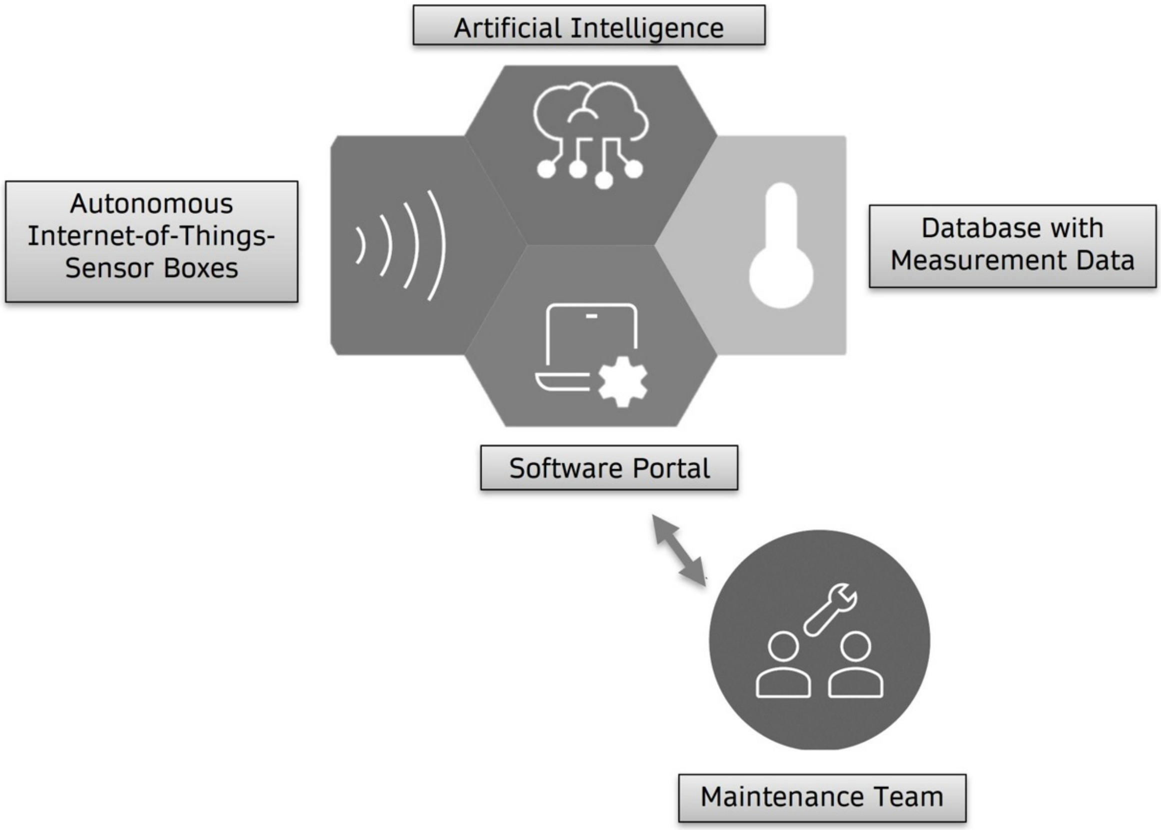


Figure 4. Smart Maintenance in the Railway Industry (own illustration, based on Streibich et al., 2021)

and profitable process environment in the smart factory.

Starting point

In a production company there are on the shop floor level typically machines from different manufacturers whose Industrial Internet of Things (IIoT) capabilities are usually provided on different, often proprietary IIoT platforms. This prevents efficient use of these capabilities across the entire value chain.

Data-based solution

With the APP store for smart factories, an industry platform is created that enables both an integrated and manufacturer-independent marketplace for the manufacturing industry and developers of industrial apps as well as horizontal app-to-app communication (see Figure 5). From the user's perspective, this is a decisive advantage over proprietary and closed platforms, as proprietary approaches carry the risk of vendor lock-in and greater technological dependency.

Concerning the technical features of the infrastructure, the platform provides integration points and interfaces that enable a technology-open data exchange in production. The access of applications to machine data and future production data is centrally managed by the machine operator. The operator always retains control of his data. The applications can be built and operated on completely different IIoT platforms preferred by the respective providers.

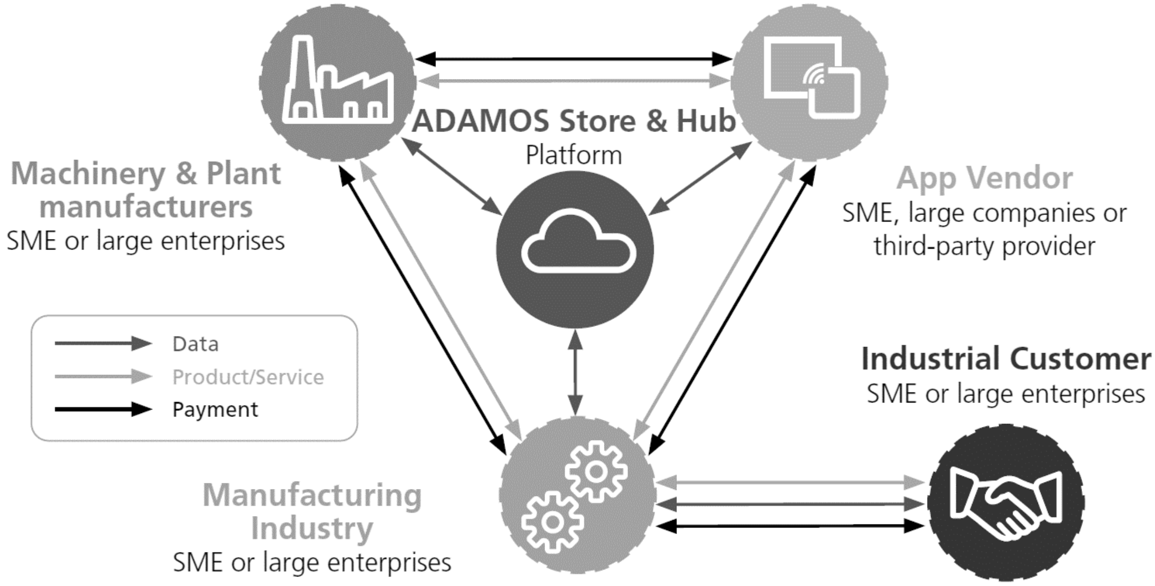


Figure 5. APP store for Smart Factories in the industry (Platform Learning Systems, 2020).

Business model innovation / improved value proposition: Unique cross-manufacturer exchange of production information

The cross-manufacturer exchange of information as well as the purchase or sale of digital solutions, for example for data aggregation to create a digital twin, is simplified.

Machine operators in the manufacturing industry can flexibly evaluate data throughout the entire production process and make it available to their customers (see Figure 6).

A crucial factor for the success of the platform is the trust of platform users and their customers to participate in an open and transparent marketplace. To ensure this, the strategic alliance for mechanical and plant engineering 'Adamos' (Adaptive Manufacturing Open Solutions) has been established as an independent joint venture and operator of the open platform.

4.3 Managing complex construction projects using digital solutions

The third case study deals with a classic problem in the construction industry. Many large construction and infrastructure projects take longer, and cost more than originally planned. A platform-based, collaborative approach brings the relevant players together digitally and aims to ensure more process reliability and profitability. This business expansion is particularly interesting for construction companies and their customers.

Starting point

Comprehensive and complex construction projects for infrastructure, buildings and facilities require a high degree of coordination between all parties involved. This concerns scheduling and trade planning as well as cost planning, the quality of materials, the acceptance of services and the documentation and structuring of static or dynamic data. As a result, construction projects often drag on and cost budgets are sometimes significantly exceeded. Process optimisation and incentives for changing existing business models are therefore necessary to reverse this trend, according to the experts interviewed.

Network	Economic benefits	Technical benefit	Data-related benefits
Machinery & Plant manufacturers	- Securing customer access to monetize data and app offerings - Efficiency advantages through standardized digital sales and provision processes (subscription management, micropayments, etc.)	- Creation of an industry standard through clear interfaces - Use of technical services (e.g. Single Sign On)	- Standardized integration to machine and production data - Findings for the provision of manufacturer and machine data for production optimization and the establishment of smart production
Manufacturing Industry	- Investment reduction through "pay-as-you-use" principle - Increased efficiency and quality through easy deployment, exchange of smart services	- Improved user experience - Enlarged selection to optimize operation - Access to uniform data release models - Transparent management of data and apps	- Integration of individual machine and production data from existing applications - Data sovereignty over own data (via rights concepts)
ADAMOS	- Generation and use of network effects - Neutral positioning ensured by joint venture	- Cloud-level integration layer for faster platform scaling, customization and independence	- Continuous improvement of data services - Establishment of data-centric business models possible

Figure 6. Benefits of APP stores for smart factories (Platform Learning Systems, 2020).

Data-based solution

The joint Project Intelligence Network by the software company SAP provides a platform for the coordination of companies and network partners involved in the project (see Figure 7). In addition to communicating tasks and problems, their influence on scheduling, costs or necessary changes is analysed. In the future, knowledge-based algorithms will be used to suggest alternative solutions.

In addition to the classic coordination of processes and information on a construction site, artificial intelligence can be used, for example, to recognise which information belongs to which objects and this information can be automatically assigned. In this way, the digital twin is enriched with the corresponding metadata, prepared in a structured manner, and made available for use throughout the entire life cycle of the facilities.

Business model innovation / improved value proposition: Efficient coordination between market participants increases productivity and reduces costs in the construction industry

The biggest technical challenge at present is the lack of standards in the construction industry and the comparability of data collected during construction. The unwillingness of construction participants to cooperate openly and the high pressure on margins and competition are further hurdles. The increasing trend towards modular construction, the prefabrication of building elements and the associated standardisation as well as new contract models help to overcome these hurdles. In this way, productivity in construction could be increased like the development in industrial production, including the digitalisation of the entire supply chain.

In summary, efficient coordination between all project participants makes it possible to increase construction productivity and reduce the costs of operating and maintaining the facilities, buildings, or infrastructure (see Figure 8).

Further examples of data-driven product and process innovations as well as digital business model innovations can be found on the German AI map (Platform Learning Systems, 2023; see Figure 9), which lists and explains more than 1,200 examples from Germany alone.

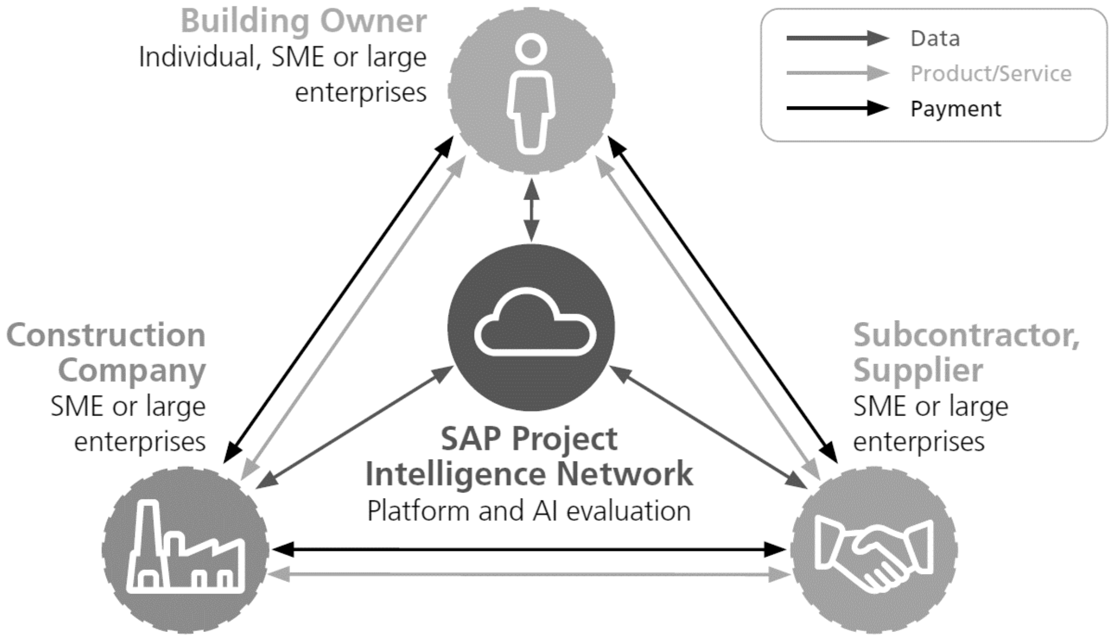
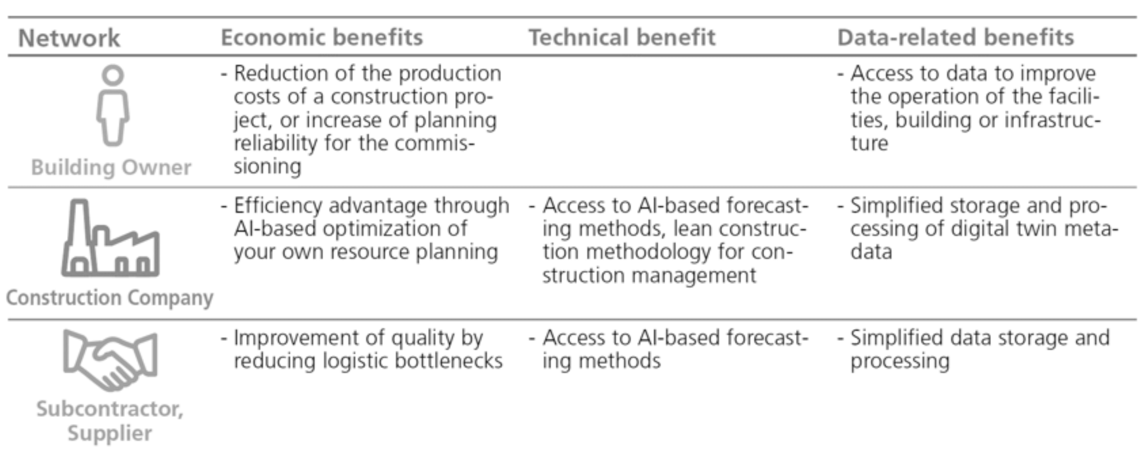


Figure 7. Collaborative building platform (Platform Learning Systems, 2020)



Network	Economic benefits	Technical benefit	Data-related benefits
Building Owner	- Reduction of the production costs of a construction project, or increase of planning reliability for the commissioning		- Access to data to improve the operation of the facilities, building or infrastructure
Construction Company	- Efficiency advantage through AI-based optimization of your own resource planning	- Access to AI-based forecasting methods, lean construction methodology for construction management	- Simplified storage and processing of digital twin metadata
Subcontractor, Supplier	- Improvement of quality by reducing logistic bottlenecks	- Access to AI-based forecasting methods	- Simplified data storage and processing

Figure 8. Benefits of collaborative building (Platform Learning Systems, 2020)

Figure 9. The AI map shows the status quo for AI implementation in Germany (Platform Learning Systems, 2023).

5 Conclusion: New business models for the digital age

The paper has shown that business models do not have a permanent value but are exposed to a continuous change of markets, customer needs and regulatory constraints such as sustainability, security and ethical requirements or changing supply conditions in a conflict-ridden world. Established industrial companies and new competitors are continuously working on the further development of their value propositions and business models. In doing so, they are increasingly turning to digital and platform-driven solutions that they develop with software companies or that they bring to market themselves. New revenue potentials and process optimisations for cost reduction are possible with platform-based approaches, and multi-sided markets open greater reach and sales opportunities than single-sided markets do.

Industrial companies need to adapt to the new market conditions in the digital age better today than tomorrow to secure their future business success and remain competitive (Kagermann et al. 2018). Apparently, many companies have already understood this and are on their way.

However, the study results raise some key questions that companies should pay more attention to in the future. The extent to which traditional industrial companies can survive in the digital age and maintain their dominant position even against new market players and tech giants from the USA and China also depends on these key questions:

- Companies should consistently examine how they can further develop their existing business model and fundamentally renew themselves. A particular focus should be on how the company's products and services can be enhanced with connectivity, sensor technology and smartness to enable digital process optimisation and digital business model innovation.

- It is also interesting to identify how the analysis of real-time product and machinery usage data can bring new insights that can be exploited or marketed. Approaches such as predictive maintenance, condition monitoring or pay-per-use revenue models for machines or vehicles are conceivable.
- Artificial intelligence brings with it new forms of human-machine interaction, for which a new leadership culture, consistent training and further education and more responsibility for the individual are required. Companies should ask themselves what this means for corporate culture and organisational development.
- In general, the question is where digital methods such as real-time analytics and Artificial Intelligence can be used in products and services to increase personalisation and product and service quality. Can products, for example, be offered as "as a service" market services, complementary to classic sales models?
- The question also arises as to the extent to which parts of the value chain can be fully digitalised. And would this digitalisation of the supply chain shift the control points in favour of one's own company?
- Who could be suitable partners for platform-based collaboration? How can the innovation ecosystem be expanded to include research institutions, large companies, but also specialised SMEs and start-ups? Because in view of the increasing complexity of networked and digital products, hardly any company can master the entire value chain.
- Innovation ecosystems enable a company's own core competencies to be supplemented by the complementary competencies of third parties, making market services completer and more convincing.
  The three practical examples have shown how the complex transformation process can be managed in a promising way. But for each company, its own roadmap looks different. It is important to take these examples as an opportunity to define your own path and follow it consistently. Because without digital transformation, there can be no sustainable market success and, in the medium term, no competitiveness in the digital age.

Acknowledgments

The author would like to thank the anonymous reviewers for their helpful comments on a draft of this paper. This study incorporates results from the *Platform for Self-Learning Systems* project (09/2017-12/2025), funded by the German Federal Ministry of Education and Research. The author declares no conflict of interest in terms of the design of the study, the collection, analyses, or interpretation of data, in the writing of the manuscript, or in the decision to publish the results.

6 References

acatech – National Academy of Science and Engineering (2023). *Platform Learning Systems*. Retrieved from:
https://www.acatech.de/projekt/lernende-systeme-die-plattform-fuer-kuenstliche-intelligenz/

acatech – National Academy of Science and Engineering (2016). *Industrie 4.0 in a global context.* Berlin.

acatech – National Academy of Science and Engineering (2015). *Smart Service Welt: Recommen-*

dations for the Strategic Initiative Web-based Services for Businesses. Berlin.

Brynjolfsson, E. & Kahin, B. (2002). *Understanding the Digital Economy: Data, Tools, and Research.* MIT Press.

Christensen, C. M. & Raynor, M. E. & McDonald, R. (2015). What Is Disruptive Innovation? *Harvard Business Review*, Special Feature, 2015.

Cooper, R. G. & Friis Sommer, A. (2020). New-Product Portfolio Management with Agile Challenges and Solutions for Manufacturers Using Agile Development Methods. *Research Technology Management* 63 (1), pp. 29-38.

Cusumano, M., Gawer, A. & Yoffie, D. B. (2019). *The Business of Platforms: Strategy in the Age of Digital Competition, Innovation, and Power.* New York City, Harper Collins.

Daugherty, P. & Wilson, H. J. (2018). *Human + Machine. Reimagining Work in the Age of AI.* Cambridge, Ingram Publisher Services.

Falk, S. & Winter, J. (2020). Turning data into value. *NEO*, 04/2020, pp. 14-17.

Jullien, B., Pavan, A. & Rysman, M. (2021). *Two-sided Markets, Pricing, and Network Effects.* Toulouse School of Economics, Working Paper, No. 1238.

Kagermann, H. & Winter, J. (2018). The second wave of digitalization. In Mayr, S., Messner, D. & Meyer, L. (Eds.), *Germany and the World 2030: What will change. How we must act.* Berlin, Econ.

Kagermann, H./Winter, J. (2017). Industrie 4.0 und plattformbasierte Geschäftsmodellinnovationen. In Lucks, K. (Ed.): *Praxishandbuch Industrie 4.0,* Stuttgart, pp. 21-32.

McAfee, A. & Brynjolfsson, E. (2017). *Machine, Platform, Crowd.* New York, Norton & Company.

Mundie, C. (2014). Privacy Pragmatism. Focus on data use, not data collection. *Foreign Affairs*, 93, 28pp.

Muro, M., Maxim, R. & Whiton, J. (2019). *Automation and Artificial Intelligence: How machines are affecting people and places.* Retrieved from: https://www.brookings.edu/research/automation-and-artificial-intelligence-how-machines-affect-people-and-places/

Nicholson, J., Gimmon, E. & Felzensztein, C. (2017). Economic Geography and Business Networks: Creating a Dialogue between Disciplines: An Introduction to the Special Issue. *Industrial Marketing Management*, Vol. 61, pp. 4-9.

Parker, G. G., Van Alstyne, M. W. & Choudary, S. P. (2016). *Platform Revolution: How Networked Markets Are Transforming the Economy.* New York, Norton & Company.

Platform Learning Systems (2023). *Map on AI.* Retrieved from:
https://www.plattform-lernende-systeme.de/map-on-ai.html

Platform Learning Systems (2020). *Creating Value from Data.* Munich.

Porter, M. E. & Heppelmann, J. E. (2015). How Smart, Connected Products Are Transforming Competition. *Harvard Business Review* (October 2015), pp. 97-114.

Rochet, J.-C. & Tirole, J. (2016). Two-sided markets: a progress report. *RAND Journal of Economics*, Vol. 37, No. 3.

Rysman, M. (2009). The Economics of Two-Sided Markets. *Journal of Economic Perspectives*, Vol. 23, No. 3, pp. 125–143

Streibich, K.-H. & Winter, J. (Eds.) (2021). *Resiliente Vorreiter aus Wirtschaft und Gesellschaft* (*Resilient pioneers from business and society*). acatech IMPULS. Munich.

Tiwana, Amrit (2013). *Platform Ecosystems: Aligning Architecture, Governance, and Strategy.* Waltham/Massachusetts, Morgan Kaufmann.

Werne, J. & Winter, J. (2021). Point of no return: Turning data into value. *Journal of AI, Robotics & Workplace Automation*, Vol. 1 (1), pp. 43-57.

Winter, J. (2010). Upgrading of TNC subsidiaries: The case of the Polish automotive industry, *International Journal of Automotive Technology (IJATM)*, Vol. 10, No. 2/3, pp. 145-160.

Winter, J. (2017). Europa und die Plattformökonomie (Europe and the platform economy). In Bruhn M., Hadwich K. (Eds) *Dienstleistungen 4.0 (Services 4.0).* Springer Gabler, Wiesbaden, pp. 71-88.

Winter, J. (2020). The evolutionary and disruptive potential of Industrie 4.0. *Hungarian Geographical Bulletin*, Special Issue on Industry 4.0, Vol. 69, No. 2, pp. 1-15.

Winter, J., Frey, A. & Biehler, J. (2022). Towards the Next Decade of Industrie 4.0 – Current State in Research and Adoption and Promising Development Paths from a German Perspective. *Sci*, Vol. 4 (3), 31, pp. 1-16.

Biographies

Johannes Winter. Johannes Winter was born in Hannover, Germany, in 1977. He studied economics, politics and geography at University of Osnabrück, University of Göttingen, Germany, and University of Cantabria, Spain. He received the Diploma degree in human geography from the University of Göttingen in 2004, and the Ph.D. degree in economic geography from the University of Cologne in 2008. From 2004 to 2008, he was a research assistant with the University of Cologne. From 2008 to 2014, he was a scientific officer and personal advisor to the president of the National Academy of Science & Engineering (Acatech). From 2015 to 2022 he headed the Acatech technology department and was the managing director of the Platform for Artificial Intelligence, chaired by the German Research Minister and the Acatech president. Since 2022, he has been the Chief Strategy Officer and a member of the extended board of directors of the L3S Research Center, which is a joint institution of University of Hannover and Technical University of Brunswick. His research interests include business model innovation, innovation ecosystems, and AI-driven applications. He is the author of more than 120 articles, a member of various innovation policy commissions, and an affiliate of Acatech. *CRediT Statement: Conceptualization, Methodology, Investigation, Writing - Original Draft, Writing - Review & Editing.*