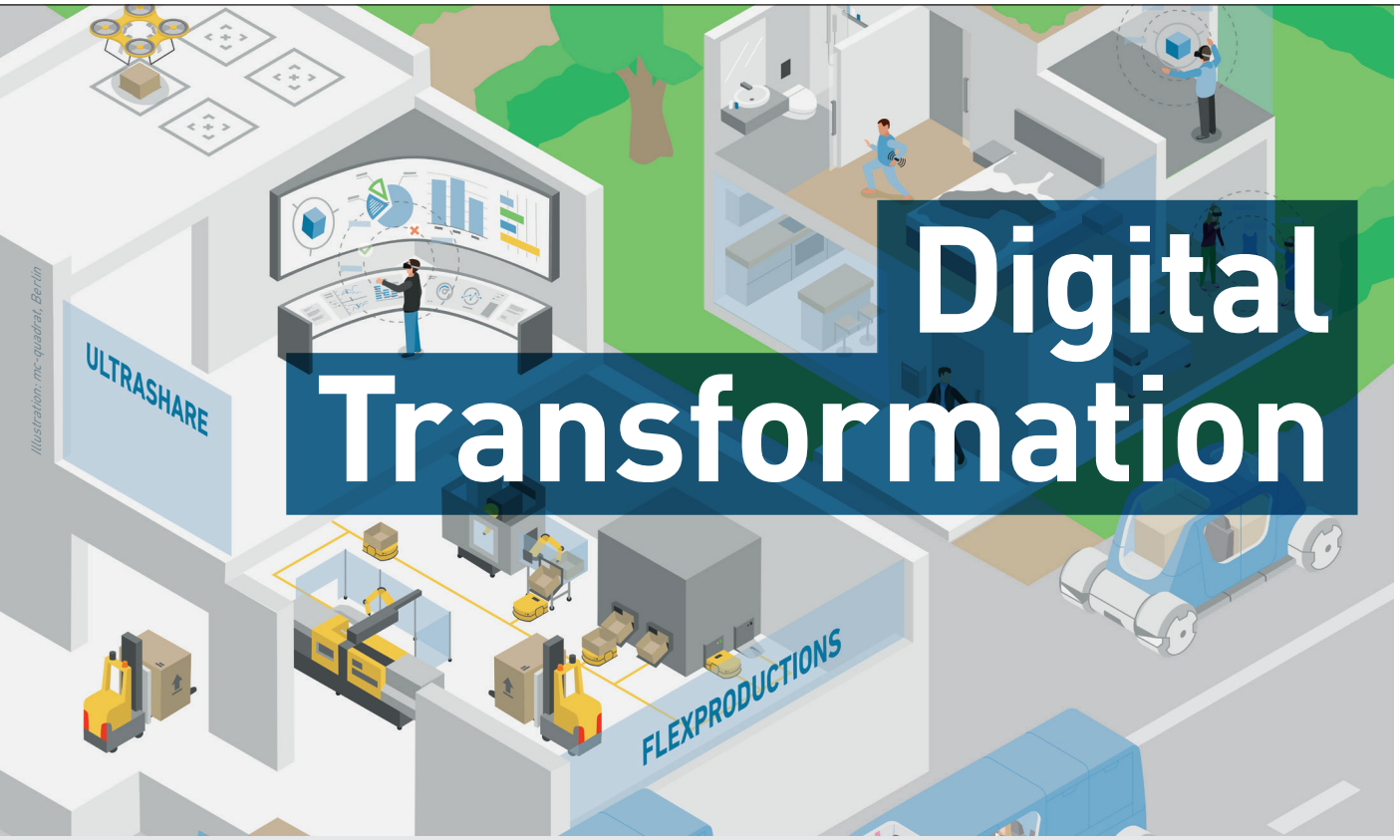
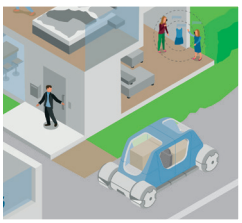
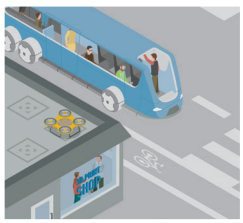
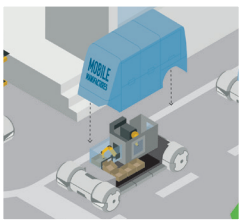
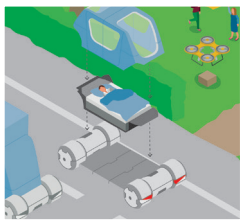


Digital Transformation

How information and communication technology is fundamentally changing incumbent industries

International comparison of the maturity level of the automomotive industry, mechanical engineering and logistics industry



Executive Summary

Final report of the joint project „IKT-Wandel“ funded by the German Federal Ministry for Economic Affairs and Energy

Funded by:
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

DEUTSCHES DIALOG INSTITUT fortiss LMU SIEMENS

1 | Project objectives and methodology

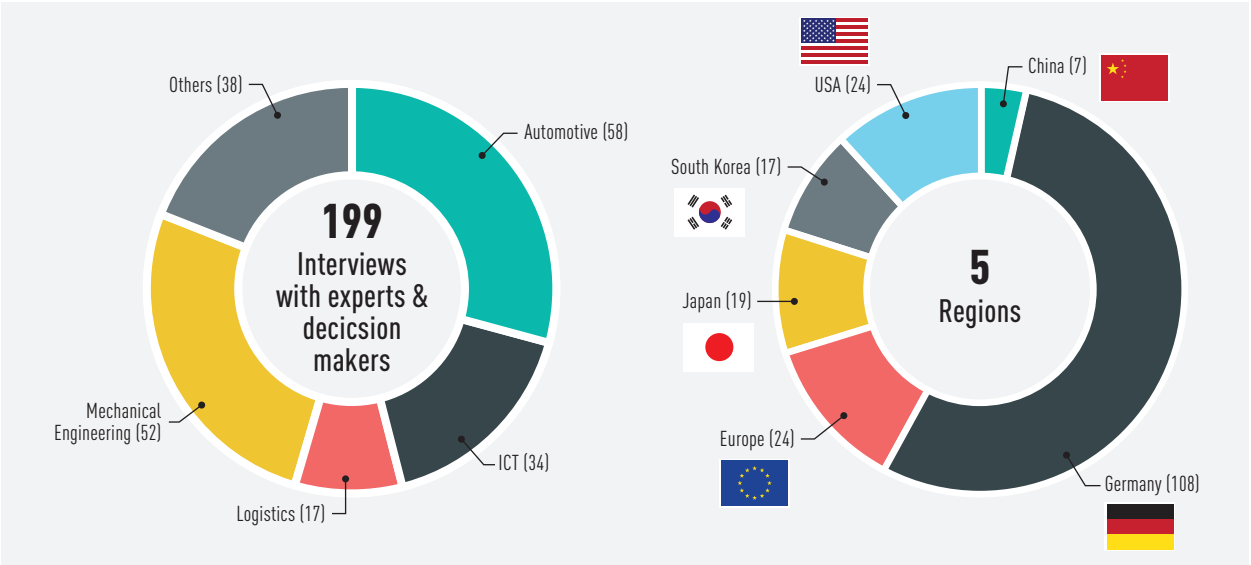
"Data is the raw material of the 21st century [...]. Germany is actually lagging behind other countries in some instances when it comes to putting this data to work, but data is clearly going to become an absolute priority issue in the future because the ability to work with large volumes of data helps to determine access to the customer. This means companies that know how to make good equipment or good cars but do not have sufficiently good access to the customer stand to lose their status as producers and their role as the principal link in the value chain, so it is vital Germany catches up in this area." [1]

German Federal Chancellor Angela Merkel, March 12, 2016

Following on from the 2010 study "Mehr Software (im) Wagen" (The Software Car), the present project investigates the significance of the digital transformation for companies in the automotive, mechanical engineering and logistics sectors. Business models, strategy, organization and technology are the main elements investigated. Particular attention is also paid to the importance of the digital transformation for cooperation between the political, business, scientific and societal domains. The objective of the study is to understand and describe the causes and driving forces of digitalization and identify the associated implications, as compared at an international level, for the various sectors. An outline of recommended actions for business, research and politics is also included. *Figure 1* shows the countries, regions and sectors from which the people interviewed for the study were drawn.

The empirical investigation of the different facets – business models, strategy, organization and technology – was based on the Future of Business method. [2] The consortium established its own firm understanding of the principle aspects of digitalization at the present time by studying current developments and conducting an intensive trend analysis. The results of Venkatraman's "IT-Enabled Business Transformation: From Automation to Business Scope Redefinition" [3] were combined with Buss' "IT Maturity and the Road to Responsive IT" [4] model and the ICT architecture

Figure 1: Source/affiliation of interviewees for the digital transformation project



1) The quotation is taken from the podcast „Merkel: Wir müssen uns sputen" [There's no time to waste], which can be downloaded from the Chancellor's website at https://www.bundeskanzlerin.de/Webs/BKin/DE/Mediathek/Einstieg/mediathek_einstieg_podcasts_node.html?cat=podcasts&id=1923720
2) Cf. Döricht (2013): Strategic Visioning – Future of Business, in: Moehrle/Isenmann/Phaal (Eds.): Technology Roadmapping for Strategy and Innovation. Charting the Route to Success, Berlin/Heidelberg, p. 257–265.
3) Cf. Venkatraman (1994): IT-Enabled Business Transformation: From Automation to Business Scope Redefinition, in: Sloan Management Review 35, 2, p. 73–87.
4) Cf. Andrew Buss: Getting IT to Fire on All Cylinders, presentation at Data Centre World, ExCeL Exhibition Centre, London, February 27, 2014.

evolution model from the Software Car study [5] to produce a five-stage maturity model to underpin the field investigations and assessments. This maturity model forms the link between the actual position and the future vision, for the purposes of the consortium, and provides a way to perform a sector-neutral comparison of maturity in the context of the international expert survey.

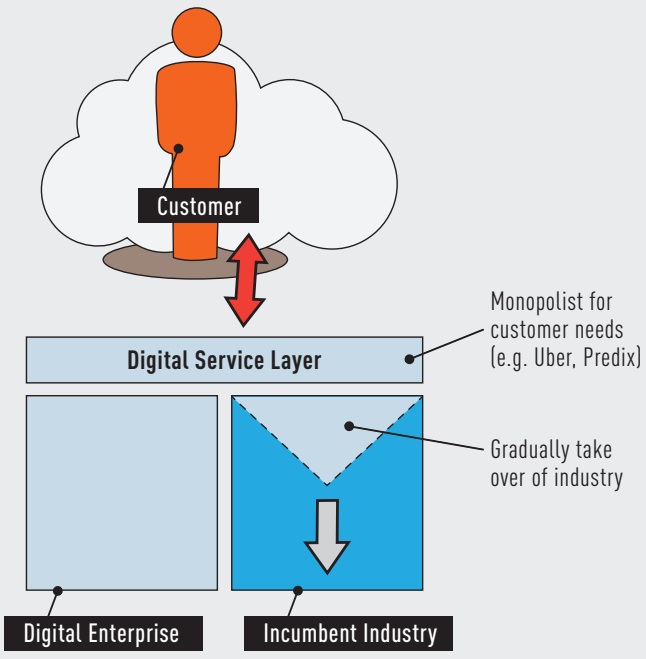
2 | Summary of key findings and implications

This summary is largely based on the wide-ranging discussion of the interview results and the findings and implications determined therefrom contained in chapters 5 to 9.

No sector is immune to the effects of digital disruption. As the prior "Mehr Software (im) Wagen" (The Software Car) project has already ascertained in the context of the automotive industry and as Marc Andreessen compellingly explained in his essay "Why Software is Eating the World", digitalization is set increasingly to pull the rug out from under established traditional industrial value creation structures. Real-world activities that have hitherto been very much infrastructure driven can be combined at the digital level based on data and then packaged in novel integrated solutions to meet a specific customer requirement, for example.

The re-imagining of (direct) customer access is the key to success here: customer-generated usage data and other information gives companies the ability to de-

Figure 2: No sector is immune to the effects of digital disruption.



5) Cf. the final report of the German Federal Ministry of Economic Affairs and Energy-funded joint „eCar-IKT Systemarchitektur für Elektromobilität": Mehr Software (im) Wagen. Informations- und Kommunikationstechnik (IKT) als Motor der Elektromobilität der Zukunft, 2010 study, p. 48 et seq.

velop superior functionalities and improve them continuously. The greater focus on end users implicit in this approach represents a great opportunity, especially for companies in the B2B sector, but also a great challenge. Suddenly it will become possible – thanks in significant measure to digital platforms – to move away from traditionally linear value creation processes and involve the customer in value creation as well.

Digital companies, usually active in the B2C arena, are already familiar with these mechanisms, in contrast, and have since their inception built their activities around a digital, less cost-intensive service layer (see *Figure 2*) that enables them not just to occupy the customer interface, but also to make inroads into other sectors. Traditional companies with a clear sector focus will tend to find it much more difficult to acquire the market and ICT expertise necessary to enable them too to launch optimal service packages in other sectors.

Successful transformation presupposes a comprehensive realignment of established business models factoring in the customer layer and the relevant technical possibilities based on rapidly evolving digital technologies.

Section 2.1 below provides an initial summary of the principal findings concerning socioeconomic changes in the area of business models, organizational structures and strategy. Section 2.2 outlines the main findings of the project in the area of technical changes. Section 2.3 explains the significance of platform ecosystems as a consequence of socioeconomic and technical forces for change and as an increasingly dominant organizational element in a digital economy. Section 2.4 presents a concluding summary addressing the importance of constructive interaction between politics, business, science and society.

2.1 Socioeconomics

2.1.1 The customer interface is key strategic and economic territory in emerging platform-centered ecosystems

Findings

Observation of markets in which digitalization already plays a major role and that have accordingly already been through a digital transformation shows that increasingly, the companies that achieve the strongest market positions and the highest margins are those that operate close to the customer interface on the basis of digital platforms. This means that the proportion of value added contributed by physical (intermediate) activities and basic hardware products is decreasing continuously.

Companies that exercise control – through the use of corresponding software interfaces – over the interface to customers are able to realize bigger margins. This development creates a great risk of hardware-based intermediate activities becoming commoditized or interchangeable.

This could lead in the automotive sector, for example, to traditional vehicle manufacturers and OEMs being reduced to the status of suppliers by new overarching mobility providers such as Uber (see *Figure 3*), which are able to assume a dominant position in the value creation process thanks to their direct and often virtually uncontested access to passengers. This position enables them take up and drop intermediate activities more or less at will. It then becomes a logical step – and one that can already be observed in action – for platform companies operating close to the customer to pursue backward integration on the basis of customer insights with a bearing on competition (Amazon's expansion into logistics, for example).

Implications

The trend described appears to offer two advantageous positions for companies: full integration of the value creation steps (for example Tesla, Enercon) and specialization in the customer interface (for example Uber, Alibaba). Companies that fail to occupy one of these two positions – and this specifically includes German OEMs – run the risk of ceding control over the customer interface to overarching services and aggregators.

This is also of relevance to those small and midsize companies in Germany that operate mainly as component suppliers in the sectors investigated with a small B2B customer base and a role very remote from the

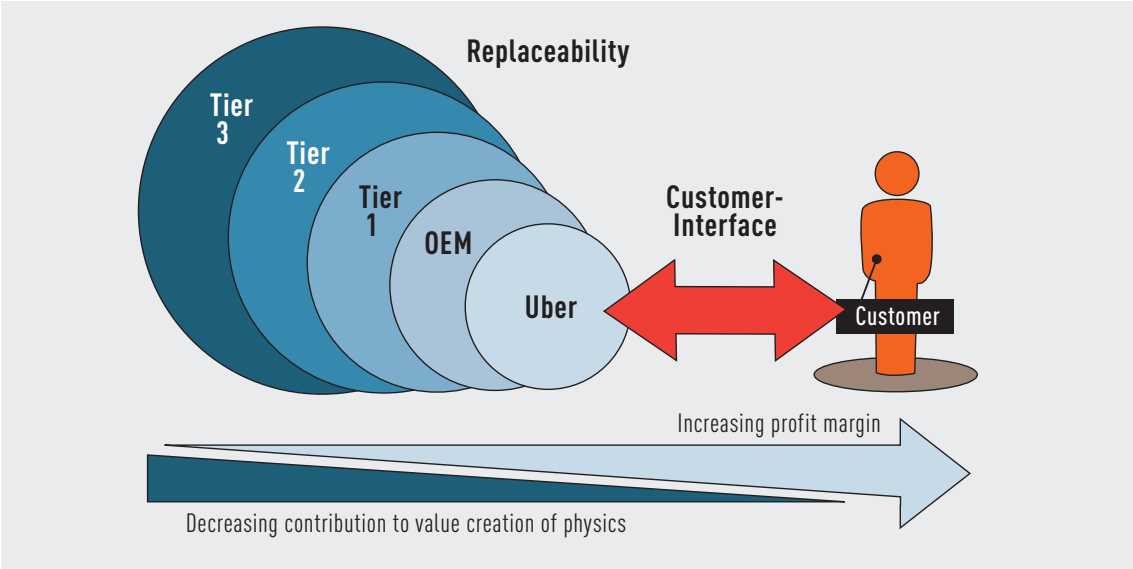


Figure 3: The customer interface is the key position in platform-centered ecosystems (study graphic)

end customer. The strongly hardware-centric and highly specialized nature of these companies has made it difficult for them to incorporate an end customer focus into their strategic orientation and increase the flexibility of their production operations in an economically viable manner down to a batch size of one. Developments in the area of Industry 4.0, however, are now presenting SMEs for the first time with options for taking precisely these steps and increasing their end customer focus or entering into direct value creation relationships with the end customer. These changes will make it much easier for component suppliers, for example, to implement forward integration measures or offer their intermediate product directly to the end customer, for example for repairs.

Summary and recommended action

- Two advantageous positions: full integration (for example Tesla, Enercon) and customer interface (for example Uber, Alibaba)
- German OEMs run the risk of ceding control over the customer interface to overarching services and aggregators unless they change their approach
- German SMEs in the sectors investigated mostly occupy component supplier roles with a small B2B customer base and a role very remote from the end customer
- SMEs have found it difficult to focus on the end customer and achieve batch size one capability due to their strongly hardware-centric and highly specialized nature
- However Industry 4.0 offers SMEs the opportunity to target end customers in an economically viable manner and venture into customized end customer services

Recommended action: Focus more closely on the end customer (user) – the complex and highly fluid nature of performance relationships in value creation networks will tend to blur the boundaries between B2B and B2C.

2.1.2 Integrated customer-focused service provision with product service systems (PSS)

Findings

The digital transformation is increasingly causing companies in the sectors considered to integrate what have previously been separate products and services to create what have become known as product service systems (PSS). Implicit in this change is a need to adopt co-design methods that look at the value of the product and the value of the services based on the

product simultaneously in the design process rather than separately. It is also becoming economically expedient for companies to integrate different activities (production, operation and maintenance, for example), including through the use of ICT, in order to provide all elements of the solutions customers require and this in turn favors a redistribution of sales revenue from traditional product sales business to service/self-service business.

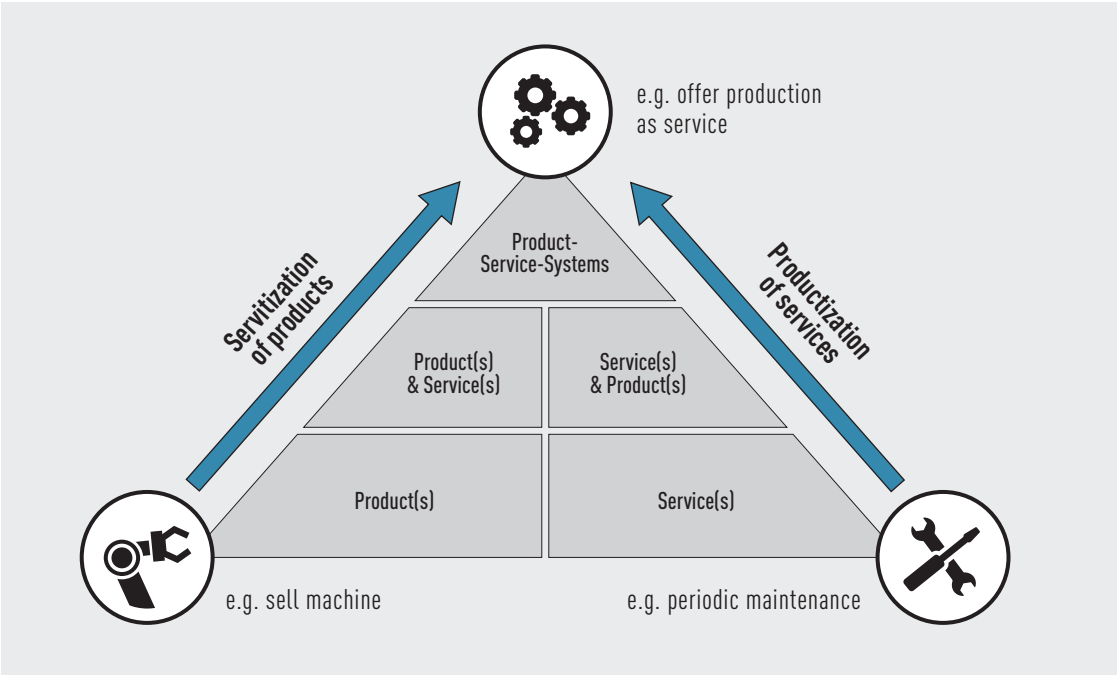
The effect of the changes discussed can be seen in the increasing prominence of product servitization. If sensor systems to complement a production machine are also provided, for example, it becomes possible to create a virtual clone or "digital twin" of the physical machine. The ability to acquire and analyze large volumes of machine and usage data opens up the possibility of creating completely new services (such as predictive maintenance). The spread of digitalization is also generating new potential for innovation in the area of services, especially when it becomes possible to sell services in the same way as physical products (for example in the form of an app abstracted from a maintenance service).

This productization of services and the servitization of products ultimately enable providers to offer a superior portfolio by selling benefits, functions and/or results rather than just physical products (see *Figure 4*). PSS thus enable providers to scale and differentiate their portfolio in line with customer needs based on intelligence derived from data.

Implications

German companies, especially those that have hitherto concentrated on providing and selling physical products, need to take note of these developments, rethink their strategic direction and start integrating different activities (production, operation and maintenance, for example) using ICT in order to turn themselves into usage-oriented service providers. If companies are to ensure they can meet the whole of the customer's need in full, moreover, it also appears essential that purchasers and other value creation partners be involved in the conceptual design and creation process for the proposition offered and that service capabilities be expanded. Such measures could help companies to head off the threat of being reduced

Figure 4: Activity performance with product service systems (PSS)
(study graphic based on Baines et al. 2007)



to the status of a mere hardware supplier. Usage-based propositions also promise to enable small and midsize companies that have not previously been able to afford capital-intensive acquisitions (such as highly-automated production systems) to access precisely this type of resource. SMEs in particular thus stand to gain new value creation potential and opportunities to convert capital costs (CAPEX) into operating costs (OPEX).

Summary and recommended action

- Use of ICT-supported integration of different activities (production, operation and maintenance, for example) to help companies that have previously just provided products turn themselves into usage-oriented service providers
- Promote greater involvement of customers and other value creation partners and the development of service capabilities
- Take steps to counter the threat of being reduced to mere hardware supplier
- Tap new value creation potential offered by usage-based access for capital-intensive PSS

Recommended action: Development and integration of products and services to create PSS that enable providers to scale and differentiate their portfolio in line with customer needs based on intelligence derived from data

2.1.3 Digital products and services offer novel monetization opportunities throughout the life cycle

Findings

Digitalization is creating new monetization opportunities for companies, most significantly through the virtualization of functions using software and the ICT-based connectivity of products and services. The significance of more dynamic and more flexible revenue models is accordingly growing all the time. The main objective now is not to generate revenue through the selling price but rather to create additional long-term revenue sources through product improvements and enhancements once the product has been sold.

Tesla's enhancements to its vehicles' core functionality (for example the Autopilot function), which can be installed in the vehicle and then improved continuously over the air (OTA) for a fee, are one example of such after-sales product changes and modifications (see *Figure 5*). Function enhancements not only change the life cycle of products and services, but also offer companies significant potential for monetization even after their initial sale. Providers of such enhancements can come from anywhere in the entire ecosystem. This ability to continue earning from a product/service after sale not only opens up potential additional sources of revenue, but also allows companies to offer their products and services at or even below cost at first in order to achieve broad penetration of the target market quickly. These products and services can then be fully monetized once established in the market.

Pricing algorithms make it possible to factor relevant environmental data (for example concerning the weather, events, traffic density, changed consumer preferences, etc.) into pricing virtually in real time in an essentially fully automated process. Prices can also be adjusted dynamically as a function of supply, demand and other influencing factors (as in the case of Uber's surge pricing model, for example).

Implications

One of the most significant implications of the emergence of novel monetization possibilities right across the (product) life cycle is the growing need to decouple revenue generation from the provision of a (basic) good/service. Also important for companies is the ability to tap new sources of revenue (for example within the ecosystem) and indirect sources of revenue (based on user data, for example). Finally, it can be seen that in markets characterized by strong network effects (especially on the basis of platforms and/or standards), it is often necessary at first to adopt an aggressive market expansion strategy and, in some cases, to be prepared to accept initial losses (for example Amazon, Tesla, Uber).

Summary and recommended action

- Monetization possibilities are increasingly decoupled from the provision of a (basic) good/service and extend across the entire (product) life cycle
- Companies need to be able to tap new sources of revenue (for example within the ecosystem) and indirect sources of revenue such as user data and to adapt prices dynamically
- It is often necessary to adopt an aggressive market expansion strategy at first in markets characterized by network effects (especially on the basis of plat-

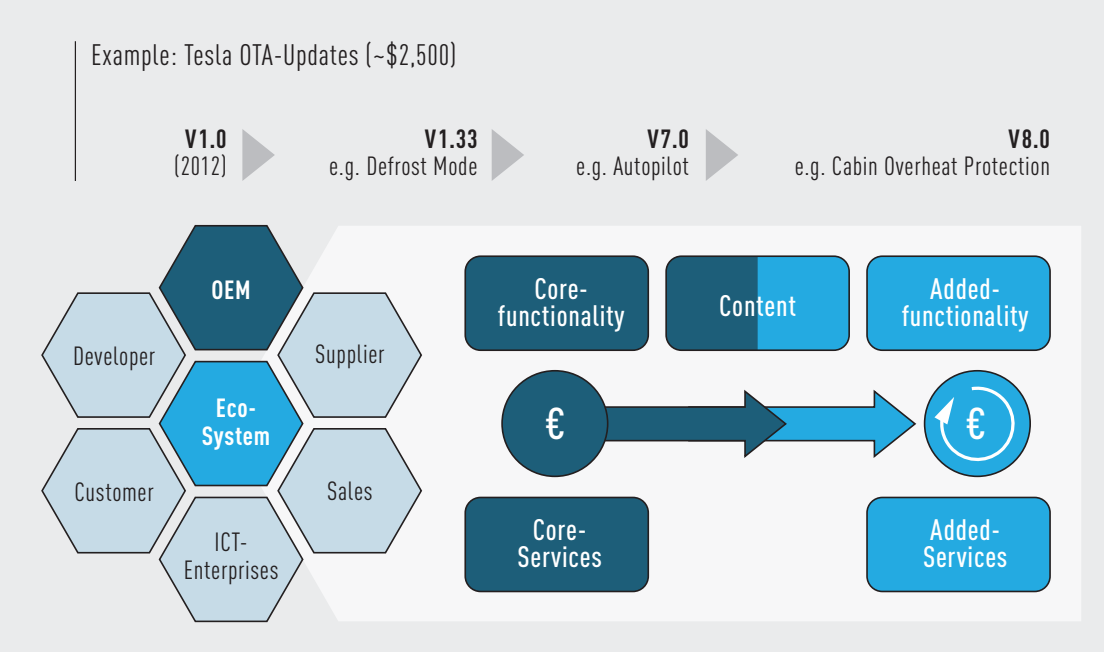


Figure 5: Novel monetization possibilities following the Tesla example
(study graphic based on Schömann 2015)

forms and/or standards) and, in some cases, to be prepared to accept initial losses (see also Amazon, Tesla, Uber)

Recommended action: Revenue models need to be reviewed and strategically adapted to incorporate new revenue models and recurring and dynamically evolving revenue opportunities right across the (product and market) life cycle.

2.1.4 Many companies do not recognize the relevance of the digital transformation and cannot cope with the necessary strategic and organizational realignment

Findings

How likely a given company is to recognize the strategic relevance of ICT-induced change and take operational steps in response appears to depend largely on its size, its willingness to change and the level of distress it faces if it does not change. Large companies often have specialist units dedicated to addressing the digital transformation, but such organizational provisions are seldom to be found in SMEs (not least due to a lack of financial and human resources). There is always the possibility with SMEs, however, that the proprietor or managing director will be able to initiate, facilitate and implement a strategic realignment directly and SMEs in this position could potentially prove more flexible than large companies or corporate groups, with their at times rather rigid, complex and highly political management and leadership structures.

A company's willingness to embrace change ultimately depends to a significant extent on the level of distress associated with not changing, which suggests that companies will be more likely to realign themselves strategically and organizationally in the context of ICT-induced change if the perceived negative consequences would otherwise be too great.

The main obstacle to such strategic and organizational realignments at mature companies is path dependence: managers are effectively trapped by the implicit rules and regulations of the company's traditional business areas and the specific investments made and associated capabilities developed (for example the optimization of internal combustion engines in the automotive sector). The initially unrestricted scope to act is thus significantly constrained by critical junctures in the decision-making process

such that eventually the company is to all intents and purposes locked on course.

This means that it is principally relatively young companies from other sectors, which are unaffected by path dependence, that drive ICT-induced change, create innovative business models and take on new value creation roles. Established companies still have the option to set up new corporate units to operate in parallel with their existing core business (such as the BMW i unit established to develop electric automobiles) with the express objective of designing their own range of products and services from the ground up and developing the necessary organizational structures free from the path dependence that inhibits the company's more established operations. Making a success of this approach means managing to continue to optimize the old business (exploitation) on the one hand while simultaneously pursuing completely new business idea (exploration) on the other – an ambidextrous approach that is admittedly not easy to achieve (see *Table 1*).

Implications

One implication of evident importance for companies is that adopting a focus on software and services requires suitably adapted development principles as well as novel organizational principles. This puts the emphasis very much on dynamic models like Agile, Scrum and DevOps, for example, rather than linear phase models with sequential development stages such as the waterfall model. Established companies in particular also need to overcome inherent path dependence and apply the ambidextrous organizational structures concept to create a "company within the company" or even an entirely self-contained company (for example Trumpf Axoom, GE Predix, Siemens Next47, Flex Elementum) to help them adapt to ICT-induced change by enabling them to develop prospective new business areas in parallel with their traditional core business. All instances of organizational rigidity must be eliminated, moreover, and network-type capability-based organizational structures (for example Daimler's CASE initiative and swarm organizations) and service-oriented organizational structures (for example Amazon's service oriented architecture/API-based organization) must be implemented to create a fast and nimble organization.

Summary and recommended action

- Moving to a software-oriented/service-oriented model requires novel organizational principles (Scrum and DevOps, for example)
- Creation of a „company within the company" or self-contained corporate units (for example Trumpf Axoom, GE Predix, Siemens Next47, Flex Elementum)
- Promotion of network-type capability-based organizational structures (for example Daimler's CASE initiative and swarm organizations) and service-oriented organizational structures (for example Amazon's service oriented architecture/API-based organization)

Recommended action: Strategic and organizational realignment requires that any existing path dependence be consistently overcome, where appropriate by creating ambidextrous or completely self-contained corporate units.

Table 1: Ambidextrous organizational structures (based on O'Reily/Tushmann 2004)

Alignment of	Exploitative (old) business	Exploratory (new) business
Strategic focus	cost, profit	innovation, growth
Critical tasks	operations, efficiency, incremental innovation	adaptability, new products, breakthrough innovation
Competencies	operational	entrepreneurial
Structure	formal, mechanistic	adaptable, loose
Controls	margins, productivity	milestones, growth
Culture	efficiency, low risk, quality	risk taking, speed, flexibility, experimentation
Leadership	authoritarian, top down	visionary, involved

2.1.5 Organizations need to formulate a digitalization strategy to drive their transformation

Findings

The companies from the automotive, mechanical engineering and logistics industries surveyed in this project are responding in different ways to the digitalization of product and service ranges and of customer interaction. Creativity, enthusiasm for experimentation and a willingness to take risks are among the characteristics required if companies are to leave their familiar well-trodden paths successfully. The strategic focus has hitherto generally been on the digitalization of existing processes rather than on adapting products, services and the customer interface for future requirements. Such adaptation demands, among other requirements, function-oriented data-driven product service systems, a stronger focus on the end customer and highly individual solutions – all based on novel business models.

Companies need to identify their future role in newly emerging cross-sector value creation networks and adapt themselves flexibly to the changed underlying conditions if they are to devise a successful strategy for the digital transformation. Most of the companies surveyed indicated that digitalization was an important part of their corporate strategy, but hardly any of them gave any indication of actually having a comprehensive digitalization strategy.

Implications

A series of overarching implications for strategy can be identified for German companies, whose approach to mastering ICT-induced change can generally be described as "organized disruption" (and thus lies somewhere between the more skeptical attitudes seen in Japan and the substantially more proactive approaches taken in the USA). Companies need first of all to step up and accelerate their strategic digitalization activities significantly. They must also provide suitable training and continuing development measures at the same time to ensure that employees and managers – and hence the whole of German industry – become very aware of digitalization and have at least a general understanding of the associated issues.

The accelerating rate of change that goes hand in hand with the digital transformation additionally dictates shorter strategy cycles, a focus on own core competencies and a greater willingness to cooperate. While it may be sufficient in the short term just to adapt business models, companies cannot escape the need to initiate a profound change of corporate culture to reflect the impact of ICT-induced change in the medium term.

Summary and recommended action

- „Organized disruption": German companies find themselves in the middle of the pack in international comparisons and need to step up and accelerate their strategic digitalization activities significantly
- Establish training/education/awareness of the factors discussed above across German industry
- The rapid rate of change associated with digitalization requires shorter strategy cycles and a greater willingness to cooperate/a focus on own core competencies
- Short term: continuous adaptation of business models; medium term: initiation of a cultural transformation
- Enthusiasm for experimentation and a willingness to take risks essential to a long-term future in the market

Recommended action: The key requirements of a comprehensive digitalization strategy are the adaptation of the portfolio ready for the future, a thorough cultural transformation, enthusiasm for experimentation and a willingness to take risks.

2.1.6 Digitally transformed organizations and business processes operate in virtual value creation cycles centered on the user and are able to make optimal use of highly integrated smart physical systems

Findings

Alfred Chandler's observation in his book The Visible Hand: The Managerial Revolution in American Business that "structure follows strategy" implies that all aspects of an organization's structure must reflect the organization's strategic intentions. "Structure" in this case encompasses all employees, posts, procedures and processes plus culture, technology and the elements associated with the organization. It defines how all of the parts and processes work together.

Structure needs to be fully integrated with strategy. If an organization changes its strategy, it must also change its structure to support the new strategy, oth-

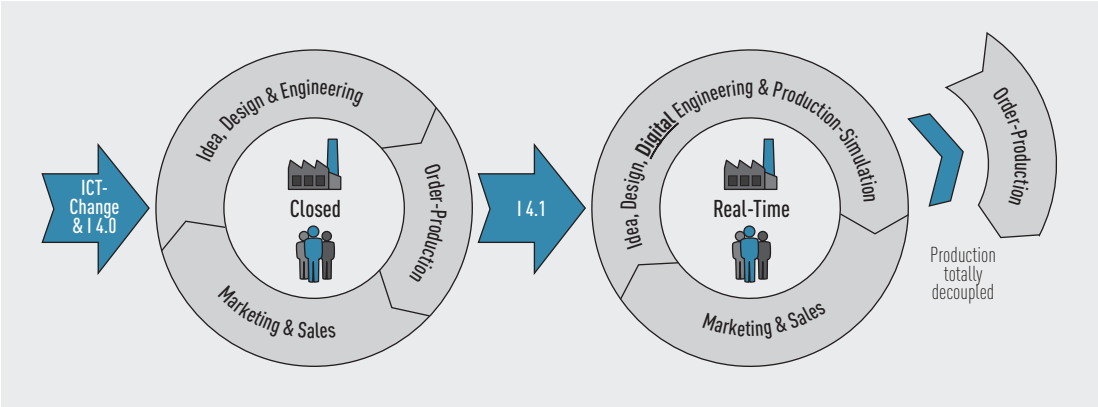


Figure 6: Value chains become user-centered value creation cycles

erwise the structure will drag the organization back to its old strategy. *Figure 6* shows how radical the effects of a digital strategy can be on an organization's structure: the digitally transformed organizations operate with user-centered business processes that can make optimal use of the possibilities of highly integrated smart product service systems (PSS).

Implications

The increasing presence of software in products and services associated with the rise of PSS is enough on its own to change the value creation process fundamentally. Not only can software be developed and tested in a much more agile manner and using completely new methods, but it also – in the form of ICT-based tools – opens up new ways of organizing the relevant value creation steps within and between organizations. That one of the explicit objectives of Industry 4.0 is to virtualize further the design, engineering and production planning phases (for example through the use of digital twins) only reinforces this trend. One consequence of the developments described is that end users are increasingly able to assume a more active role in value creation and are in fact tending to become an integral part of the process.

Physical production, however, is starting to become a limiting factor as the pace of development continues to accelerate. The increasing digitalization of the production process and the availability of enhanced digital development and simulation methods are making it possible to test, improve continuously and even trade more and more of the preliminary stages of physical production in the virtual world. Once a certain point is reached (referred to symbolically as "Industry 4.1" in *Figure 6*), there will be contract manufacturers for which the manufacture of prototypes will be all but indistinguishable from series production in time and cost terms (right half of *Figure 6*).

When this level of specialization becomes established, it is likely to trigger consolidation on a massive scale. It is assumed that this system will behave in the same way as similar mature markets, with supplier networks replacing vertical integration (for example in the automotive industry).

Summary and recommended action

The recommended actions already presented in sections 2.1.1 to 2.1.5 all come together here. It nevertheless bears reiterating at this juncture that the complex and highly fluid nature of performance relationships in value creation networks is blurring the boundaries between B2B and B2C business relationships.

- Companies set up for B2B would do well to push collaboration with prosumers and (smaller) companies with a more pronounced end customer focus
- Stronger strategic focus (for companies centered on B2B) on open forms of collaboration with (end) customers (in some cases even if this initially harms profitability)
- Opening up product/service interfaces and/or participation in open source developments
- Use of design thinking, open innovation, crowd sourcing or similar approaches

2.2 Technology

2.2.1 Integrating mechanical, electronic and ICT elements in one system is key to product service systems (PSS)

Findings

The freely-programmable components emerging from the coalescence of mechanics, electronics and information technology put in place the main prerequisite for the interlinking of modern value chains across sector boundaries. This process gives rise to PSS with capabilities that could not be realized just within the individual physical technical fields. New and modified functions are implemented first in software (software-defined hardware). This renders systems scalable and enables customer wishes to be met faster, for example with over-the-air updates. The use of overdimensioned hardware (overprovisioning) allows hardware components to be kept in the marketplace for longer as elements of infrastructure. This investment is financed by marketing new and/or supplemental software functions.

The smart phone is one example of this high-level integration in respect of both hardware and software. It integrates numerous hardware components including radio modules, camera and motion sensors and uses software to provide telephony, photography, calender, navigation and other functions.

Implications

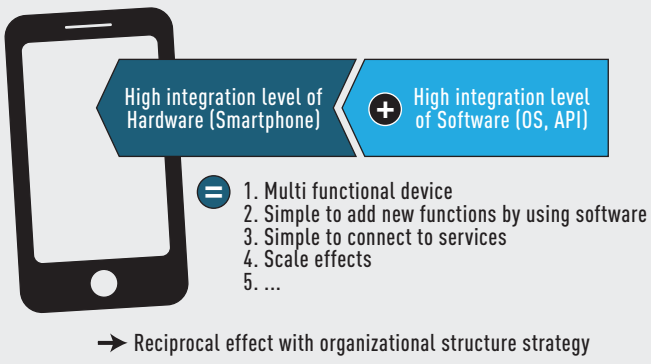
As the smart phone example makes clear, ICT capabilities are critical for high-level integration. The same principles can be applied in all established German industries. The fact that companies can provide functions and differentiate their proposition in the markets just with software (which also makes it straightforward to enhance functionalities) removes many of the barriers inhibiting access to other sectors too. This development can also be expected to encourage the use of generalized hardware encapsulated with flexible APIs.

The high-level integration of mechanics, electronics and information technology remains an important core competency in the physical world, however, and it is here that German industry should concentrate its efforts in order to shape future PSS and develop market-dominating digital ecosystems on this basis. A suitably aligned corporate strategy and an effective organizational structure are essential if a company is to make effective use of the potential offered by overprovisioning and software-defined hardware.

Summary and recommended action

- ICT capabilities are crucial for high-level integration in all established German industries

Figure 7: High-level integration of hardware and software in a smart phone



- It is possible for companies to provide functions and differentiate their proposition in the markets using software alone
- Relatively straightforward enhancement of functionalities and hence easier access to other sectors

Recommended action: PSS are a prerequisite for flexible customer-focused data-driven scaling and differentiation of the portfolio in a world in which ICT-based products are designed first and foremost to be ready for future functions rather than to provide a wealth of preconfigured functions at the point of launch.

2.2.2 Considerable uncertainty remains around the handling of large volumes of data

Findings

There is uncertainty in all sectors as to appropriate priorities in data acquisition and analysis and the specifics of potential new data-based business models. It is apparent that all sectors have ground to make up in the handling of large volumes of data. The classical approach is to deploy models that attempt to translate the complexity of the real world into a mathematical model that maps reality to a sufficient degree. This is often done with a clearly defined problem domain already in mind, which makes it possible to indicate clearly what data in what quality and at what frequency is required and also enables very precise specifications to be derived as to the nature, scope and position of the sensors.

This level of determinism, however, appears unsuitable for generating meaningful conclusions in a highly dynamic infinity (of problems) such as is encountered in autonomous driving, for example. A braking assistant can still be tested using deterministic methods, but it is hardly possible to map all situations at a roundabout sufficiently accurately using traditional methods. Models are growing more and more dynamic and even mutating models are becoming increasingly common. One problem thrown up by this trend is that traditional methods for development and verification and for checking defined quality criteria using reproducible tests cannot be applied to statistical or experimental approaches. It is impossible, for example, to establish definitively that a function in autonomous driving that is based on a huge quantity of data[6] operates correctly in all possible situations.

Implications

German industry on the whole remains strongly hardware-centric. Industrial companies take the view that it is necessary to carry out intensive testing in advance and consider every possibility in order to achieve the high level of quality sought. The experts' responses indicate that industrial companies in the US, on the other hand, tend to be driven by software and data. The requisite product and service quality is achieved using simulation, statistical approaches, machine learning and direct customer feedback.

Large parts of the automotive industry persist in trying to meet the technical challenges faced using (hardware-centric) deterministic approaches. By its own admission, however, the automotive industry must first overcome some serious shortcomings, especially in the area of data analysis, if it is to establish data-driven and experimental approaches. The mechanical engineering industry appreciates the significance of sensitive production and process data and is balancing the risk of disclosure against the potential of data-driven PSS. The logistics industry is adopting a wait-and-see stance and believes it can still overcome the "data head start" enjoyed by companies like Amazon and Uber.

Summary and recommended action

- Germany is hardware-centric: high quality is achieved through advance testing
- USA is driven by software and data: high quality is achieved by means of simulation, machine learning and customer feedback
- The automotive industry believes it will resolve the technical challenges over the next two years and admits to substantial capability shortfalls in the area of data analysis
- The mechanical engineering industry fears that third-party data analysis will compromise its intellectual property and acknowledges a shortage of data analysts
- The logistics industry has adopted a reactive stance, still believes in the „PSS fast follower" approach and has faith in its ability to catch up even to Amazon, for example

Recommended action: Creation of an information infrastructure for platform-centered ecosystems including the development and establishment of a suitable infrastructure (methods and technologies) for ag-

6) Several million gigabytes of data are required to verify the safe operation of a driver assistance function (cf. section 6.5.2).

gregation services in information ecosystems. Suitable aggregation methods for different aspects, such as real time or data quality, must be considered and so must the mechanisms for consistent data interpretation, such as data ontologies.

2.2.3 Making technical systems autonomous has far-reaching technical, economic, regulatory and social consequences

Findings

Technical systems are becoming increasingly autonomous as a consequence of the technical developments in high-level integration and data analysis discussed above and autonomous technical systems can be expected to penetrate all areas and sectors of the economy over the coming years. Reports from the experts indicate that semi-autonomous and highly automated systems are going to become a reality in the near future.

The leap from a highly automated system (one simple example is the combination of braking assistant and lane-keeping assistant in a vehicle) to a fully autonomous system capable of managing with no user intervention, however, still remains out of reach. There are essentially two reasons for this: technical obstacles (some of which have been highlighted in the two preceding sections) and regulatory requirements. There is therefore some doubt as to whether a mastery of partial autonomy necessarily implies the ability to develop fully autonomous systems as well.

Remarks made in the interviews (especially those with representatives of the automotive industry), moreover, suggest that it has not yet proved possible to formulate any economically viable business models for fully autonomous vehicles. The experts from the mechanical engineering industry are most familiar with the opportunities and consequences of autonomous systems, not least as a result of the Industry 4.0 initiative, but this sector also exhibits the greatest variation in the level of expertise. SMEs in particular feel implementation is beyond their current reach. The experts regard the logistics industry as having the furthest ground to cover in realizing autonomy due to its lack of vision in respect of PSS and limited ambitions in terms of establishing an end-to-end digital information flow. This and the industry's wait-and-see attitude suggest it may not in fact be able to make good the deficit.

Implications

Not only is there as yet no economically viable business model in Germany, but the country also apparently still has no concept for authorizing autonomous vehicles or systems. The USA appears to be one step ahead, at least in the automotive sector, having recently adopted a 15-point checklist for self-driving cars that allows statistical verification, including with the use of models involving machine learning.[7]

Considerations of this nature are relevant for mechanical engineering too in the context of autonomous systems (Industry 4.0 is still regarded as the international benchmark). Here too researchers and politicians alike need to address pressing issues such as the possible ground rules for virtual type approvals. The logistics industry has considerable ground to make up in the field of automation but simultaneously faces a massive threat from the backward integration moves of customer-oriented companies like Uber and Amazon. The latter in particular are investing heavily in infrastructure of their own capable of satisfying the new speed and flexibility requirements in order to ensure an end-to-end digital information flow.

All areas of technology face one overriding dilemma – a dilemma that also has (very significant) socioeconomic aspects – in this context: new functions (such as autonomy) and business models require the right data in appropriate quality and with the necessary real-time characteristics. There is at the same time considerable uncertainty as to the legal framework conditions and, even more significantly, the scale of additional revenues as compared with the technical and human resources that have to be committed. The result is an unknowable financial risk that increases as a function of the amount of hardware required for the solution. This situation is then further complicated by unresolved questions in relation to the possibility of gaining approval for systems that have been tested primarily in the virtual sphere.

Summary and recommended action

- There is no evidence among the long-established OEMs in Germany of a concept for the approval of fully autonomous vehicles
- New OEMs in the USA are experimenting with a virtual type approval based on decisions stemming from the use of machine learning methods

7) http://www.nytimes.com/2016/09/21/technology/the-15-point-federal-checklist-for-self-driving-cars.html?rref=collection%2Ftimestopic%2FTransportation%20Department&action=click&contentCollection=timestopics&region=stream&module=stream_unit&version=latest&contentPlacement=2&pgtype=collection

- The Industry 4.0 initiative launched in Germany is the international benchmark. All other regions believe they are lagging behind Germany with regard to the digitalization of mechanical engineering. There are though very large variations in the level of expertise in this sector, with SMEs in particular often feeling overwhelmed
- The logistics industry faces a massive threat from the backward integration moves of customer-oriented companies (for example Uber)

Recommended action: Development of new technologies for functional safety in autonomous systems. These technologies (development methods, agile system development, machine learning, etc.), furthermore, cannot be deployed in the absence of verifiable inspection and testing procedures, which are required not least in connection with liability issues associated with the official approval of autonomous systems. It is particularly important from the technical perspective that the separation of the design and operation phases be addressed in this connection.

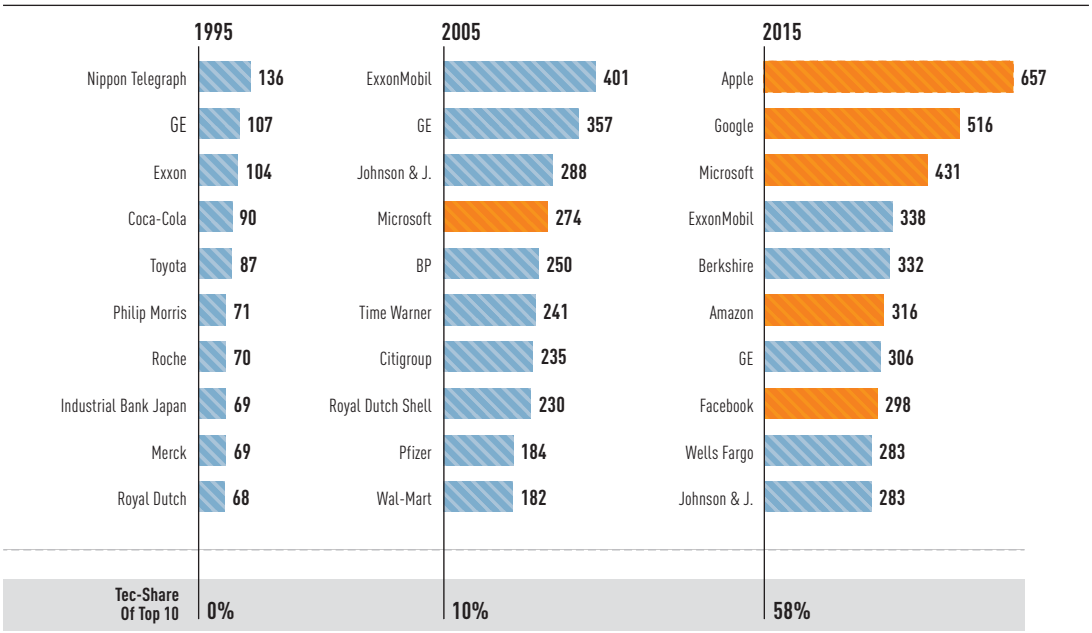
2.3 Platform ecosystems

2.3.1 Platform ecosystems are the logical consequence of the prevailing socioeconomic and technical forces for change

Another increasingly obvious effect of digitalization, along with the transformation of traditional propositions into PSS, is the growing significance of platform ecosystems and their spread from traditional end customer business into the B2B domain. The economic relevance of platform companies has rocketed in a very short space of time to the extent that five of the ten most valuable companies in the world are platform operators (Apple, Google, Microsoft, Amazon and Facebook; see *Figure 8*).

Software platforms (for example an operating system) are of course only the vehicle: what really matters is the ecosystem that emerges on the platform. Digital ecosystems have an enormous reach and spread readily across sector boundaries. The data contributed by platform participants and generated through platform use provides the basis for further digital business models, which in turn lead to further barriers to entry for competitors.

Figure 8: The ten most valuable companies in the world between 1995 and 2015 in billions of US dollars [8]



8) Yahoo Finance; in Anlehnung an Schmidt (2016): https://netzoekonom.de/2016/01/19/keine-industrie-ist-vor-digitaler-disruption-gefeit/

2.3.2 German business underestimates the relevance of platform ecosystems and overestimates its own capacity to influence the rules that govern them

Platforms require that activities be modularized. Activities previously provided in combination have to be broken down into their constituent elements from which the (corporate) customer can build the package it requires. Observations in the consumer market have shown that network effects in terms of supply and demand on platforms can unleash strong concentration pressures and it therefore appears likely that only a small number of competing platform ecosystems (and platform ecosystem providers) for each purpose will prove viable. There is little possibility of catching up with established platform ecosystems (user network, usage data) once a strong provider has become established and has its ecosystem under careful development. The belief is widespread among companies in the German SME sector that individual companies can influence this development on their own, but the evidence thus far suggests otherwise and this could turn out to be a serious misjudgment.

Strong mechanisms for trustworthiness and security and a clear legal framework for data-driven ecosystems need to be established to help German business create new platform ecosystems and bring its influence to bear on existing ones. The rapid establishment of these conditions could create a unique selling point and convince sensitive and conservative sectors to give a European/German platform precedence over non-European providers.

The ecosystems for information-intensive services and products discussed in detail in Chapter 7 are of central importance in respect of the recommended actions for the three sectors discussed. The key properties of an ecosystem – a complete living community and its physical environment – into which the community is integrated and with which it is organized into a system fit for survival, are as follows:

- **Open** – it can be influenced positively through interdependencies with the surrounding structures, especially the surrounding value creation networks, to create the value proposition
- **Dynamic** – typified by flexibly evolving structures, in particular the entry of new and the departure of established ecosystem members and the flexible design of individual services and products
- **Complex** – marked out by interactions, usually two-way, between the members of the ecosystem and in particular by the various contributions of the members to acquiring information, which forms the basis for the ecosystem's products and services

Summary and recommended action

- Splitting, sharing and combination: modularization of activities so that the necessary component activities can be packaged up flexibly as required by the situation at hand
- Only a limited number of platform ecosystems will endure for each purpose
- There is little possibility of catching up with established platform ecosystems (user network, usage data).
- Companies in Germany underestimate the relevance of platform ecosystems and overestimate their own capacity to influence the rules
- Strong mechanisms for trustworthiness and security and a clear legal framework for data-driven ecosystems could create a unique selling point

Recommended action: Establishment of shared platform ecosystems for data-intensive digital products and services Efforts here should focus on establishing joint platform solutions for highly competitive segments of industry with a strong SME presence that are not up to building such a solution independently and are in competition in some respects and cooperate in others (coopetition).

2.4 Politics, business, science and society

2.4.1 Functions of digitalization in a parliamentary democracy – citizens and the state

Findings

Private and public-sector institutions and convened bodies are negatively affected by poor integration of relevant players due to high complexity and particularism. The necessary conditions, in terms both of methodology (Consensus Building/Mutual Gains) and technology (collaboration software, Web 2.0), are in place for a fundamental shift in collaboration within and between convened bodies from a situation dominated by independent and isolated particularism to a creative ecosystem, for example in the form of swarm intelligence as an efficient connected interface that learns dynamically in multi-actor processes.

SMEs account for over 93 percent of value creation in Germany but have only very limited involvement in the relevant decision-making bodies. This is due to the difficulties many SMEs face in accessing such convened bodies and/or the fact that these convened bodies appear to be of little – if any – relevance to them.

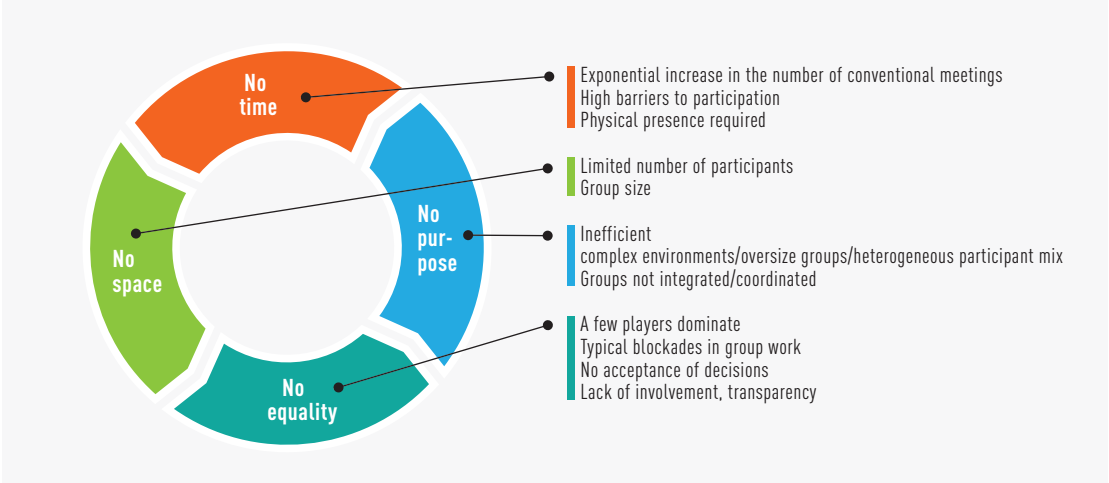
Traditional convened bodies are overwhelmed by increasing complexity (see *Figure 9*). They stand in direct competition with their participants' day-to-day operating business for time, space, priority and justification under cost/benefit criteria. Digitalization has the capacity to overcome these challenges, but only if potential players are permanently integrated – with a dedicated analysis of requirements and relevance looking at both content and processes – at an early stage to ensure that the convened bodies do not make themselves irrelevant to the very people they need to reach.

Implications

Digitalization is not a product in and of itself. Like every ICT program, it too lives by its content (the "rubbish in rubbish out" principle). The most compressed high-level integration of software and hardware is worthless if the players are not committed to the principles of collaboration. Success in digitalization comes to those who make others successful.

The foundations for the success of a digital cooperation platform are laid early on in the conceptual design phase through acceptance by SMEs of the content and processes and through joint phased development. Each participant must have the opportunity to (help) shape the platform, in line with its own specific ideas, on the basis of an initial design hypothesis with no

Figure 9: Complexity overwhelms traditional convened bodies



pressure from the group in protected meeting rooms (joint fact finding rather than decide-announce-defend). Results must be compiled through a neutral intermediary in a methodologically defined process and fed into a jointly backed platform concept that participants have committed to support. The system content, structure and processes are then elaborated jointly in stages.

Recommended actions

Systemic, method-based integration of SMEs through the structured establishment of digital platforms:

- creation and expansion, involving the participants, of a platform for opinion forming
- Pilot digitalization of existing supported projects
- Support for tangible demonstrations of the opportunities (and risks) of digitalization (with products and services similar to participants' own proposition), for example in the form of regional innovation centers
- Targeted dissemination of results from public joint projects

2.4.2 Changing the political system

Findings

Political actors and institutions have increasingly fallen under the influence of special interest groups – companies, associations and privileged elites – to the extent that politics often benefits only the few. Organized coalitions of special interest groups, lobbying interests and power plays are becoming transparent and generating significant criticism. The transparency of the internet allows the volume of criticism to rise and fosters higher expectations among citizens regarding the provision of information and participation in decisions. Decision-making infrastructures that are influenced and shaped by special interests (lobbyists, associations, etc.) lose credibility or are disregarded. Digitalization gives parties that wish to become involved more avenues through which to do so. Stimulated by factors such as education, living standards, social complexity and life expectancies, customers, citizens and entrepreneurs nurture a desire for personal control and self-determination. Information monopolies are coming to an end. The legitimation of power is fading.

The legacy principles of power and leadership under which an organized minority demands the allegiance of unorganized majorities have had their day. Business, science, politics and society are all experiencing a paradigm shift. Majorities organized via Facebook, Google and similar are relentlessly draining the power from minorities organized along analog lines.

Implications

There is a new quality to leadership. Blurred boundaries, speed and interactivity are making their mark on political life, driving widespread upheaval and taking politics above and beyond its formal bounds. A new normality brings with it a new public with new expectations.

Every citizen expects to be directly involved in policy formation and political decision processes. There exist outside of the institutional authority of politics and business parallel latent means – with capacity to spare – capable of replacing fixed costs (for example in administration) and adding new (digital) possibilities. Crowd citizens are emerging and organizing online and there are "crowd demagogues" and "crowd populists" already prowling the net.

Transparency, credibility and the needs of the citizen necessitate a fundamental rethink of the historical state system. Parliamentary democracy – and with it the pillars of free and democratic coexistence – finds itself in competition with unconstrained communities online. The new digital world challenges parliamentary democracy to strike the right balance between responding to public pressure in the short term and making prudent decisions for the longer term. It must establish, understand, mold, formulate and actively defend its competitive advantages and/or adapt.

Recommended actions

No other resource in our free and democratic society can match the state's power to bring about change and it is vital that the state too engage with the rapid transformation associated with digitalization. The state demands the closest attention and should become the center of innovation. Politics cannot be allowed to lose touch in the course of this fundamental shift to new forms of opinion forming and leadership; indeed it is more important than ever in this system-critical phase that it stand tall as a model and source of innovative thought and keep on reinventing itself to perform its mission effectively. Credibil-

ity and competence requirements necessitate the phased introduction of a strategic development department for political entities.

Rethinking and adaptation of the political system in accordance with the requirements of the digital society. Defend the credibility of politics:

- generate and prioritize hypotheses with broad use of collaboration software
- Initiation of concrete pilots in receptive departments of the political administration in order to demonstrate practical feasibility methodologically and technologically and aid the spread of methods and technology to other areas
- Creation of some form of strategic development department for politics (joint fact analysis, derivation of solution spaces based on technical and organizational psychology factors, creation of initial implementation pilots)
- Creation of a publicity campaign to raise awareness and simultaneously boost confidence in politics

3 | Concluding remarks

Digitalization brings enormous challenges for established sectors of industry such as automobile manufacturing, mechanical engineering and logistics. The associated transformation processes are entirely comparable in terms of scale with previous industrial revolutions such mechanization using the power of water and electrification with the use of conveyor systems for mass production. The consequences will include far-reaching changes to industrial value creation structures. The emergence and dominance of software-based, platform-centered ecosystems in particular illustrates how previously unknown and still relatively young companies can very quickly corner a market and overturn the existing balance of power in the sectors considered. If they are to master the digital transformation successfully, established companies must convert their activities into data-driven product service systems, make these product service systems available on the basis of platforms and, very importantly, take control of the customer interface.

Many of the prerequisites for doing just this now appear to be almost within reach, but the detailed technical challenges remain immense and it can therefore still be difficult at times, despite making every effort, to ascertain what is reality and what wishful thinking. What is quite clear, however, is that the Internet of Things will present a host of completely new challenges with regard to the collection, management and effective analysis of data. This is particularly true in the context of bringing autonomy to systems, processes and services. The established methods of deterministic model generation and all of the verification and formal approval procedures based on them cannot cope with the practically infinite complexity of the real world. Fluid, mutating models that evolve with the aid of simulation and machine learning methods and can be verified via system updates and feedback from the real world appear to be one possible solution and are the subject of much attention as a result. Undoubtedly it will be necessary to trial new approaches at every level.

The extent of the change required of established companies is enormous. The high speed of economic and technical developments demands rapid adaptation, but this leaves established companies on the horns of a dilemma: a fundamental realignment of the portfolio requires an equally far-reaching transformation of the organization and its capabilities and structures, all of which will have been underpinning the company's commercial success for years. Companies have to overcome substantial path dependence to implement such changes, for example by adopting ambidextrous organizational structures that permit them to pursue prospective developments in digital business areas in parallel with their established core business. Ultimately the strategic fusion of existing and newly acquired capabilities can open up unique competitive advantages, but this requires equally effective collaboration on the part of all players from all domains – business, science, politics and society. The necessary conditions for effective collaboration between these four cornerstones of our economy include not just the aforementioned technical capabilities, but also a thorough understanding of the individual decentralized expectation and participation culture born out of new ICT-based transparency and forms of social interaction.

Part of the idea of mutual gains is thinking in terms of how others benefit. This requires the courage to maintain an open stance and the willingness to accept and incorporate decentralized individual needs. The political domain needs to take the opportunities and risks associated with the transformation of democratization driven by new media just as seriously as the much more tangible technical challenges. It cannot afford to forgo its authority to lead in the face of competition from the new opinion forming processes emerging from digitalization by making the error of reducing the challenge simply to questions of technology. Lasting acceptance demands joint fact finding rather than the authoritarian decide-announce-defend approach.

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