Executive Summary

Embodied Intelligence: Driving the digital transformation 2.0

Results of an investigation in the context of embodied intelligence, to identify the social, economic as well as technical developments and challenges and to use these to conclude recommendations for action for politics, business and science.

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1 Introduction

Technical progress is always moving on, computers are becoming more powerful and versatile. Artificial intelligence is also developing in the same way. What seemed impossible just a short time ago is now already available to the broad masses. Progress in artificial intelligence is also driving the development of autonomous machines forward. Autonomous vehicles, also referred to as “AI on four wheels”, are a good example of AI-based robotics, consisting of hardware and software – comparable to body and mind.

For a long time, robots and AI did not necessarily have much in common, and some researchers in both disciplines still think the same way. But the development of autonomous machines shows how AI and robotics are coming together in an increasing number of areas. The authors can see parallel developments in computer intelligence and robotics, where the emphasis is on morphological calculations and sensor-motor coordination in evolutionary robotic models. In the neurosciences and cognitive sciences, by contrast, the focus is on embodied cognition and robotic development models of embodied learning of symbols. The emergence of embodied intelligence is closely related to these developments. Embodied intelligence is the computational approach to the development and understanding of intelligent behaviour of embodied and situated agents. It is expressed by considering the strict coupling of the agent and its environment (situatedness), the restrictions of the agent’s own body, perceptual and motor system and “intelligence” physically linked to the agent.[1] Machines with embodied intelligence are systems that can regulate themselves. They currently respond in a relatively rigid way to changes in the environment, but will become more adaptive in future. These are systems that function with little, if any, human intervention. You can already see the first examples now, but they will only appear on a mass scale in much more sophisticated forms in the future. Machines with embodied intelligence are considered by the authors to be the central basic innovation in the next growth cycle, in conjunction with the platform economy.

[1]Based on: Cangelosi, Angelo; Bongard, Josh; Fischer, Martin H.; Nolfi, Stefano: “Embodied Intelligence”, in Janusz Kacprzyk & Witold Pedrycz (Eds.), Springer Handbook of Computational Intelligence. Springer, Preprint (2015),pp. 697–714, https://www.researchgate.net/publication/283812826_Embodied_Intelligence

1.1 Methodology

The current study combines the theory of long waves according to Schumpeter/Kondratieff with innovation methods for strategic forecasting. In the view of the authors, huge changes will occur in the socio-economic systems in the immediate future – determined by the digital transformation.

Kondratieff cycles describe processes of reorganisation in society and their socio-technical basis. According to Kondratieff, an economic cycle is a "long wave" in the economy that lasts 40 to 60 years. The Russian academic Nikolai D. Kondratieff (1892–1938) is regarded as the founder of the theory of "long waves". As director of the Moscow Institute of Economic Research, he published his findings in 1926. There Kondratieff shows that it is not wars or revolutions, but the dynamics of the market economy that cause the long waves. A Kondratieff cycle can be demonstrated by general economic data, such as official economic statistics. According to this theory, we have reached the end of the fifth Kondratieff (innovations in communication and information technology). The sixth Kondratieff (innovations through autonomous systems) is in its initial phase. It is therefore not yet able to set the world economy on a stable, robust course of growth and lead society to greater social order. Kondratieff identifies four characteristics that bring about a transition to a new Kondratieff cycle:[2]

- Exhausted potential for use of old basic innovations (cycle of approx. 40 to 60 years)
- Large surplus of financial capital (versus physical capital)
- A strong recession phase (phase of radical change)
- Social/institutional changes

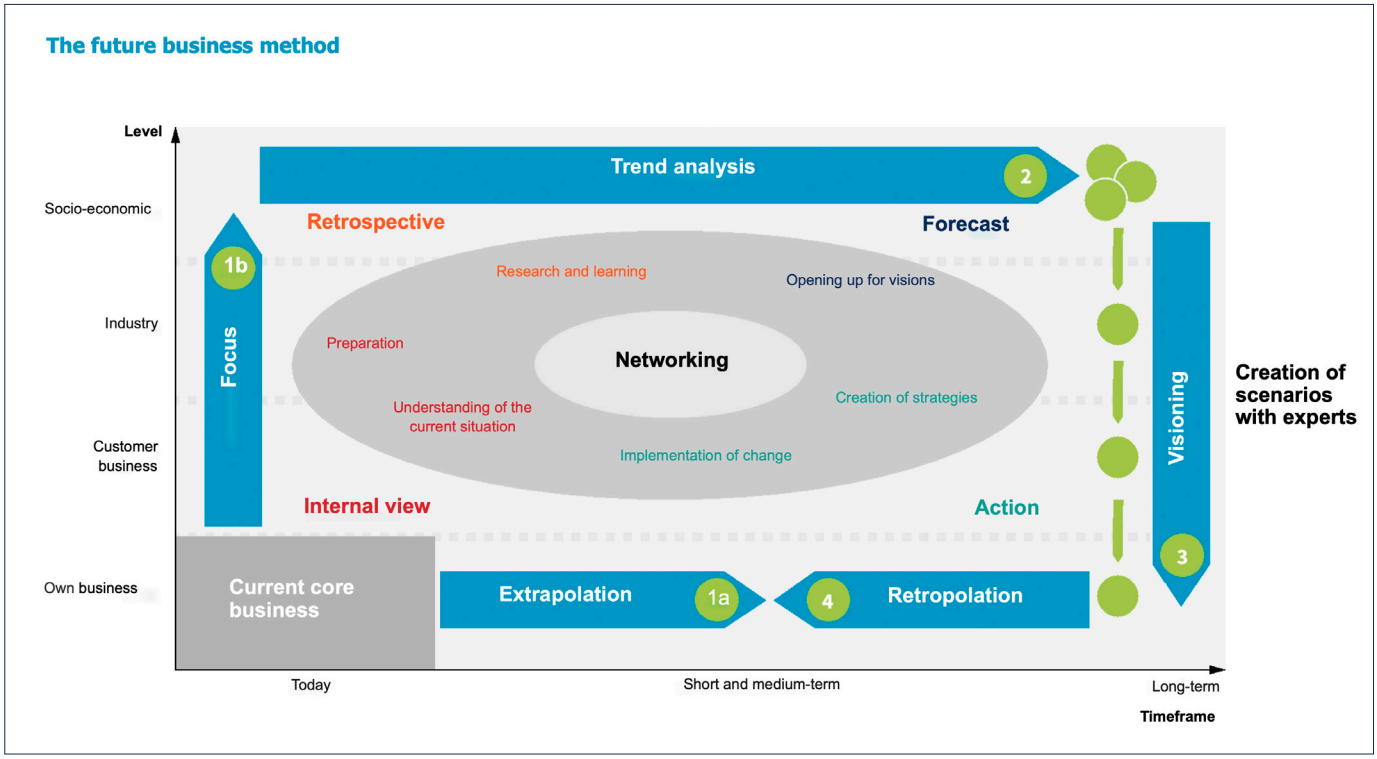

Figure 1: The future of business method in the context of the current study

[2]Allianz Global Investors, "The sixth Kondratieff – long waves of prosperity" (January 2010), https://www.allianz.com/content/dam/onemarketing/azcom/Allianz_com/migration/media/press/document/other/kondratieff_en.pdf

The future of business method shown in Figure 1 offers a proactive approach to assessing risks and opportunities in the current transformation phase for society, politics, the economy and science. The systematic analysis of trends and their structures leads to the realisation that we will have to deal with massive changes in trends in the short and medium term. The principles for thinking ahead and anticipating future developments are formed by the historical analyses of the Kondratieff cycles and the success criteria of old and new hyperscalers.

Hyperscalers or companies with hyperscale structures are businesses that operate large data centres distributed around the world and provide other firms with computing power, storage space and network capacity in the form of cloud computing. As a result, these businesses have a strategic basis for future developments in the context of the digital transformation.

The application of the future of business method makes it possible to overcome existing patterns of thinking and to develop a visionary view of the future. The present study helps to identify signs of change and the extent to which they follow rules. It also makes it possible to shape the future in a more conscious way. The main opportunity for stakeholders in society consists in realigning themselves strategically in the long term. The extrapolative methods of strategy development pursued by most current projects do not provide much help in the current situation.

Digitalisation is a fast process which is leading to a completely new dimension in the value creation architecture in the context of the digital transformation 2.0. Here, the authors see the link between platform economy and embodied intelligence as essential, as it generates a combination of low transaction costs and low functional costs. In the view of the authors, this aspect represents the crucial basic economic innovation for at least the next 20 years. Added to this is the necessity to get a sustainable energy supply for a more autonomous society up and running as a first stage in order to overcome one of the biggest challenges for humanity. This factor will have a much more far-reaching effect and will shape the sixth Kondratieff cycle. The approach of the purpose economy combines the two aspects and therefore acts as a shaping element in the transition between the Kondratieff cycles. The present summary is based essentially on the core findings of the study and on the discussions of the interview results and the resulting insights and implications for recommended actions.

2 Transformation

Most stakeholders regard the digital transformation, which stands for constant change, as inevitable. But the term “digital transformation” remains nebulous for many. A unified explanation based on a multitude of published definitions of the digital transformation is provided by Cheng Gong and Vincent Ribiere[3] and differs significantly in its specificity from other approaches used in the literature. This unified definition has been extended and developed in the BIG project. It refers essentially to an expansion of machines with embodied intelligence which – alongside human beings – will be the main actors in the digital transformation. According to the study, the digital transformation expanded to include embodied intelligence and its combination with platform economies will emerge in the medium term as the central basic innovation of the sixth Kondratieff cycle.

[3]Gong, Cheng; Ribiere, Vincent: “Developing a unified definition of digital transformation”, Technovation, Volume 102 (2021), 102217, ISSN 0166-4972, https://doi.org/10.1016/j.technovation.2020.102217

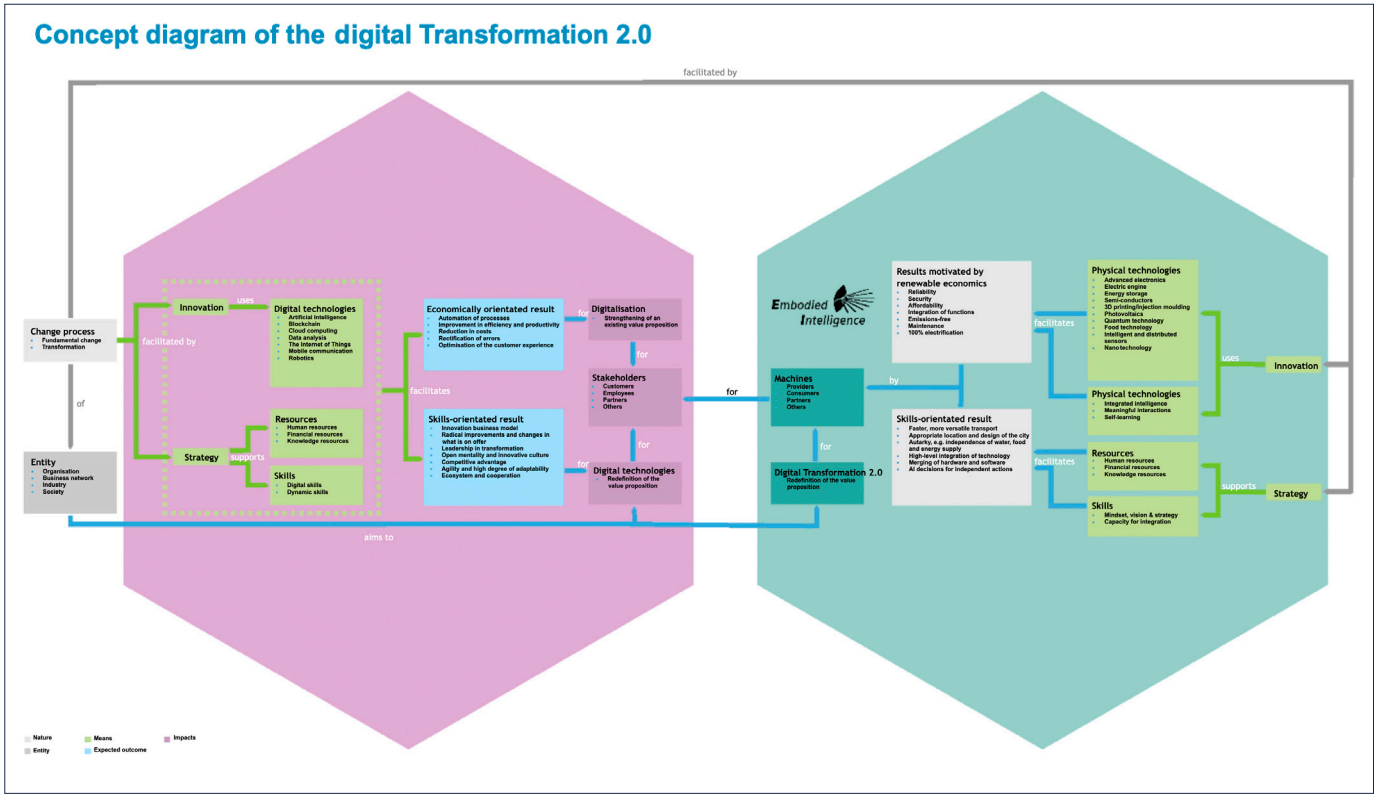

Figure 2: Concept diagram of the digital Transformation 2.0 with a sample of the necessary technologies, resources and skills[4]

Although the global energy transition began over 20 years ago, other measures are necessary to reduce CO_2 emissions and mitigate the effects of climate change. The authors believe that the necessary conversion of the global energy sector from fossil fuels to a CO_2-neutral energy supply by the second half of this century will also accelerate the development of a new form of machines with embodied intelligence. In particular, the combination of embodied intelligence with renewable energy and the use of the platform economy to boost energy efficiency is considered to be a central lever in achieving the necessary reduction in CO_2 emissions.

[4]Gong, Cheng; Ribiere, Vincent: "Developing a unified definition of digital transformation", Technovation, Volume 102 (2021), 102217, ISSN 0166-4972, https://doi.org/10.1016/j.technovation.2020.102217

3 Digital economy

A digital economy functions in a different way to a non-digital economy. In the internet economy, this is evident in particular in the form of powerful network effects and returns to scale through the number of users of a platform. If the expected benefit of a product or service increases with a growing number of users, this is referred to as a direct network effect. Positive direct network effects come about above all on internet platforms. For example, the added value of participation in social media platforms increases for each individual user as the number of users increases. With indirect network effects, the size of the network of one user group influences the behaviour of another user group.[5]

Platform economy is a term that characterises the economic approach of the most valuable companies in the world at the moment, which offer platform-based services instead of conventional products. Platforms operate via a so-called core transaction. It determines the way in which producers and consumers create and consume values. The core transaction consists of a series of actions which the users must carry our to exchange "values" (content, services or products) with the help of the platform; it forms the basis for every platform transaction. In general, the core transaction on any platform consists of four actions:

- **Creating:** A producer creates a value and makes it available via the platform.
- **Connecting:** A user carries out an action that connects them to this value.
- **Consuming:** A user consumes the value created by the producer.
- **Compensating:** The consumer reimburses the producer with the value of the service that they have consumed.

Platforms create and mediate values. This is done through the highly automated digital processing of the core transactions in conjunction with network effects that further optimise the functional scope for the users of the platform. All four of these actions are necessary for a platform to process transactions successfully. Taken together, these platforms offer users a repeatable, cost-effective opportunity to exchange values, enhanced with additional functions.

User-specific data forms the basis of the success of digital platforms. Recording, storing and analysing extensive data volumes about users and their preferences therefore play a crucial role in effective networking of users, content and services. This makes it possible for users to carry out "valuable" transactions (based, for example, on tailored suggestions of products and content or display of ads) and to generate values in this way. The value of a platform therefore increases in scale exponentially with the number of its users. This is in contrast to the standard approaches in the area of data analytics in the industrial field. Here data is mostly used only to optimise an existing production process, to improve quality, for example, or service intervals for machines.

[5]bidt – Bayerisches Forschungsinstitut für Digitale Transformation, https://www.bidt.digital/glossar-digitale-oekonomie/

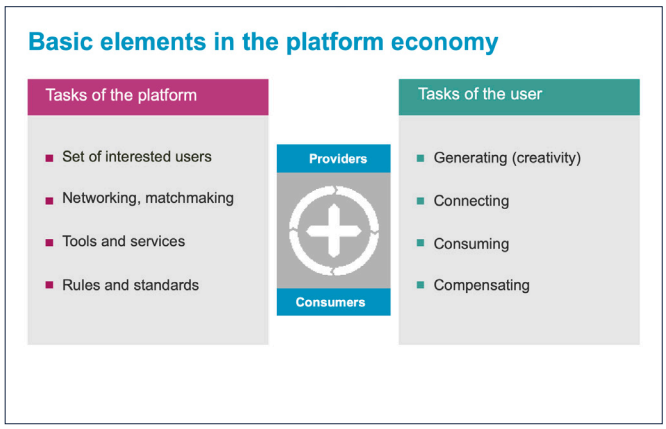

Figure 3: Basic elements in the platform economy

In addition to the user-based core transaction, the platform operator generally has four central concerns:

- Continuously increasing the number of interested users
- Ensuring networking and matchmaking between users
- Providing and developing tools and services
- Defining rules and standards on the platform and guaranteeing their implementation

The user orientation leads to an entirely new target system for the platform economy and differs fundamentally from traditional target systems based on customers and products. Traditional firms increase in scale through the number of products made by a plant; cutting the costs involved in making the products is a particular focus of optimisation. In a modern company orientated towards the platform economy, the interest focuses on scaling of the user base. The key here is a reduction in the platform costs per user, and the potential added value for the user of the platform is optimised. Customers of a digital platform may be users, but are very often also third parties who do not participate in the core transaction, but are involved in the platform through an indirect business model (advertising), for example.

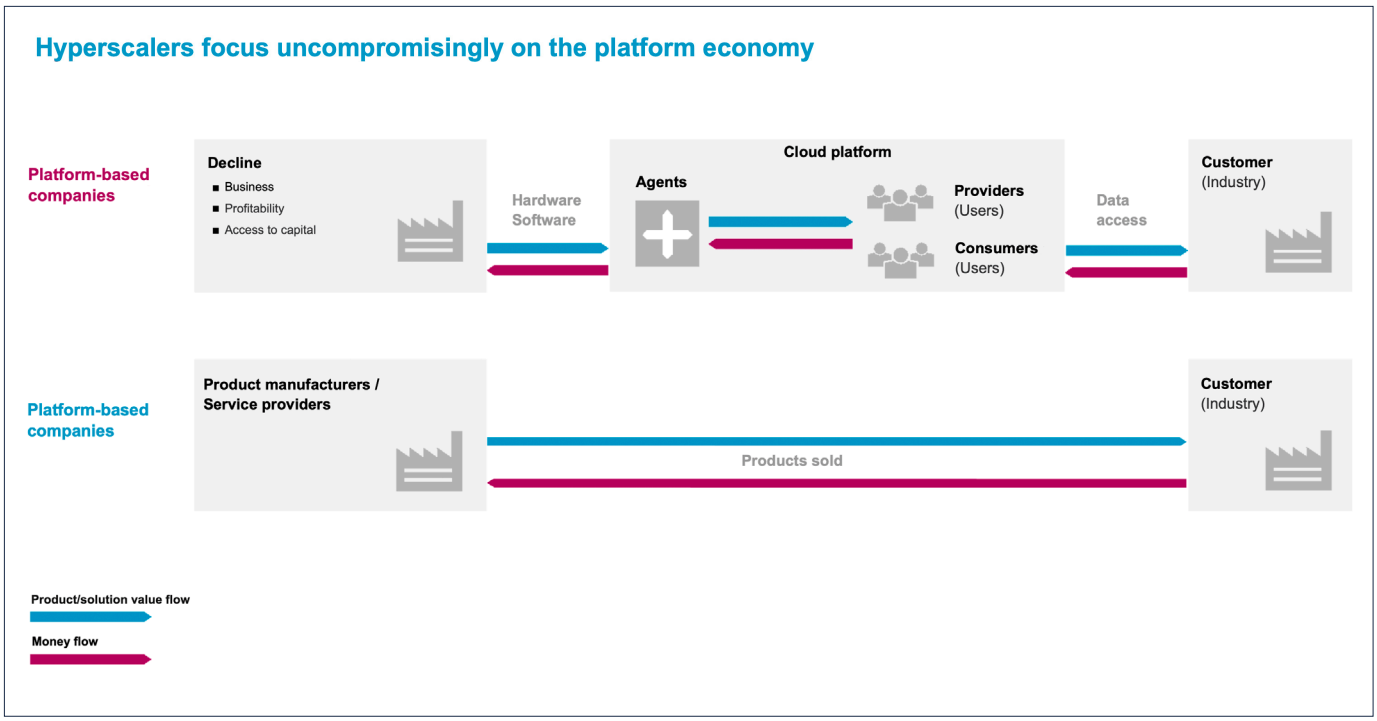

Figure 4: Comparison between established companies and hyperscalers

4 Embodied intelligence

Global networking and increasingly rapid growth in the availability of suitable end devices for broad user groups has facilitated the rapid growth of the hyperscalers over the last 20 years. Initially, it was PCs that offered a large number of users access to the internet and to the first e-commerce services. With the iPhone (and various Android smartphones), a physical platform came onto the market in 2007 which provided people with internet access at all times. The fact that it is extremely simple to operate made it possible for user groups who were not interested in technology to access platform services. As a result of constant use and the features integrated into smartphones (GPS, a camera, for example), it was also possible to capture huge volumes of data about their owners and the world in which they live. This forms the basis for a multitude of services and ultimately also for the growth of the hyperscalers.

One aspect that has not received sufficient consideration so far is the enormous resource efficiency through high-level integration with which, for example, smartphones can deliver services in 2022. If you consider the raw materials and energy consumption associated with most devices (television sets, stereo systems, telephones and cameras) that are replaced by smartphones, it is apparent that the functions provided by smartphones are not only delivered cost-effectively, but also with extremely sparing use of resources. This facilitates high-level integration of a wide range of hardware components, which leads to significant synergy effects inside the devices. As a result of the spatial proximity of these components and access to all the data within the device, either significant improvements in function or additional functionalities can be created through data fusion.

The authors assume that future models will not only record their environment and interact with users, but that they will also come with appropriate additional actuators. As a result, they will also be able to provide services of a physical nature in the real world. The primary example of this is autonomous vehicles. Over the coming years, their manufacturers will be attempting to create self-driving robot taxis with no human driver. In this context, integration of these vehicles into the platform economy plays a key role in connecting users and providers, for example, or providing autonomous vehicles with services such as energy supply, cleaning and other services. As a further self-driving development of mobility providers already in existence today such as Uber and Lyft, autonomous vehicles embedded in a platform economy will create the basis for attractive and affordable mobility services for broad groups of the population. With radical consequences: for many people, it will no longer make economic sense to own their own car, which will not be used for the most part and takes up urban space. The associated sharing of vehicles also significantly reduces consumption of resources for delivery of the function (transport of people and goods). The authors see in autonomous vehicles the first heralds of a new type of machine, referred to in the research as “embodied intelligence”.

Informationsdienst Wissenschaft puts it like this: “In the course of the last three decades, research into intelligence has gone through a change which has led to the latest research area of ‘embodied intelligence’. This area is closely linked to the realisation that intelligence is not just a matter of the brain. Rather, observations in nature have shown that intelligent behaviour develops primarily through the interaction between the brain, the body and the environment. There is plenty of evidence of this in us as human beings. For example, the backswing phase of the leg when running takes place without any control by the brain but solely through the interaction of the body and the force of gravity. The muscle-tendon principle helps to stabilise the body position without the brain having to intervene at any point. The relevance of this basic idea of interaction is being recognised increasingly in general research into intelligence.”[6]

[6] idw – Informationsdienst Wissenschaft e. V. (2013), https://idw-online.de/de/news520174

Accordingly, "embodied artificial intelligence" represents a new form of artificial intelligence. It benefits in various ways from the fact that it is embedded in a physical body that interacts with the physical environment. On the basis of observation, researchers have concluded that embodiment is a key element in the development of intelligence in the course of evolution and want to make use of this principle for the development of forms of artificial intelligence. The physical environments in which forms of embodied intelligence operate present a challenge to the learning behaviour of artificial intelligence as a result of the often complex and always different structures. The example of autonomous vehicles illustrates this, as they have to adjust to a multitude of constantly varying environments on the roads. The capacity of forms of embodied intelligence to make decisions that take account of complex situations and turn them directly into actions means that they are in a position to participate as users in platform economies. They can contribute to optimising the costs of services offered over the platforms by minimising the functional costs through their specific intelligence. In the case of autonomous vehicles, this can be done by optimising routes, for example, and minimising journeys with no passengers and downtimes.

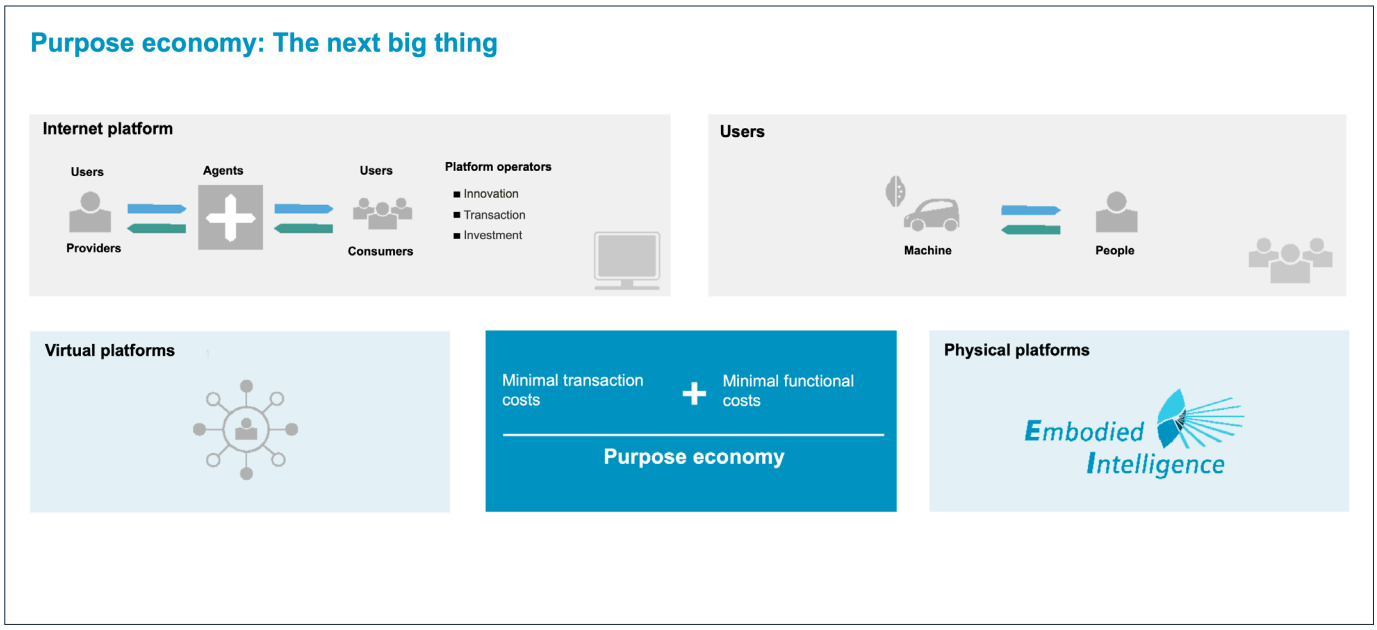

Figure 5: The platform economy and embodied intelligence are enablers for the purpose economy

The present study proposes an innovative value creation architecture which facilitates a transformation to the purpose economy. The purpose economy is a term coined by Aaron Hurst. He describes the way in which work changes to reflect the desire of employees to achieve a higher social purpose in their work. The theory of the purpose economy states that companies will only be successful in the long term if they have a clear sense of the social purposes with which employees can identify.[7] The combination of minimal transaction costs for exchanging values in the platform economy and low functional costs resulting from the increased use of machines with embodied intelligence leads to greater resource efficiency. This economic framework can help define a clear corporate purpose and develop new business models. In addition, it represents a good basis for realigning corporate strategy in the direction of energy and ecological sustainability.

[7]Interview with Aaron Hurst, Think:Act Magazine (2018), https://www.rolandberger.com/en/Insights/Publications/The-definition-of-the-purpose-driven-economy.html

5 Technological needs of future value creation

We are on the cusp of the transition from the fifth to the sixth Kondratieff cycle. Everything began with the invention of the steam engine, which triggered early industrialisation in the first Kondratieff cycle. The key innovations in the fifth Kondratieff cycle include the development of the personal computer and the smartphone with standard operating systems, the (mobile) internet and the other technologies that follow on from that, such as email communication, social media, etc. For the sixth Kondratieff cycle, the authors see the platform economy, business intelligence, big data, transformation technologies and embodied intelligence (EI) as the basic innovations. The latter is based on the high-level physical integration of various domains such as IT technology, electrics/electronics, material technology and biotechnology. The lead industry of autonomous, land-based vehicles is carrying these basic innovations onto the markets. Significant scaling takes pace here with an associated cost degression in the central basic technologies. These are then available in sufficient quantity, certified quality and at affordable prices for all new solutions. The authors of the study are of the opinion that in the transformation phase in particular, the absolute primacy of the technology cannot be assumed, but that it will be necessary to take more account of compliance with the laws and necessities of economics. Certain laws emerge from an analysis of the course of Kondratieff cycles: The first phase is characterised by the development of new infrastructures and by a decline in growth in the existing industrial base from the previous cycles. In the second phase, the infrastructure that has been set up serves as the basis for new applications to generate growth.

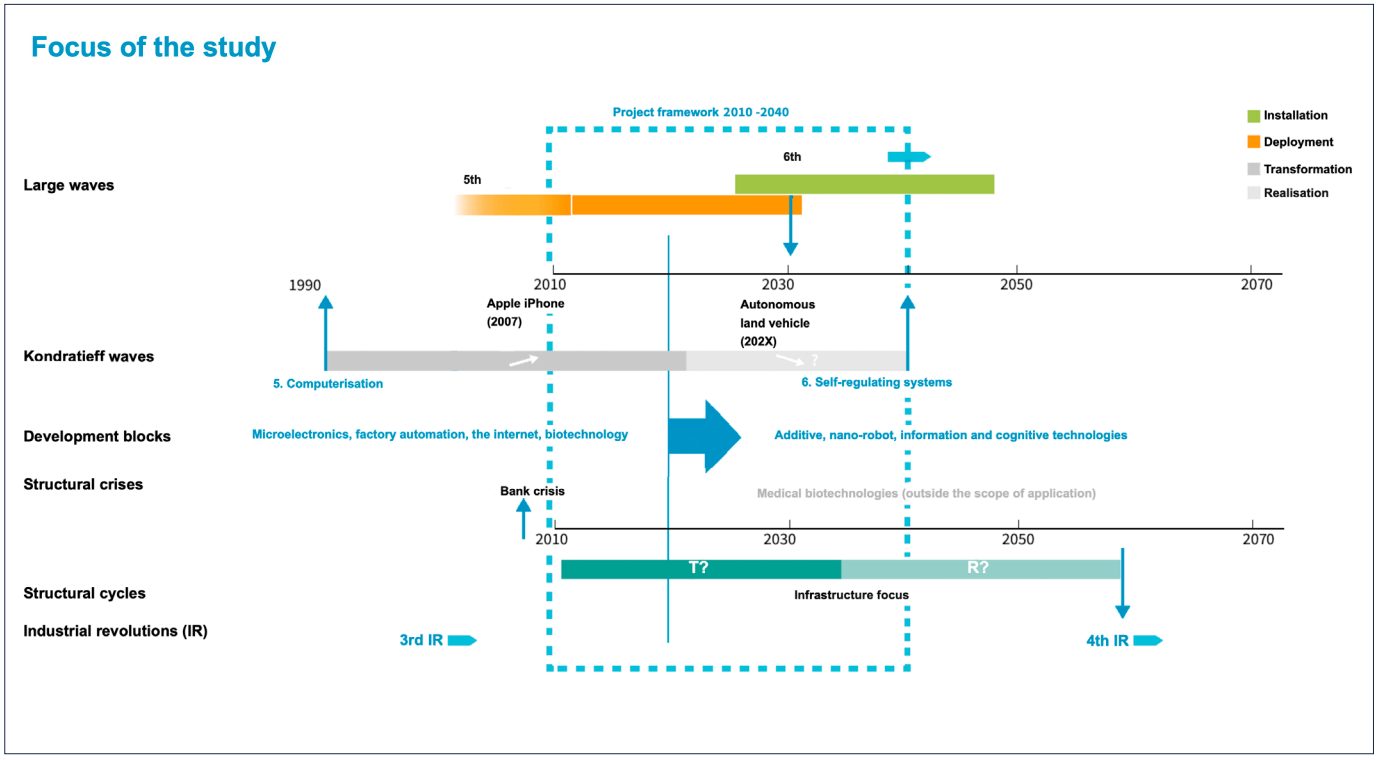

Figure 6: Chronological focus of the study on the basis of the Kondratieff waves, derived from Josef Taalbi

We are currently in an extended transformation phase, in other words at the start of the development of the new infrastructure (transport, energy, communications, medicine, agriculture, etc.). This process will extend well into the 2030s. All indicators suggest that the effect of this transformation will bring permanent change to urban infrastructures. The enormous number of potential users means that a correspondingly large demand is anticipated, which in turn makes investment in the infrastructure attractive. The authors also see the first signs of a 180-degree turn in value creation chains towards more value creation involving the end consumer. That includes all areas of life – from generating energy through to production.

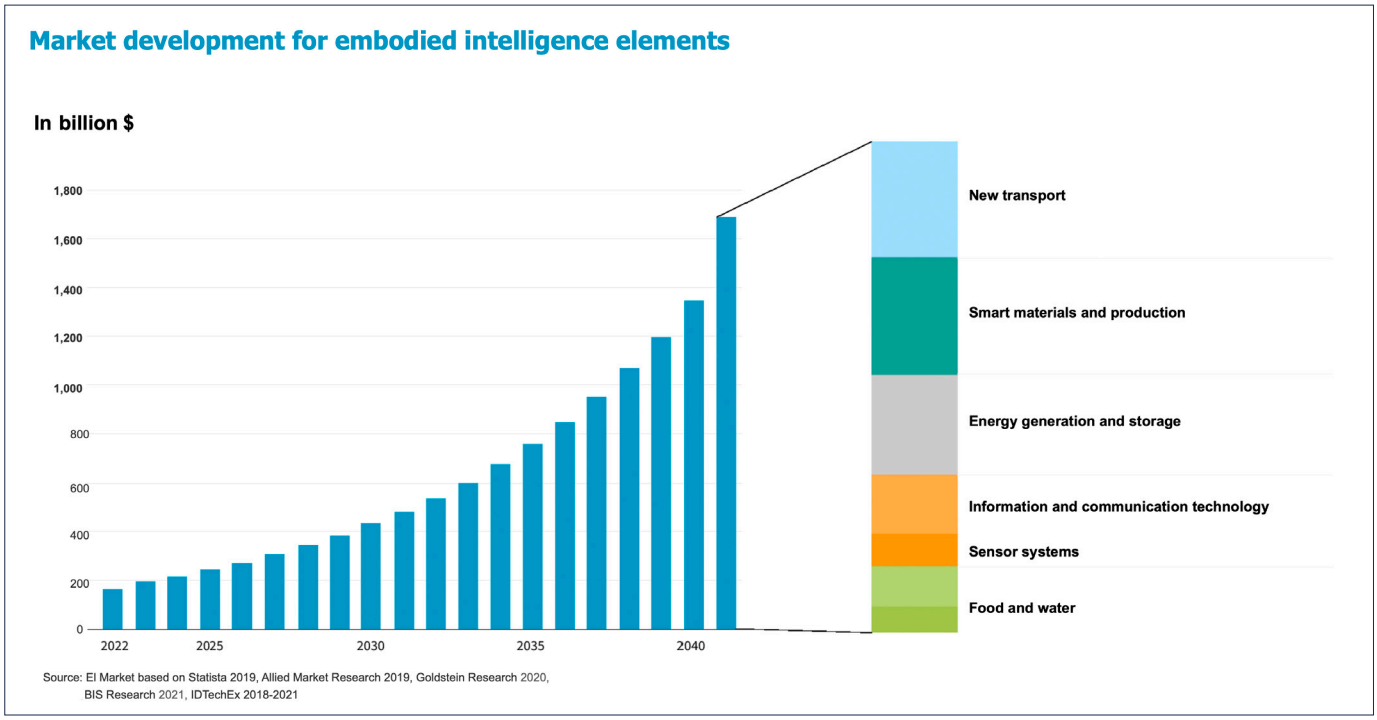

Figure 7: Market development of subsections of embodied intelligence

6 Recommendations for action

6.1 Assessment of the status quo

The digital transformation has affected all areas of the economy and society and will fundamentally change our lives. Processes are accelerating, innovations and new jobs are being created. Users are enjoying improvements, in the area of mobility for example. On the other side of the same coin, the digital world also creates fears when, for example, artificial intelligence advances into ever more areas of life. According to a survey by the Bitkom digital association[8], 75 percent of those surveyed were afraid of greater control of employees through AI and almost two thirds (65 percent) of job losses. These fears correspond to people's desire for security and transparency. They want to retain control over their lives. People want to make decisions and be able to survive on their own. Governments must therefore put in place clear prerequisites for the digital transformation and ensure that the economy – from start-ups to large companies – uses them beneficially.

[8]Bitkom digital association (2020), https://www.bitkom.org/Presse/Presseinformation/Die-Menschen-wollen-KI-und-haben-auch-Angst-vor-ihr

Dell's "Digital Transformation Index" compares the digital maturity of 18 countries; Germany is somewhere in the middle here, with 56 out of 100 points. One reason for this: there is still a high proportion of companies in the Federal Republic that are among the so-called "digital evaluators". These are firms that are only gradually getting to grips with the digital transformation. In other countries, such as the USA, China, Mexico and Brazil, there are more companies with mature digital strategies. These are referred to as "digital adopters".[9]

Another report, the "Digital Riser Report", looks at the digital competitiveness of 140 countries. Here, the Federal Republic is almost at the bottom of the list of G20 countries. The leaders are China, Saudi Arabia, Brazil and Argentina.[10]

The requirements of society and of each individual citizen are high. It is therefore important to understand why the transformation is moving so slowly in Germany in particular. With this in mind, a self-assessment of the strengths, weaknesses, opportunities and risks expected in connection with the digital transformation 2.0 was carried out. In addition to a comprehensive research of the literature, this study included dialogues with decision-makers in politics, the economy and academia, and semi-structured expert interviews. The statements were backed up by an online survey. Figure 8 shows a summary of the most important findings for each of the points.

Figure 8: SWOT matrix with the key findings

The main point that emerges in comparison to the same questions asked in the study "Digitale Transformation - Wie Informations- und Kommunikationstechnologie etablierte Branchen grundlegend verändern" [11] ("Digital Transformation - How information and communication technology is fundamentally changing established sectors") from 2016 is that the transformation process has made hardly any progress in the last six years. There seems to be a lack of enthusiasm everywhere, and there is even a failure to see the necessity for the impending change processes. Maintaining and managing things are the dominant patterns of behaviour – especially at management level.

[9]bidt – Bayerisches Forschungsinstitut für Digitale Transformation (2020), https://www.bidt.digital/digitalisierung-in-unternehmen-im-weltweiten-vergleich-deutschlands-digitaler-reifegrad-im-mittelfeld/

[10]European Center for Digital Competitiveness – "Digital Riser Report 2021", https://digital-competitiveness.eu/wp-content/uploads/Digital_Riser_Report-2021.pdf

[11]"Digitale Transformation – Wie Informations- und Kommunikationstechnologie etablierte Branchen grundlegend verändern" (2016), ISBN: 978-3-9818237-0-7, https://download.fortiss.org/public/digitale_transformation/digitale_transformation_de_gesamt.pdf

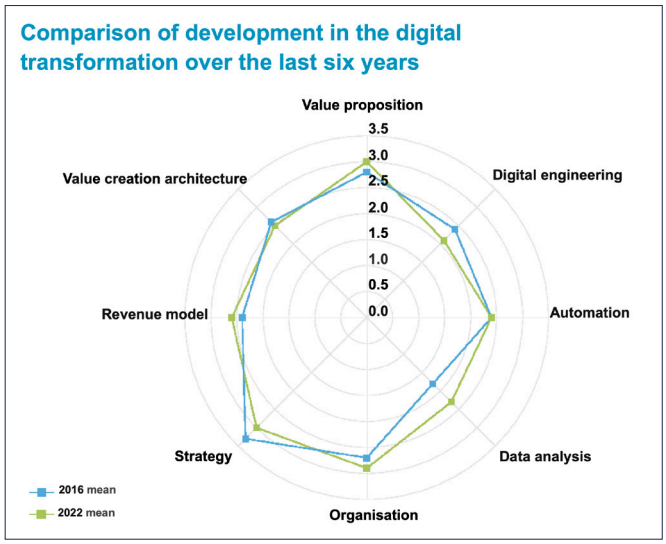

Figure 9: No significant changes in the core areas of digitalisation since 2016

Based on these findings and insights, basic recommendations for various areas of society will be set out in the next section. A distinction is made between the areas of the economy, science and education, and politics, which are dealt with separately below. The recommendations for action are set out in such a way that they are able to provide appropriate answers to current challenges. The independence of energy, food and water supplies, climate change, faster migration to the cities and other migration phenomena and the problem of dysfunctional national governments are considered particularly important in this context.

6.2 Recommendations for politics, the economy and education, science and research

The recommendations for action that are connected directly to EI and the platform economy relate to the time horizon of this study. The authors regard the acceleration of urbanisation, migration, demographic change, the attempt to achieve independence in energy supply and in water and food supply to some extent, climate change and the dysfunctionality of governments as the most important areas for action in the period up to 2035. They can be shaped particularly effectively by embodied intelligence and the platform economy.

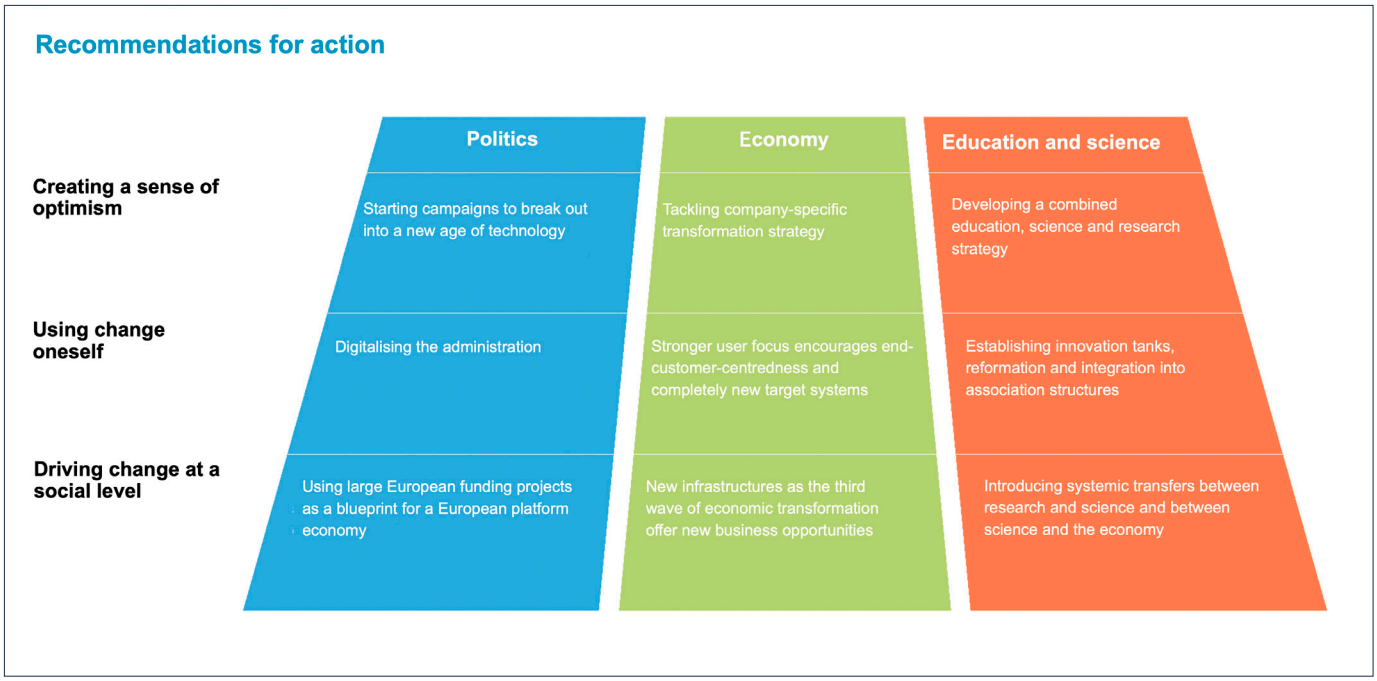

Figure 10: Areas of action for politics, the economy and education and science

6.2.1 Recommendations to the political sphere

Politics can support the transformation to an economic architecture that is ready for the future with the help of regulation, public purchasing policy, acting as a focus for all the efforts and development of the infrastructure. A basic prerequisite is an efficiently functioning state system. Not only is huge political support required for the difficult social transformation tasks ahead of us, but the state must also act as a role model to some extent. The modernisation of the state must be driven forward with a sense of responsibility both politically and organisationally and must be based on the principles of the platform economy.

Starting campaigns to break out into a new age of technology

The harmonisation of ecology and economy by merging independent forms of intelligence with highly integrated devices as potential users of platform economies represents a unique opportunity for sustainable affluence. This manifests itself in a minimisation of both the functional costs and the transaction costs.

The authors recommend initiating a breakup of the economy, academia and society. The creation of cross-segment alliances of opinion-shapers and multipliers from the economy, academia and society plays a key role here.

The transformation phase which has already been in progress for some time, i.e. the development of new infrastructures (transport, energy, communications, medicine, agriculture, etc.), should essentially be controlled by politics. The role of economic policy and the state in providing virtual and physical infrastructures has much greater importance today than 100 years ago. Today's challenges for infrastructure investment – in digitalisation and decarbonisation, for example – also differ fundamentally. A strategy is required to set up infrastructures as a sort of state "building development plan", which is aligned in the long term (up to 2035) with the requirements of people and machines with embodied intelligence. All indicators suggest that the effect of this transformation will first bring permanent change to urban infrastructures. The enormous number of potential users means that a correspondingly large demand is anticipated, which in turn makes investment in the infrastructure attractive.

The authors also see the first signs of a U-turn in value creation chains towards more value creation involving the end consumer. That includes all areas of life – from generating energy through to production. The new infrastructures will not be very profitable initially. The state therefore has to take responsibility and should rethink its own role in terms of a public service for creation and initial operation of the infrastructures.

Digitalising the administration

Digitalisation of the administration is happening only slowly in Germany. The digital transformation must bring about a cultural change in the administration, and develop and extend agility and flexibility in politics more strongly – irrespective of existing structures and responsibilities. It is important for the administration to work in a more modern and effective way. The willingness to think of processes disruptively starting from their objective and not simply to convert analogue processes into digital ones creates a leaner administration. It can then focus on the key content, instead of getting bogged down in the complexity of formalities.

The authors recommend requiring a willingness to change on the part of the administration and putting it into practice more consistently. Germany needs more innovative talent in public service at all levels to grow into the "digital generation". Not only the national government, but also the federal states should accept and fulfil their role as drivers for the application of the principles of the platform economy and challengers calling for the use of solutions based on embodied intelligence. Politics must continuously confront industry with the need for new technologies. This should be done not only through its own innovative state solutions, but also by running competitions, giving prizes and reward-

ing achievement of long-term goals. Such competitions encourage cooperation between large companies, SMEs and academic institutions, which supports the formation of particularly productive clusters.

Using large European funding projects as a blueprint for a European platform economy

Hyperscalers and the first high-tech companies have recognised the race for global market leadership of embodied intelligence in products and production processes and started to implement them. They focus uncompromisingly on the platform economy and enjoy high investor trust as a result. Europe must bring together its strategic skills and competences to create a whole to avoid losing touch with the global competition.

The authors recommend pursuing a fundamental European approach, but also to question it critically and evaluate it. Virtual infrastructures require a clear objective and a long-term vision, which also includes the sovereign tasks of digitalised administration. The virtual infrastructure for a leading platform ecosystem could be set up by a European operating company on the basis of the revised principles. Examples of this include the approach of Gaia-X or the 6G Flagship programme. A clear objective and vision must be established for this, which not only attempts to digitalise existing infrastructures and industries, but which points to the future and represents a basis for the platform economy. In this way, Europe could decouple itself from excessive dependence on the existing hyperscalers with its own platform.

6.2.2 Recommendations for the economy

In the current environment of large and continually growing digital companies like Google, Amazon and Apple on the one hand and the developing ecosystem of start-ups on the other, firms and their managers should make their own way. Disruptive change presents large challenges to the economy. The main problem is recognising the necessity of this change. Many companies simply shut their eyes to it and managers of German companies do not yet understand how the systems of the platform economy work. It involves user-based and mainly indirect forms of business. Too little is being invested in these new types of profitability. The only solution is to explain and build knowledge. It is also necessary for the stakeholders to be able to act in all areas of business (including in their structure). Otherwise, the attempt to change will fail because of the conventional thinking that predominates in traditional companies.

Established markets are disappearing and completely new ones are taking over their function. Firms should show more courage to change to new markets and customers and, in particular, address end-customer markets too. Questioning one's own standpoint is a difficult proposition in the still very hierarchical structures of German companies. The entire knowledge of a company should be made transparent. Managers can be role models for their employees and encourage them to contribute their ideas and then implement them courageously. Germany needs a culture of bravery and responsibility.

Tackling company-specific transformation strategy

The global pandemic has accelerated the need for a transformation strategy, as the markets are becoming increasingly disruptive and require fast decisions on the basis of structured, forward-thinking analyses. The managers responsible must act now and tackle their company-specific transformation strategy. Part of the problem with the term "digital transformation" is that everyone conceives of it differently. Managers often believe that the digital transformation begins with the technology, while the reasons for it are only discussed subsequently. This approach tackles the problems the wrong way round. For a successful digital transformation, it is essential first to identify the business-related user demands and objectives that are relevant for the

future and to develop a strategy on that basis. A digital transformation strategy is a detailed, broadly based plan which sets out how a company can overcome the significant challenges that arise because of the merger of the physical, digital and human worlds. The development of a timetable for the short, medium and long-term digital transformation that is based on business circumstances and not on technology is the most important principle. The authors therefore recommend accepting the challenges of the digital transformation. This can be achieved by training employees and managers to deal with change. The aim is to establish a new culture that puts people at its centre. Everyone involved must internalise an understanding of change and the transformation strategy developed in the company. The prerequisite for this is a structured strategy process and a sustainable communication strategy both internally and externally. The core elements include an understanding of the platform economy and the possible business implications of embodied intelligence.

Stronger user focus encourages end-customer-centredness and completely new target systems

Companies must develop new target systems. Data analysis is the key element in decision-making in the world of the cloud (Software as a Service or service providers). It is essential for firms to implement basic processes so that they can manage and monitor appropriate KPIs at regular intervals.

Four KPIs[12] are described below, for example, which any successful entrepreneur should be aware of in future – whether they are a service provider, a system integrator changing to cloud services, or an established hosting provider. These KPIs differ in particular in their target system and are user-centred:

- E-commerce KPIs: customer lifetime value (CLV), percentage of repeat purchases, number of buyers per month
- SaaS KPIs: customer retention, interactions with customers, number of paid users
- Media KPIs: total of streamed hours, average revenue per user (ARPU), time spent listening
- Tech KPIs: number of actions completed per user, daily active users (DAUs), monthly active users (MAUs)

The authors recommend placing more emphasis on the user as an actor in a platform-based ecosystem. The user's needs and wishes should be at the centre and should be adapted in the subsequent user relationship. All objectives and target systems must be revised completely for this and KPIs must be realigned.

New infrastructures as the third wave of economic transformation offer new business opportunities

The change in the infrastructure primarily addresses urban functions. These include transport, production of electricity, new ICT and new materials and production processes. Mechanisms for generating solar, wind and hydroelectric power in cities reduce the importance of remote power stations and connection via mains networks. Extraction of coal, oil and gas and the associated long transport routes are minimised. As a result, cities use up less space as they grow and gain in independence.

The authors recommend learning from the pioneers. Tesla is often taken to be an electric car manufacturer, but sees itself as an infrastructure provider. The company is an energy provider and operates as a supplier to electric vehicles through a huge network of charging stations throughout the world. At the same time, the company supplies households with energy generation and energy storage technologies with the aim of revolutionising the market in the energy business. But Tesla is also one of the most modern telecommunications providers, which, with the aid of its own space technology, is developing a satellite-based communication infrastructure and offering appropriate communication services to end consumers and machines with embod-

[12] Cardillo, Anthony: "How To Find Your North Star Metric (80+ Examples)", Finmark Metrics & Reporting (2021), https://finmark.com/north-star-metric/

ied intelligence. And in turn, these new machines with embodied intelligence will increasingly form part of the infrastructure themselves and offer corresponding mobility services.

Medium-sized German businesses should tackle the issue of new urban energy infrastructures and combine them with water and sewage transport and solutions involving 6G and 7G mobile phone standards.

6.2.3 Recommendations for education, science and research

Despite budgets that are continually growing, scientific performance is stagnating in comparison to other countries. The big German research organisations regularly appear in the top listings with their publications, and even when it comes to the award of Nobel prizes, scientists from Germany are repeatedly on the shortlist. But other nations are more dynamic in leading the way through international perception of their scientific institutions. Here the system too often puts the brakes on those who want to set up an ecosystem for disruptive research, innovative teaching and the structures to match.[13] This also includes opportunities to use the results of research sustainably and to take them further; here, the concept of incubators and accelerators represents a particularly fruitful instrument for supporting spin-offs from the university environment in a targeted way.[14]

Future developments and the trend towards EI systems that interact ever more autonomously with people and their infrastructures will confront the areas of education, science and research with some big challenges. Research must concentrate on the principles for new material and development processes, while science develops existing technologies and approaches to using them. Education must prepare the next generations for these challenges. Appropriate areas for action in the fields of education, science and research are described below. These are intended particularly for universities, research bodies, teachers and trainees. Existing association structures are also required that will deal with both strategic and material considerations.

Developing a combined education, science and research strategy

The strategy should be based around the platform economy and EI systems and address various complexes of issues. In general, digital education should start a lot earlier. In addition to responsible and effective use of the tools, the media themselves play an important role in building up and developing not only media competence but also digital skills. This also includes skills in the areas of algorithms, software development and programming. Adaptation of content is also closely linked to intensive training of those who convey knowledge and the extension and development of educational establishments and infrastructures. Overall, the education system must focus on producing people with a broad education who are able to combine and develop various areas.

In academic areas and higher levels of education, it is a matter of establishing a connection between theory, existing solutions and their possible applications in practice. Those responsible should keep in mind an orientation towards application, the opportunities for economic exploitation and the legal aspects. Application-based research should focus more heavily on benefits and not simply develop technical solutions, since the social and economic interactions also deserve attention.

[13]Baumann, Michael; Hofmann, Thomas; Sack, Norbert; Schütte, Georg: “Ein Weckruf für die deutsche Wissenschaft”, jmwiarda Online (2021), https://www.jmwiarda.de/2021/12/07/ein-weckruf-f%C3%BCr-die-deutsche-wissenschaft/

[14]Zinke, Guido; Dr. Ferdinand, Jan-Peter; Groß, Wolfram; Möring, Janik Linus; Nögel, Lukas; Petzolt, Stefan; Richter, Stefan; Robeck, Martin Simon; Dr. Wessels, Jan: “Trends in der Unterstützungslandschaft”, BMWi (2018), https://www.bmwk.de/Redaktion/DE/Publikationen/Studien/trends-in-der-unterstuetzungslandschaft-von-start-ups.html

However, some basic principles in connection with EI systems must be researched, their potential for high-level integration identified, understood and evaluated. There is a need for appropriate research in both hardware and software in this context. A strategy of this sort should include the transformation process that is based on the principles of the platform economy (minimisation of transaction costs) in combination with EI systems (minimisation of functional costs).

The authors recommend developing a common vision for the educational, scientific and research strategy, taking account of the points outlined above. Education must move closer to the demand from science and the economy. Knowledge mediators at all levels not only need advanced training in education, but must also be able to use the available technologies. It is essential to promote and require interdisciplinarity, so that understanding across domains comes about: the humanities, social sciences, business studies and law must be combined with and linked to the natural sciences.

Establishing innovation tanks, reformation and integration into association structures

From an academic perspective, EI and platform economic systems must be integrated socially, economically, legally and technically into interdisciplinary innovation tanks. Appropriate representatives of society, the economy and politics should also be included in these. Innovation tanks support project sponsors and the associated research in designing and implementing research strategies, calls for bids and projects. They should be responsible for assessments and interim evaluations. Interdisciplinary excellence clusters must also grow at university level to reflect the requirements of the respective discipline across the board. The topic of high-level integration plays a central role in the development of EI infrastructures, especially in the areas of energy, new substances and materials and autonomous transport systems in combination with information and communication technologies.
It is important for scientific institutes and organisations to work more closely with associations and similar groups, provide information about results, objectives and implementation and use their networks for dissemination. Economic applicability and legal feasibility must be taken into account to a greater degree. While the focus is on an interdisciplinary approach, clear requirements and evaluation criteria must be identified in advance for the future challenges of EI systems in combination with the platform economy and be assessed and prioritised by the innovation tanks.

The authors recommend developing interdisciplinary innovation tanks in cooperation with associations which assist the federal and regional governments with calls for research bids and their support and are involved in the assessment of performance and results-orientated research and funding programmes. Innovation tanks should occupy a central role in the context of the excellence clusters to be set up. The clusters address the groups of topics highlighted in the study, such as the development and safeguarding of robust and reliable EI systems or material sciences with potential for high-level integration.

Introducing systemic transfers between research and science and between science and the economy

The education sector must respond to developments and structural changes with appropriate iterative adjustments of technology-heavy subject areas in implementing the education strategy. The educational establishments must put the conditions for this in place at an early stage, bring forward the right skilled employees and transfer the necessary skills in economics and science. Attracting skilled employees from abroad is not a long-term solution; regular adaptation of the content of and infrastructure for education is more important. Development of open-ended theoretical research (topics), the results of which are assessed and prioritised, is recommended. These can be taken up and developed further by the scientific community using structures that are similar to those of competition. Virtual infrastructures and the approaches of the platform economy help with the publication of the corresponding competitive programmes, acquisition of investors and marketing of the results.

In addition to coaching, testing business ideas in terms of marketability and scalability and connecting with investor networks, incubators and accelerators must also offer legal support and be able to assess social impacts. Establishment of a performance and results-orientated research and funding landscape with sustainable exploitation of results must be initiated. As far as funding projects are concerned, it is particularly important that, in addition to purely technical implementation, they also take account of cost-effectiveness, business model development, legal framework conditions and assessments of social consequences in order to achieve more sustainable usability of the results. Partly unused results from funding projects must be made available and usable within the framework of exploitation companies linked to universities and of the principles of the platform economy. The creation of the legal conditions for this must be a requirement, where necessary. Suitable concepts and exploitation strategies for economic use of patents created in universities and colleges must be developed. The results of theoretical research must be assessed by appropriate innovation tanks and incubators and should result in forward-thinking funding programs which both require short-term results and clearly map out long-term strategies.

The authors recommend that the stakeholders in science and research in part adjust to a performance-orientated research culture. Exploitation and transfer concepts must be developed in interdisciplinary consortia and the social, economic and legal aspects must be set out. In addition, the basic principles of an entrepreneurial approach and a legal understanding must be integrated into technical areas, while technological topics must be brought together with the social sciences, economics and law. The concept of accelerators and incubators can be developed in this context into an interdisciplinary exploitation and transfer infrastructure.