Interreg
CENTRAL EUROPE
European Union
European Regional Development Fund
CHAIN REACTIONS

WP
D.T.1.1

Value chain innovation model

Version 1
09.2019

Project information	
Project Index Number:	CE1519
Project Acronym:	CHAIN REACTIONS
Project Title:	Driving smart industrial growth through value chain innovation
Website:	https://www.interreg-central.eu/Content.Node/CHAIN-REACTIONS.html
Start Date of the Project:	01.04.2019
Duration:	36 Months
Document Control page	
Deliverable Title:	DT.1.1 – Value chain innovation model
Lead Contractor of the Deliverable:	BWCON
Authors:	BWCON
Contractual Delivery Date:	30.09.2019
Actual Delivery Date:	30.09.2019

Table of content

1 EXECUTIVE SUMMARY

This deliverable explains the concept of value chain innovation in the context of the CHAIN REACTIONS project.

In the first step, the concepts of value chain and value chain innovation are presented. Different value chain models and their evolution over time are shortly explained, up to the increasingly used platform-based ecosystem model going away from the traditional linear approaches to the concept of value chain.

Value chain innovation in the context of the project is explained. CHAIN REACTIONS focuses on innovations inducing the emergence of new value chains, not on optimization of existing value chains. New products and services, as well as new industrial sectors, are not always the result of breakthrough innovation; they can be the result of value chain innovation, e.g. the transformation of 'traditional' value chains into new ones - **emerging value chains** - through cross-border and cross-sectoral collaboration. The analysis of those emerging value chains shows that beyond their specificities, they have in common some key drivers: key enabling technologies, digital transformation, resource efficiency and service innovation.

In a second step, the transformative potential of the innovation drivers is explored in more details based on specific technologies or business models:

Innovation driver	**Specific technologies or business models**
Key enabling technologies	Additive manufacturing Industry 4.0
Digital transformation	Big data Smart connected products Artificial intelligence Blockchain
Service innovation	Product service systems
Resource efficiency	Circular economy

For each of the specific technologies or business models explored, the document provides a definition and their potential impact on businesses in terms of innovation and new business models, as well as an overview of benefits and challenges.

Finally, Porter's Five Forces model is presented. It helps analyzing the level of competition within a certain industry. It is especially useful when starting a new business or when entering a new industry sector. According to this framework, competitiveness does not only come from competitors. Rather, the state of competition in an industry depends on five basic forces: threat of new entrants, bargaining power of suppliers, bargaining power of buyers, threat of substitute products or services, and existing industry rivalry. The collective strength of these forces determines the profit potential of an industry and thus its attractiveness.

The value chain innovation model to be used in the further implementation of the CHAIN REACTIONS project consists in a combination of the previously described drivers for innovation and transformation in existing value chains. In practice, value chain transformations are often the result of the **convergence** of different drivers, and of course also of entrepreneurial activities!

The expected outcome of the application of this model is a **portfolio of potential innovation trajectories** in the selected industrial areas - in accordance with the S3 priorities of the partners' regions – for the CHAIN REACTIONS project: advanced manufacturing, ICT and electronics, energy and environment, health and bioeconomy.

2 VALUE CHAIN INNOVATION IN CHAIN REACTIONS

In this chapter, we present first the concept of value chains, with a focus on changes induced by technological innovation. In a second step we explain the concept of value chain innovation as we use it in CHAIN REACTIONS.

2.1 Value chain concept and models

The concept of a value chain was first developed by Porter (1985). It described the sequence and process whereby added value could be enhanced and achieved through the recognition of a series of elements or activities, some of which were seen by Porter as 'primary' and others as 'support'. Porter perceived that all firms are a 'collection of activities that are performed to design, produce, market, deliver and support its product'.

Porter's overall setting, namely, that it is a set of strategically relevant activities whereby competitive advantage is delivered and sustained. In most respects, it was not just the composition of the value chain that provided academic interest, but its applicability within firms. Porter went on to describe how implementation of the value chain could:

- enhance the competitive response
- provide a source of differentiation
- create an understanding of inter-relationships
- help focus upon a set of value activities
- provide an approach to organization structure

Global Value Chains

More than two-thirds of world trade occurs through global value chains (GVCs), in which production crosses at least one border, and typically many borders, before final assembly. The phenomenal growth in GVC-related trade has translated into significant economic growth in many countries across the globe over the last two decades, fueled by reductions in transportation and communication costs and declining trade barriers. But, at the same time, it has contributed to distributional effects that mean that the benefits of trade have not always accrued to all, which has, at least in part, been a driver in the backlash against globalization and the rise of protectionism and threats to global and regional trade agreements. In addition, new technological developments such as robotics, big data, and the Internet of Things (IoT) are beginning to reshape and further transform GVCs. This second GVC development report takes stock of the recent evolution of GVC trade in light of these developments.

The nature of the technology used in products plays a major role in determining the governance structure of value chains and the benefits of participation for developing countries. Standardization through breaking production into modules with a high degree of functional autonomy (limited mutual interference between modules) can dramatically reduce the amount of R&D, learning by doing, and the number of complementary skills needed to produce a good. This greatly increases opportunities for developing country firms to participate in formerly capital-intensive industries through reducing entry costs into global value chains. However, widespread access to standardized products with little ability to modify technical features can lead to an excessive supply of homogeneous products in a local market, resulting in intense price competition and limited technology transfer. By contrast, technology that facilitates scope for product modification and greater interaction with lead manufacturers can help boost technology transfer and product upgrading by developing country firms. The world's most powerful technology companies, both from emerging and advanced countries, work with global suppliers and even with competitors in "open innovation" environments.

Robotics, 3D printing, the IoT, Big Data, and cloud computing, among others, are transforming entire industries. The evidence suggests that automation reduces some of the incentives for GVCs to relocate to lower-wage countries. However, it is also seen that automation does not necessarily dampen the attractiveness of low-wage destinations, especially for labor-intensive tasks that require human dexterity. In the apparel industry, for example, soft materials like fabrics are difficult to handle through automation compared to solid materials such as metal or wooden objects and sewing/stitching can still be out of the reach of "robots' hands".

Supply Chain 4.0

"Supply Chain 4.0" is the re-organization of supply chains – design and planning, production, distribution, consumption, and reverse logistics – using technologies that are known as "Industry 4.0". These technologies emerged in the 21st century and are largely implemented by firms that are at the frontier of supply chain management in high-income countries. The most frequently mentioned supply management techniques are the IoT, big data analytics, 3D printing, advanced (autonomous) robotics, smart sensors, augmented reality, artificial intelligence, and cloud computing. Through these advanced techniques, a continuous flow of information between the retailer and supplier keeps the shelves stocked and there is no longer a "back room" in stores where inventory is kept. "Supply Chain 4.0" is about transforming the model of supply chain management from a linear model in which instructions flow from supplier to producer to distributor to consumer, and back, to a more integrated model in which information flows in multiple directions. While lead firms are increasingly analyzing this information through "supply chain control towers," the end effect of this development is making the goods economy more responsive to consumer demand.

In "Supply Chain 4.0", the internet makes the warehouse visible to the customer and within the warehouse, some technologies such as autonomous logistics and robotic transport can be employed to substantially improve pick-and-pack performance. Business-to-business (B2B) e-commerce consists of links in supply chains – whether transactions between parts suppliers and assemblers, between distribution centres and retailers, or online purchases of services which in many cases support the supply chain. B2B commerce can be implemented either through websites, much like business-to-consumer (B2C) e-commerce, or through electronic data interchange (EDI) which is a mature technology through which the computer systems of the buyer and seller are directly connected using a common record format. To rapidly assess and respond to changes in customer demand, tracking and tracing throughout the supply chain is enabled through sensing technologies underlying the IoT, including radio frequency identification (RFID), Bluetooth, and global system for mobile communication (GSM). Applications of IoT are increasingly used to facilitate the management strategies of "customer-managed inventory" (CMI) or "vendor-managed inventory" (VMI) in which information is initially provided by a customer and then transmitted up the supply chain to the warehouse. Technologies such as RFID tags then transmit information to the distribution centre so that orders can be fulfilled. An EDI system causes an order created electronically by the customer to be instantly duplicated without error in the vendor's computer system, and the invoice to be similarly electronically duplicated in the customer's computer system. Some of these processes are being implemented through blockchain, a distributed ledger technology that allows multiple parties to maintain copies of the same information in various locations, either in an open manner or requiring individual entities' permission to access the network. Its special feature is that historical entries cannot be altered.

New technologies gather prodigious amounts of data. Big data analytics is about using data to drive useful business intelligence, answering the questions, "What just happened?", "Why did it happen?", and "What are we going to do next?" The ability to collect and analyze data gathered in the whole supply chain makes it possible to "run scenarios within the platform", where the platform is conceived of as an overarching software solution within the supply chain control centre. Besides saving time and labor, and reducing errors, EDI enables a large amount of data capture about customer behavior which can be the basis for supply chain analytics using either "big data" or "small data" techniques. The use of modern technology and human labor in warehouses are often complements, rather than substitutes, especially in conditions where e-commerce is substantially increasing demand for certain goods and services. E-commerce is a mechanism for translating unpaid household shopping time into paid market time. Instead of consumers spending time shopping, workers in warehouses and on delivery trucks are picking goods off warehouse shelves and bringing them to the consumer's front door. Most of the jobs being created involve moving goods around either in warehouses or delivery vehicles and have many of the characteristics of factory work.

Digital technologies and the internet are becoming the foundation of entire economies. There are huge benefits in terms of inclusive patterns of growth, innovation and entrepreneurial opportunities, but the downside risks are much larger than was initially understood. Trade and investment will be vulnerable in the near-complete absence of international agreements on the uses and prohibited abuses of the internet and data.

Relevance for SMEs

Small and medium-sized enterprises, in general, have low direct participation in international trade, compared to large enterprises. This result makes economic sense as long as there are fixed costs in exporting, such as learning about foreign markets or rules and minimum scales for shipping. In theory, the spread of GVCs should reduce these effects and make it easier for SMEs to participate in trade as the break-up of the production process makes it feasible for a specialized firm to find niche markets. Yet, SMEs are underrepresented in GVCs. This may be changing, however, as access to information and communication technology (ICT) continues to grow. For example, there is evidence that the internet reduces search costs, facilitating more exchange and increasing firm productivity. Cross-border e-commerce platforms are also providing new opportunities for SMEs and even micro firms.

Further, ICT connectivity is found to be more important for small firms than for large ones when considering whether or not a firm participates in trade. Evidence underlines the importance of ICT access for SMEs to join GVCs in the digital economy, however, access to new technology varies not only between firm size but also regionally by level of development. Infrastructure constraints faced by developing countries in e-commerce range from the most basic, such as access to a steady supply of electricity, to the more complex, such as not having access to electronic payment systems or a lack of high-speed internet cables. This is a particular problem, not only because information communication technology (ICT) is necessary for e-commerce, but also because ICT is now considered a pre-requisite for joining most GVCs. No matter the internet's functionality, regardless of lacking features such as broadband connection and e-commerce platforms, e-commerce can only develop if the internet is present.

However, SMEs face a number of additional challenges integrating into GVCs with the digital economy. On top of lagging behind large firms in terms of overall digital technology use and capability, small businesses may also find it difficult to access e-commerce platforms and payment systems.

Platform-Based Ecosystem

The emergence of business ecosystems and platforms represents a very recent development that is having a significant impact upon traditional industries and product/service markets. The speed at which this new form of business model innovation has gained momentum has been largely the result of new technologies in the ICT sector such as the Internet (Web 1.0 and Web 2.0), the increasing digitisation (and dematerialisation) of products, the rapid diffusion of mobile communications, big data and cloud computing. This trend is set to continue with the roll out of the Internet-of-Things (IOT) and the increasing connectedness that will result from this.

An effective keystone strategy consists of two aims. The first is to create value within the ecosystem. This is essential otherwise it will fail to attract or retain members. Second, the keystone must share the value it creates with other participants in the ecosystem. Google created value by giving away its Android mobile software to the telecoms operators. This resulted in a large ecosystem of customers who purchased cheaper Android-enabled handsets (which benefited hardware firms such as Samsung) and who also subscribed to mobile contracts for Android phones (benefiting the telecoms operators). This large user-base also enhanced the attractiveness of the software standard to app developers who became part of the ecosystem. These developers also received software development kits (SDKs or 'devkits') i.e. development tools to facilitate the creation of software applications for Android. The Android ecosystem is also an open system (open source software) as opposed to a closed ecosystem. This is the main reason for its enormous pervasiveness (more than 80 per cent market share) compared to the Apple iOS mobile software ecosystem which is semi-closed or proprietary in comparison i.e. a 'walled garden'. Keystone organisations must ensure that the value of their platforms increases sufficiently to cover the cost of creating, maintaining and sharing them with the ecosystem members who choose to use the platforms. This allows the keystone players to share the surplus with their communities.

In business ecosystems, it is normal for most organisations to follow niche strategies. The purpose is to develop specialised capabilities that differentiate them from other companies in the network. These firms leverage complementary resources from other niche players or the ecosystem keystone. When they are allowed to thrive, niche players represent the bulk of the ecosystem, and they are responsible for most of the value creation and innovation. They operate in the shadow of a keystone which offers its resources to niche players.

Technological platforms have become increasingly pervasive as new computing technologies have become embedded within industrial ecosystems transforming the industrial and competitive landscapes.

2.2 Value chain innovation

CHAIN REACTIONS addresses the challenge for industrial regions not benefitting from innovation activities from large leading corporations to increase regional capacity to absorb new knowledge and turn it into competitiveness edge and business value. CHAIN REACTIONS focuses thereby on modern approaches considering value chains and their complex developments rather than linear technology transfer approaches.

CHAIN REACTIONS focuses on innovations inducing the emergence of new value chains, not on the optimization of existing value chains, as illustrated in the figure below:

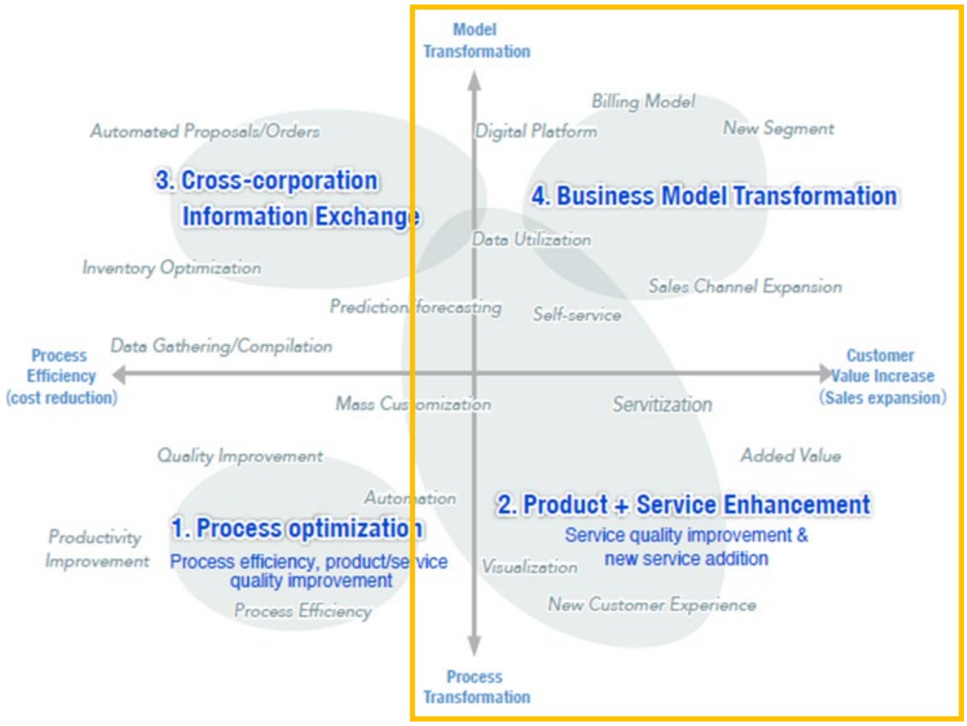

Figure 1: value chain transformation
Source: Abeam consulting

Innovation drivers

New products and services, as well as new industrial sectors, are not always the result of breakthrough innovation; they can be the result of value chain innovation, e.g. the transformation of 'traditional' value chains into new ones - **emerging value chains** - through cross-border and cross-sectoral collaboration.

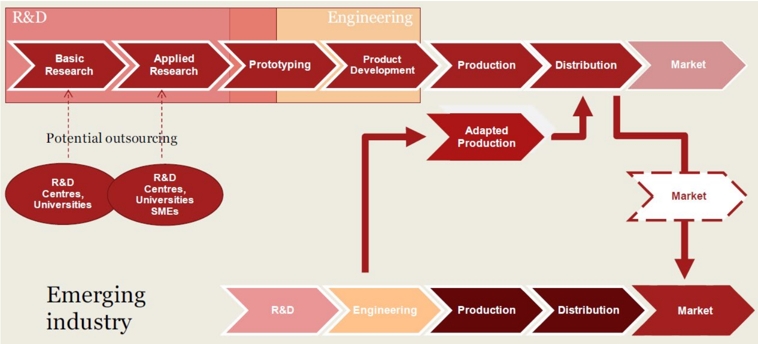

Figure 2: emerging value chains
Source: pwc

The analysis of those emerging value chains shows that beyond their specificities, they have in common some key drivers: Key Enabling Technologies, Digital transformation, Resource efficiency and Service innovation. In the following, the relevant key drivers in the context of CHAIN REACTIONS are explained in detail.

3 KEY DRIVERS FOR VALUE CHAIN INNOVATIONS

In this chapter we provide a description of the potential impact on value chains of the innovation drivers:

- Key Enabling Technologies,
- Digital transformation,
- Service innovation,
- Resource efficiency.

As it is not realistic, nor meaningful in the context of CHAIN REACTIONS, to aim for an exhaustive analysis of all the aspects of the above-mentionned innovation drivers, we focus on a limited number of relevant aspects, building on the priorities identified by the partners during the Kick-off meeting. Specific analysis on how those drivers apply to specific thematic areas will be provided in the framework of the value chain analysis (WPT3).

3.1 Key enabling technologies (KETs)

As stated in the EC definition, KETs are knowledge and R&D intensive, need a highly-skilled workforce, and require high capital expenditures. They initiate and enable innovative products, goods, and services and can assist the valorisation of research in other domains. KETS, as defined in the European Horizon 2020 framework programme for research and innovation, are:

- advanced manufacturing systems
- advanced materials
- industrial biotechnology
- nanotechnology
- photonics
- micro-/nanoelectronics

In the context of CHAIN REACTIONS, the most relevant KETs are the ones related to advanced manufacturing systems. We selected the two most relevant ones and describe hereafter their impact on industry in general:

- additive manufacturing
- Industry 4.0

3.1.1 Additive manufacturing

Additive manufacturing (AM) encompasses a range of technologies that allows physical components to be made, from virtual 3D models by building the component layer-upon-layer until the part is complete.

In comparison with subtractive manufacturing processes, in which one starts with a block of material and removes any unwanted material (either by carving it by hand, or by using a machine such as a mill, lathe or CNC machine) until one is left with the desired part, additive manufacturing starts with nothing and builds the part one layer at a time by 'printing' each new layer on top of the previous one, until the part is complete. Depending on the particular technology used, the layer thickness ranges from a few microns up to around 0.25 mm per layer, and a range of materials are now available for the different technologies.

The very earliest concepts related to additive manufacturing date back to the end of the 19th century, and early 20th century, with the introduction of layer-based topographical maps as 3D representations of terrain, together with a number of methods for using these topological models to produce 3D maps by, for example, wrapping a paper map over the topological models to produce a 3D model of the terrain.

Photosculpture, which also originated towards the end of the 19th century, and which used a series of different photographs taken from different angles around the object that were then used to carve out the object using each different angled picture as a template, so an initially subtractive process, also had several proposed methods for creating the models using photosensitive materials.

Modern additive manufacturing saw its origins in the mid-20th century with a patent, in 1951, by Otto John Munz which could be considered the origin of the modern stereolithography technique. It consisted, essentially, of a series of layered 2D transparent photographs printed on photosensitive emulsion stacked on top of each other. He developed a system for selectively exposing the transparent photo-emulsion in a layer-wise fashion in which each layer was exposed with a cross-section of an object. Much like a modern stereolithography machine, the build platform on which the part was being built was gradually lowered, and the next layer of photo emulsion and fixing agent was created on top of the previous layer. Once the printing process was finished, the result was a solid transparent cylinder containing a 3D image of the object. A weakness of this system was that the final real threedimensional object had to be manually carved or photo-chemically etched out of the cylinder as a secondary operation.

The following decades saw the development of a succession of new techniques including those of Swainson who, in 1968, proposed a process to directly fabricate a plastic pattern through the selective 3D polymerization of a photosensitive polymer at the intersection of two laser beams (with the patent assigned to the Formigraphic Engine Corporation). Work was also undertaken at Battelle Laboratories, called Photochemical Machining, in which an object was formed by either photochemically crosslinking or degrading a polymer through the simultaneous exposure to intersecting laser beams.

In 1971, Ciraud proposed a powder process that can be considered the father of modern direct deposition AM techniques such as powder bed fusion, and in 1979, Housholder developed the earliest equivalent of a powder-based selective laser sintering process. In his patent, he discussed sequentially depositing planar layers of powder and selectively solidifying portions of each layer. The solidification could be achieved by using heat and either a selected mask or by using a controlled heat scanning process such as a laser.

Other notable early additive manufacturing developments include those of Hideo Kodama, of the Nagoya Municipal Industrial Research Institute in Japan, who developed a number of stereolithography related techniques, and the work of Herbert who, in parallel with Kodama, developed a system that directed a UV laser beam onto a photopolymer layer, by means of a mirror system on an x–y plotter, to scan a layer of the model. The build platform and layer were then lowered by 1 mm into a vat of resin and the process was repeated.

Commercial additive manufacturing, as we know it today, with the development of commercially available system did not really begin until 1986, with Charles W. Hull's stereolithography patent. The patent was originally owned by UVP Inc. and the company licensed the technology to their former employee, Charles Hull, who used it to found the start-up 3D Systems. This development saw the first commercial SLA machine appearing in 1988 and, since then, almost every year has seen an exponential rise in available systems, technologies and materials.

Even the terminology relating to additive manufacturing has changed a lot over the last three decades. For most of the 1990s, the principal term used to describe the layer-upon-layer manufacturing technologies was rapid prototyping (RP), because the principal use of the various available technologies was to make concept models and pre-production prototypes. Some other terms that have also been used over the years include Solid Freeform Fabrication (SFF) and Layer Manufacturing.

In early 2009, however, the ASTM International Committee F42 on Additive Manufacturing Technologies tried to standardize the terminology used by the industry and, after a meeting in which many industry experts debated the best terminology to use arrived at the term 'Additive Manufacturing' which, today, is considered the standard terminology used by industry.

In their ASTM F2792 10e1 Standard Terminology for Additive Manufacturing Technologies document they defined additive manufacturing as: the process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies, such as traditional machining.

Unlike subtractive manufacturing, where the material is removed from a larger block of material until the final product is achieved, most additive manufacturing processes do not yield excessive waste material. If a part is properly 'designed for AM', and one is comparing it to a single part produced through conventional manufacturing, it also typically may not require the large amounts of time needed to remove unwanted material thus, potentially, reducing time and costs, and producing relatively little waste. This, however, should not be misconstrued as AM being able to always make cheaper parts than conventional manufacturing. In many cases it is, in fact, the opposite, because AM is a relatively slow and expensive technology. But this depends very much on the AM technology in use and the many possible design parameters that can be used.

It should be noted, however, that while industry has, generally, adopted the additive manufacturing term, much of the popular press and media continues to refer to additive manufacturing as 3D printing, as this is a term more easily understood by the general public. Some consider the term 3D printing to be focussed on lower-cost hobby desktop 3D printers, and additive manufacturing focussed on higher-end industrial production systems. In CHAIN REACTIONS we use the two terms interchangeably

The Additive Manufacturing Value Chain

All additive manufacturing begins with the creation of a virtual 3D CAD model. Almost any 3D computer-aided design (CAD) software can be used. This CAD model must, however, be in the form of a fully enclosed "watertight" volume (which means that a model of a cube, for example, must include all 6 faces, and have no gaps at the seams). If one of the faces of the model is missing, or there are gaps, it represents an infinitely thin surface which cannot be printed (though, depending on how bad the errors are, some AM software can be used to automatically fix the model).

The CAD file is then converted into a file format that can be understood by the AM machine. Typically, today, the most commonly used file format is an STL file (standard triangle language, stereolithography, or standard tessellation language) which is a format that converts the original CAD file into a triangulated file. The higher the resolution of the STL file, the more triangles it contains, so the better the quality of the model.

Some new additive manufacturing file formats, including AMF (Additive Manufacturing File Format) and 3MF (3D Manufacturing Format), have recently been proposed which vastly improve the somewhat antiquated STL format, as they add more information to the file, including colour and material, and allows the use of curved triangles to improve model quality. At the time of publication, 3MF appears to be gaining considerably more traction than the AMF format.

3MF, or 3D Manufacturing Format, is a file format developed and published by the 3MF Consortium. It is an XML-based data format designed specifically for AM, and it includes information about materials, colours, and other information that cannot be represented in the STL format.

The STL file produced by the CAD software is then opened in the AM machine's software, and the model is placed on the software's virtual build platform (the platform on which the part will be printed) in the most suitable orientation for printing. The print orientation can affect both the surface quality and the strength of the final part. Some processes, for example, produce highly anisotropic parts in which there is a weakness between the layers of the part or vertical direction of the print. Other processes use support material to allow overhanging parts to be printed.

The AM machine's software then slices the STL files into thin layers, and some software also let you set the other print parameters including print resolution (layer thickness), material, fill patterns, speed, etc.

Once the software has sent the part build instructions to the machine, it starts to build the part layer upon layer. How it builds each layer, and what material it uses, depends on the particular technology being used.

After the machine has finished printing the part, they are removed from the machine and post-processed. Post-processing almost always includes cleaning the part of left-over powder or resin, removing support material and, in many cases, might include further processing such as machining, if a surface requires a finer finish than the AM machine can provide, infiltration to make the part stronger, heat treatment for metal parts, or colouring and painting if the part needs to be in a colour other than that provided by the AM material.

Current Usage of Additive Manufacturing

Over the past 30 years, AM has grown to be used in an ever-increasing number of application areas. The Wohlers Report, a leading annual 'state of the industry' report, undertakes a yearly survey to find out what AM is being used for.

It is interesting to note that, although 43.9% of applications are in the rapid prototyping realm (including fit and assembly, functional models, presentation models and visual aids) the use of AM to produce real parts, both directly or indirectly, now represents over 56% of usage. This includes patterns for prototype tooling, patterns for metal casting, tooling components, and direct part production. Wohlers expects this percentage to grow substantially over the next few years as more and more industries adopt AM as part of their growing manufacturing arsenal.

Since its inception, AM has grown on two distinct fronts. The last decade, in particular, has seen good improvements on high-end machines capable of producing excellent quality parts in a number of materials. At the same time, there has been enormous growth in the DIY and desktop 3D printer community with a wide range of entry-level additive manufacturing systems with prices ranging from a few hundred to a few thousand dollars. Entire communities (the reprap, fablab, and makerbot communities, for example) have developed, often with an open-source approach to sharing knowledge on additive manufacturing which has greatly benefitted the industry.

It is only over the last few years that additive manufacturing has improved in quality to the extent that some companies have started to use it as a viable production technology. As new polymer and metal materials are developed and the speed and precision of the machines further increase, more additive manufacturing machines are likely to find their way into mainstream production lines.

Additive manufacturing also has a number of qualities that give it the ability to manufacture parts that cannot be made by traditional manufacturing techniques. Understanding this is vital to understanding when, and when not, to use AM. It is also important to note that AM will never completely replace traditional manufacturing. It is a complementary technology that, if used because of the value it can add, and if the parts it produces are specifically designed for AM, then it can add great value to the company. Some of the advantages AM has over conventional manufacturing are listed below.

The Advantages of Additive Manufacturing

AM can be an expensive process, so in order for its use to be profitable as a production method, it must bring added value to a product. This can either be through reducing life cycle costs for the product or through enabling a higher price to be charged to the customer. This is achievable in a number of ways as described below.

- **Part Complexity**

Additive manufacturing enables the creation of parts and products with complex features, which could not easily have been produced via subtractive or other traditional manufacturing processes. With conventional manufacturing, the more geometrically complex a part becomes the more expensive it becomes to manufacture and, at a certain point, it becomes impossible to manufacture. AM works in the opposite way: The more geometrically complex the part is, the more suitable it is for AM, as it costs no more to produce a complex part than a simple one (there are some exceptions to this, particularly if support material is hard to remove). If a part is very simple, however, AM can become an expensive way of producing the part compared to traditional manufacturing.

With AM, more complex shapes can be created, both for external forms and internal structures. This can result in improved product performance and/or increased aesthetic attraction. The former can be translated into lower running costs and the latter into increased price.

With traditional injection moulded or die-cast parts, for example, the parts must be removable from the die in which they are made and must, therefore, be designed in such a way that this can be done. For simple 'open and close' die parts this is not a problem but, as the complexity of the parts increases, a number of 'moving cores' becomes necessary which can greatly increase the complexity, and cost, of the tool. And, past a certain level of complexity, the parts cannot be manufactured at all or must be broken down into a number of smaller components that then need to be assembled to make the final component possible. With AM, this is no longer a problem as the complex part can be manufactured directly.

It should be noted that additive manufacturing does not remove all manufacturing restrictions. It, instead, replaces them with a different set of design considerations that designers must take into account if they wish to successfully use the technologies.

A simple example of the type of restrictions that additive manufacturing suffers from is the inability to manufacture entirely enclosed hollow volumes. A completely sealed hollow sphere, for example, is still impossible for current additive manufacturing technologies to make because there is no way of removing the excess resin, powder, or support material, from the inside of the sphere. One must, therefore, leave a hole of a minimum diameter in the part in order to remove the excess material from inside the part.

These new design considerations are, however, much less restrictive than traditional manufacturing technologies, and easier for designers to both understand and comply with without them affecting design intent in a major way.

- **Instant Assemblies**

With additive manufacturing, it is possible to manufacture complex interlocked moving parts in ready-made working assemblies. Though two components may be permanently linked together, they are made as a single component and come out of the machine assembled and ready to work.

There is a foldable guitar stand that was printed using a powder bed fusion technology. The entire guitar stand is, however, manufactured in a single operation with no assembly whatsoever required. If the guitar stand were to be manufactured using traditional manufacturing methods, it would require, at least, sixteen components and an assembly procedure to attach all the separate components together.

To additively manufacture complete assemblies, the designer needs to leave a minimum gap between the moving components. The material in these gaps is not processed by the AM machine so, after the part is finished, can be removed to leave the surrounding components free to move. The size of this gap varies from process to process but is, generally, in the order of a fraction of a millimetre. It is important to understand that the required gap between moving parts is considerable, by engineering standards, so if moving parts with tight engineering fits are required, it is unlikely that AM would be able to print them in an assembled configuration.

- **Part Consolidation**

Part consolidation is when several simpler parts are replaced by a single more complex AM part. This reduces assembly and inventory costs.

- **Mass Customization**

With additive manufacturing parts can be made on-demand, as there is no longer a long lead-time to get tooling produced. The tooling required for conventional mass-manufacturing typically takes from a few weeks to several months to produce. This feature of additive manufacturing has a great impact on new product time-to-market and on the ability to easily produce model changes throughout the life of a product. It also has implications in stock control: As components can be made on the spot, companies may no longer need to hold large stock of spare parts as they simply manufacture the parts when needed. This feature of additive manufacturing is often referred to as ‘manufacturing-on-demand’.

From a product design perspective, it also means that every component made can be completely different to the others in a production run without significantly affecting the manufacturing cost or manufacturing time. This opens the door to mass-customization in which, though mass-manufactured, each product can be customized to each individual customer. This is already beginning to happen in industries including hearing aids, dental crowns, implants, medical prostheses, customized orthotic shoe inserts, and the high-end interior design and fashion industries.

For this new way of designing products to be used effectively, the product design and the computer-aided design industries will need to develop new methods for integrating personalized customer data into their designs. This development has already started, particularly in the hearing aid and the dental industries, in which specialized software exists to automate the processes of patient data acquisition. The patient’s personalized data is acquired, usually through a laser scanning process, and the software then automates the process of cleaning of the data, shelling the part, inserting mounting points for electronic components, etc. This increased automation in CAD software now needs to be extended to encompass other industries, including consumer product industries.

- **Freedom of Design**

One of the greatest advantages additive manufacturing gives the designer over traditional manufacturing is freedom of design. Because of constraints of traditional manufacturing technologies, a product, which the designer may have originally envisioned as having a certain aesthetic and functionality, may need to be compromised so that it can be cost-effectively made. Most designers are quite accustomed to hearing the response of “it cannot be made like that” from manufacturing engineers. They may then need to compromise their design to the extent that the product loses the essence that truly embodies the designers vision. With additive manufacturing, complexity and geometry often no longer affect manufacturability. Almost anything the designer imagines can be made precisely as the designer conceived it (with the proviso that the parts may require substantially more labour in the post-processing stage).

Though this is directly related to product complexity, discussed above, we are, here, talking about the ability it gives designers and engineers to be less restricted by manufacturing constraints, and thus allows them to innovate in a way that may not have been previously possible.

- **Light-Weighting**

Topology optimisation is a method of removing as much material as possible from a part while maintaining sufficient mechanical properties. It consists in performing a finite element analysis (FEA) and then iteratively removing unnecessary material.

Topology optimisation has been available for a long time, but complex designs could not be manufactured with conventional manufacturing. AM, however, is capable of making most complex designs from topology optimisation. This opens up a whole new engineering area dedicated to making lighter products. In the context of aeronautics, for example, any weight savings can represent large savings in fuel.

- **On-Demand Manufacturing**

The term “on-demand manufacturing” or “manufacturing on-demand” is a manufacturing process in which goods are produced as and when required and, in the context of additive manufacturing, where required. With conventional manufacturing, an assembly line produces large quantities of products, which are then kept in stock until they are ready for shipping to their intended location. With on-demand manufacturing, products are made only once the customer’s order comes in, and only as many products as are immediately required are made. If AM is being used, the AM system can be located near where the customer is, and the products can be made locally, rather than shipped around the world.

One can see the potential this has in entirely disrupting our existing supply chains. The benefits of this new supply chain are increasingly evident. It has the potential to lead to:

- Cost savings by eliminating or significantly reducing inventory requirements. Warehouses full of spare parts and stock could become a thing of the past. Instead of a physical inventory of parts, we now switch to keeping a digital inventory of parts and only make the parts physical the moment they are required.
- Digital files also provide the ability to quickly produce new product iterations at little to no additional cost. And as keeping stock of old product is no longer necessary, these changes can be instantly implemented.
- With a single source for a variety of parts, businesses that use 3D printing contract manufacturers deal with less risk, more control and added agility in relation to their product lifecycle.
- Local facilities can 3D print designs on-demand from files sent across the globe, or they can print securely from a nearby supplier.

Prior to the industrial revolution, the supply chain was extremely small. Most production was local to where the products where being sold and transporting products over long distances was often not feasible. The supply chain often began with the end-user making the product for themselves, perhaps with some bartering for parts from local trades-people and, if the product was good, it could then be sold to the rest of the market which, in most cases, was local to the village the maker lived in. In contrast, once mass-production began during the industrial revolution, products began to be mass-manufactured in a location, and then transported to the end-user somewhere in the world, through a complex supply chain of middle-men. Each of these middle-men adds a percentage cost to the product to make their margins, and the environmental footprint caused by all the transport and storage of the products can now be seen to be having an impact on the world we live in.

3.1.2 Industry 4.0

The modern global economy is at the threshold of the new industrial revolution, which is proved by a lot of actual tendencies. First, large duration of the global economic crisis of the early twenty-first century and impossibility of overcoming it with the help of the existing possibilities of economic systems shows depletion of the potential of the previous technological model. In the sphere of industrial production, the crisis was first manifested in overproduction of industrial goods and impossibility of selling it in domestic economic systems or in the global markets—which led to massive bankruptcy of industrial companies around the world and increase of protectionist measures from governments of various countries. Second, according to the modern provisions of the economic theory (in particular, the theory of economic cycles, the theory of crises, the theory of innovations, etc.), overcoming the global crisis requires starting a new wave of innovations. This tendency is supported by intensive progress of a lot of countries in formation of the knowledge economy, due to which potential of the global economic system as to its future innovational development is strengthened. Innovations are a generally acknowledged global priority of socio-economic development.

Cyber-physical systems enable the virtual digital world of computers and software to merge through interaction—process management and feedback control—with the physical analogue world, thus leading to an Internet of Things, data, and services. One example of CPS is an intelligent manufacturing line, where the machine can perform many work processes by communicating with the components and sometimes even the products they are in the process of making. An embedded system is a computational system embedded within a physical system; the emphasis is on the computational component. Therefore, we can think of all CPS as containing embedded systems, but the CPS's emphasis is on the communications and physical as well as the computational domains.

Manufacturing sector

The manufacturing sector is on the cusp of the 4th industrial revolution (I4.0), bringing with it new technologies and techniques that will change the products, processes and supply chains involved in every aspect of the industry.
The Fourth Industrial Revolution, known as "Industry 4.0", emerged in Western countries in 2011 as a project (initiative) aimed at increase of competitiveness of the processing industry (Lu et al. 2016). Specialists offered integrating into industrial processes so-called "cyber-physical systems", or automatized machines and processing centres, connected to the Internet. The purpose is to created such systems that would allow machines to changes production models if the necessity arises.

Key I4.0 Technologies

Industry 4.0 is a coming together of several key technologies in order to produce a system greater than the sum of its parts. The latest advances in sensor technologies, for example, produce not just more data generated by a component but a different type of data, instead of just being precise. Sensors can have self-awareness and can even predict their remaining useful life. Therefore, the sensor can produce data that is not just precise, but predictive. Similarly, machine sensors through their controllers can be self-aware, self-predict and self-compare. For example, they can compare their present configuration and environment settings with preconfigured optimal data and thresholds. This provides for self-diagnostics. Sensor technology has reduced dramatically in recent years in cost and size. This made the instrumentation of machines, processes, and even people financial and technically feasible.

Big Data and advanced analytics are another key driver and enabler for the IIoT as they provide for historical, predictive, and prescriptive analysis, which can provide insight into what is actually happening inside a machine or a process. Combined with these new breed of self-aware and self-predicting components analytics can provide accurate predictive maintenance schedules for machinery and assets, keeping them in productive service longer and reducing the inefficiencies and costs of unnecessary maintenance. This has been accelerated by the advent of cloud computing over the last decade whereby service providers like AWS provide the vast compute, storage, and networking capabilities required for effective Big Data at low cost and on a pay-what-you-use basis.

This technology ushers in even greater connectivity that will allow manufacturers to maintain their competitive edge in a rapidly changing world, and respond flexibly and quickly to customers' requirements. Not all manufacturers are at the same stage of knowledge about what this will mean for their business. Indeed, we are at the start of this I4.0 journey and understandably, many manufacturers are still getting to grips with the subject.

The benefits of I4.0 technology adoption for manufacturing will be widespread, with smarter supply chains, smarter production and smarter products. Manufacturers will need to keep pace with the change, they themselves say it will be happening more quickly than ever before and it will fundamentally change their customers' expectations. This is isn't just a regional phenomenon, it is a global shift, which offers opportunities for European manufacturers as global supply chains are joined up more effectively. But this global shift also presents a risk if European manufacturers fail to keep pace. Manufacturers currently feel Europe's industry isn't geared up for the change, but that their business is – demonstrating a need for greater communication across supply chains and industrial sectors about the benefits. The I4.0 journey starts with optimising existing business processes and many are doing this – we outline some practical use cases in this report. Manufacturers will be prioritising smarter supply chains and embedding smarter production processes within their business.

The experts also distinguish the basic characteristics of Industry 4.0:

- transition from manual labour to robototronics, which ensures automatization of all production processes;

- modernization of transport and logistical systems, caused by mass distribution of unmanned vehicles;
- increase of complexity and precision of manufactured technical products, manufacture of new construction materials due to improvement of production technologies;
- development of inter-machine communications and self-management of physical systems, conducted with the help of "Internet of things";
- application of self-teaching programs for provision of constant development of production systems.

But beyond technology there are also steps manufacturers must take to prepare their business to ensure any move towards I4.0 is a success. These include applying visionary thinking as there will be less certainty on return on investment, changing the internal innovation culture of their business and boosting the role of IT and technology in decision making across all parts of the business.

The manufacturing sector is on the cusp of the 4th industrial revolution, ushering in new technologies and techniques that will change the products, processes and supply chains involved in every aspect of industry. This technology will enable manufacturers to maintain their competitive edge in a rapidly changing world, and respond flexibly and quickly to customers' requirements.

Manufacturers view the core to all of this as being about connectivity. Physical networks link with cyber networks together as one system to allow a real-time flow of information. Data is collected, turned into information and insights, and can be acted upon quickly.

There are three core components to this transformation

1. The Industrial Internet of Things (IIoT) – machines and technologies collecting, sharing and acting on data between themselves
2. Big data – the capture of data on everything and real-time analysis of that data by machines and systems
3. Secure and reliable digital infrastructure – a resilient network to link everything up

Data collected can help firms to understand what really is going on, whether that's how a product is being used or how production processes are performing. Data collection can happen in real-time and more importantly can be analysed immediately. Issues or problems can be acted upon quickly, maximising equipment efficiencies, minimising downtime and gaining new data-driven insights to help drive growth strategies and respond to customer demands.

These increased insights will also enable and drive possible new business models, giving the opportunity for higher value activity to derive competitive advantage such as mass customisation, service-enhanced business models, service-oriented business models, factory-less goods producers and the circular economy.

When these technologies reach some threshold number and receive necessary development, which prepares them for implementation (practical application) into industrial production, the process of transition from quantity to quality is started. In synergy, these transitions take place in the bifurcation points (critical states of the system). This transition marks the start of the industrial revolution, which is systemic transformations in industry. This causes the need for new infrastructure and presents serious challenges for the state (growth of expenditures for modernization of the real sector economy) and society (mastering of new industrial products, increase of qualification of industrial specialists, etc.). A new technological mode is established in the course of the industrial revolution—i.e., transition to completely new technologies of industrial production. Reorganization of production and mass modernization of technologies and equipment leads to growth of efficiency of industrial production. As a result, in the real sector of economy, which is treated as an economic system in this research, synergetic effect appears—which is caused by reduction of the volume of consumed resources and energy (economy of resources and energy) with simultaneous growth of the volumes of industrial production, reduction of cost by means of achievement of the "scale effect", improvement of logistics (increase of the speed of transportation of intermediary and final industrial products, reduction of probability of products' defects, possibility of transportation of large items, etc.) and growth of complexity (increase of quality: precision, reliability, sustainability to temperature changes and improvement of technical characteristics) of issued industrial products. The final result of industrial revolution is transition to a new level of development (new quality of growth) of the real sector of economy.

The most important difference of transition to Industry 4.0 from previous industrial revolutions is elimination of human from the production process. While previous industrial revolutions allowed for certain reduction of human's participation (industrial specialist) in the production process, with preservation of his important role in the work of the production system, the new industrial revolution will lead to human's elimination from the production system. This will require reconsideration of the essence of this system's work, as it will turn from socio-technical into fully technical system. Artificial intelligence allows for full elimination of mistakes caused by "human factor", thus ensuring rationalization and optimization of all business processes. Another difference is revolutionary change of not only separate but all business processes of an industrial company. The capabilities of artificial intelligence allow for deep change, modernization, and optimization of all components of the production and distribution system, including logistics, management, marketing, etc. For example, it is possible to simplify and accelerate deals due to full automatization of the process of development of products and its manufacture. With receipt of order from a customer, it is possible to develop a technical solution (project, draft, etc.) and create an initial model with 3D printer by the order from the computer, and then the project is passed to production and the necessary volume of products is created automatically. Thus, human does not participate in any of the above operations. Another difference is caused by the possibility for simultaneous usage of the possibilities of globalization and minimization of negative social consequences. Industry 4.0 envisages global interaction of companies. Computers, which are controlled by AI, can exchange the incoming information in real-time via the Internet, this passing orders into production. During the previous industrial revolutions, optimization of productionwas accompanied by negative social externalities that were connected to reduction of the population's living standards of the territories on which the industrial companies were located and to negative influence of production on these companies' employees.

There will be ways that I4.0 technologies and techniques can create value across the manufacturing ecosystem. Ultimately ambitions will be rooted in winning new business – increasing sales and growing market share and will be tailored towards the needs of each individual business. New technology as part of I4.0 will be the enabler of these ambitions. In very broad terms, there are three areas where I4.0 technologies will support in delivering this:

- Smarter supply chains – greater coordination and real-time flow of information across supply chains and relationships allows better tracking of assets and inventory and integrated business planning and production. This unlocks new ownership and collaboration models across supply chains.
- Smarter production – the use of data analytics and new production techniques and technologies (such as autonomous robots, multi-purpose production lines and augmented reality) helps to improve yield and speed up production. This allows new business models to be pursued such as mass customisation.
- Smarter products – Rapid innovation and a faster time to market is enabled by data collected from products along with user feedback, whether direct or collected via social sentiment on the internet. This data also allows remote diagnostics and remote/predictive maintenance.

The I4.0 Journey

The journey starts with conceptualising the realm of possibility from their unique business context, to optimising or evolving existing processes before a revolution is ushered in and with it fundamental changes in current business models. All of these steps will be driven by business ambition and strategy, which will not be the same for everyone.

There are many different benefits to this transformation. In the short term, the focus will be on improved operational efficiency through better use of capital, workers and resources. Over the medium term the transformation will unlock new products, services and business models that will allow value to be added and captured in different ways.

- The first phase – Conception – where companies figure out what I4.0 is all about, what it can offer and how it could apply to their business.
- The second phase – Evolution – a period where there can be some advancement on current practice; concepts and some off the shelf solutions can be implemented and tested, further optimising current processes and putting in place new solutions.
- The third phase – Revolution – this will be the huge step change in terms of how value is derived and how interaction with customers and suppliers happens.

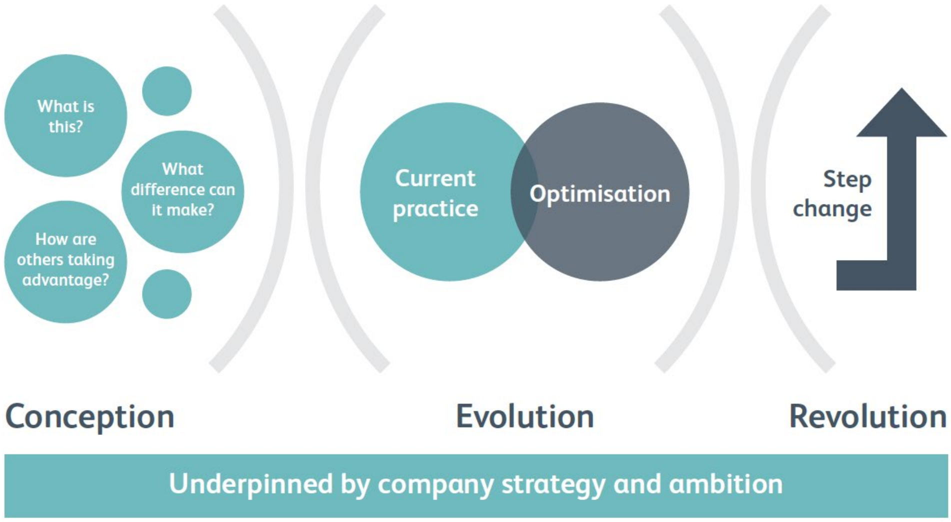

Figure 3: I4.0 journey

Source: EEF: THE 4TH INDUSTRIAL REVOLUTION: A PRIMER FOR MANUFACTURERS

It will be happening in different phases: a research and conception phase, an evolution of business processes followed by a revolution in business models and ways of creating value. For some the concepts will not be new – different companies will be at different stages of awareness and adoption and will be approaching this from different angles. All of this will be overseen with the ambitions and strategy of a successful and growing business in mind.

Industry 4.0 Architecture

Industry 4.0 is reliant on the structure of M2M technology. Sometimes, it is older established technologies and practices that have been around for decades, that can spark innovation, and as a result, IIoT's architecture is often seen as a natural evolution of M2M. This is particularly true within manufacturing, which is the biggest user of IIoT technology, primarily due to its long history with machine automation, robotics, and M2M communication and cooperation.

There are many industrial systems deployed today that are interconnected (M2M)and they combine a mixture of sensors, actuators, logic components, and networks to allow them to interconnect and to function. The difference with the Industrial Internet approach is that these industrial systems (ISs)will become Industrial Internet systems (IISs)as they become connected to the Internet and integrate with enterprise systems, for the purpose of enhanced business process flow and analysis. The IISs will provide operational data via its sensors to enterprise back-end systems for advanced data processing and cloud-based advanced historical and predictive analytics. The advanced cloud services will drive optimized decision-making and operational efficiencies and facilitate the collaboration between autonomous industrial control systems. To realize these goals, IISs require a standard-based, open and widely applicable architectural framework. By providing reference architecture, the IIC (Industrial Internet Consortium) have provided the means to accelerate the widespread deployment of IISs, using a framework that can be implemented with interoperable and interchangeable building blocks. The interchangeable nature of the Industrial Internet reference architecture is notable, as it is designed to be flexible and cover a wide range of deployment scenarios across many industries, such as energy, health care, and transportation, for example. Therefore, the reference architecture is a common framework that works at a high level of abstraction, which enables designs to follow and adhere with the reference architecture without burdening the design with unnecessary and arbitrary restrictions.

Furthermore, by de-coupling, the architecture from the technical specifics and complexities the Industrial Internet reference architecture transcends today's available technologies. This approach will drive new technology development through the identification of technology gaps based on the architectural framework.

3.2 Digital transformation

Digital transformation is the change associated with the application of digital technology in all aspects of human society (source: Wikipedia). It is the "transformation of business and organizational activities, processes, competencies and models to fully leverage the changes and opportunities of a mix of digital technologies and their accelerating impact across society in a strategic and prioritized way, with present and future shifts in mind". (Source: i-scoop). The digital transformation of the European economy and public sector is of vital importance to ensure Europe's competitive advantage in the global economy and to deliver growth and jobs.

Digital transformation offers new business opportunities and can fundamentally change business models. But it affects the whole value chain from product development to sales. It requires an enterprise-wide change which is driven by digital technologies. The transformation process must be integrated into every aspect of the company. It should be supported by equally important amendments in culture, leadership, skills and processes. SMEs should pro-actively rethink their core businesses to adapt to the challenges.

The OECD sees important differences in ICT adoption and usage between large and smaller firms, with SMEs facing several barriers to adopting ICTs and digital technologies in their operational activities. In particular, SMEs lag in their adoption of cloud computing and other sophisticated digital technologies. A report prepared for a joint G20 German Presidency/OECD conference states that "the ability of SMEs to swiftly adopt new technologies, to learn by doing, innovate, and optimise their production, is constrained by their small scale, limiting their ability to reap the benefits of the digital economy. It is essential to foster use of more sophisticated digital technologies among SMEs, especially cloud computing, which allows smaller firms to overcome some of the barriers associated with the high-fixed costs of ICT investment" (Source: OECD).

In the following, we investigate the transformation potential of three technologies gaining momentum in terms of industrial applications:

- Big data,
- Artificial intelligence,
- Blockchain.

3.2.1 Big data

Rapid developments in communication and computing technologies have been the driving factors in the spread of internet technology. This technology is able to scale up and reach out to more and more people. People at opposite sides of the globe are able to remain connected to each other because of the connectivity that the internet is able to provide now. Getting people together through the internet has become more realistic than getting them together physically at one place. This has led to the emergence of cyber society, a form of human society that we are heading for with great speed. As is expected, this has also affected different activities from education to entertainment, culture to commerce, goodness (ethics, spiritual) to governance. The internet has become a platform of all types of human interactions. Services of different domains, designed for different walks of people, are being provided via the internet. Success of these services decisively depends on understanding people and their behaviour over the internet. For example, people may like a particular kind of service due to many desired features the service has. Features could be quality of service like response time, average availability, trust and similar factors. So service providers would like to know of consumer preferences and requirements for designing a service, so as to get maximum returns on investment. On the other side, customers would require enough information to select the best service provider for their needs. Thus, decision-making is key to cyber society. And, informed decisions can only be made on the basis of good information, i.e. information that is both qualitatively and quantitatively sufficient for decisionmaking. Fortunately for cyber society, through our presence on the internet, we generate enough data to garner a lot of meaningful information and patterns. This information is in the form of metaphorical due to footsteps or breadcrumbs that we leave on the internet through our various activities. For example, social networking services, e-businesses and search engines generate huge data sets every second of the day. And these data sets are not only voluminous but also in various forms such as picture, text and audio. This great quantum of data sets is collectively christened big data and is identified by its three special features velocity, variety and volume.

Collection and processing of big data are topics that have drawn considerable attention of concerned variety of people ranging from researchers to business makers. Developments in infrastructure such as grid and cloud technology have given a great impetus to big data services. Research in this area is focusing on big data as a service and infrastructure as a service. The former looks at developing algorithms for fast data access, processing as well as inferring pieces of information that remain hidden. To make all this happen, internet-based infrastructure must provide the backbone structures. It also needs an adaptable architecture that can be dynamically configured so that fast processing is possible by making use of optimal computing as well as storage resources. Thus, investigations on big data encompass many areas of research, including parallel and distributed computing, database management, software engineering, optimization and artificial intelligence.

Big data is now an emerging area in computer science. It has drawn attention of academics as well as developers and entrepreneurs. Academics see challenge in extracting knowledge by processing huge data of various types. Corporates wish to develop systems for different applications. Further, making big data applications available for users while on move is also on-demand. These interests from several quarters are going to define growth in big data research and applications. This, the idea of big data as a service, makes a ground rationalising intent of study in big data. There is a point on complexity in big data processing and lists out some guidelines for the same. Processing of big data needs a system that scales up to handle huge data size and is capable of very fast computation. Some applications need batch-processing system and some need online computation. Real-time processing of big data is also of need for some usages. Thus, big data architectures vary based on nature of applications. But, it is seen in general a big data system design mostly keeps two things at priority; firstly managing huge heterogeneous data and secondly managing computation at demanding less and less time. Currently, study on data science has engaged itself for solutions at the earliest. Success in big data science largely depends on progress in both hardware and software technology. Emergence of non-volatile memory (NVM) is expected to address some solutions that currently memory design for big data processing faces. For fast computations, for the time being data on chip (DOC) could be an effective solution. In addition, cloud computing has shown a way for resource utilisation for big data processing. Not only technology but also computing platform has a hand in success of big data. In that context, there are several tools that provide effective platforms in developing big data systems.

Introduction

Our world is now literally swamped with several digital gadgets ranging from wide variety of sensors to cell phones, as simple as a cab has several sensors to throw data on its performance. As soon as a radio cab is hired, it starts sending messages on travel. GPS fitted with cars and other vehicles produce a large amount of data at every tick of time. Scenario on roads, i.e. traffic details, is generated in regular intervals to keep an eye on traffic management. Such scenarios constitute data of traffic commands, vehicles, people movement, road condition and much more related information. All these information could be in various forms ranging from visual, audio to textual. Leave aside very big cities, in medium-sized city with few crores of population, the emerging data could be unexpectedly large to handle for making a decision and portraying regular traffic conditions to regular commuters. Internet of things (IoT) is the new emerging world today. Smart home is where gadgets exchange information among themselves for getting house in order like sensors in a refrigerator on scanning available amount of different commodities may make and forward a purchase list to a nearby super market of choice. Smart cities can be made intelligent by processing the data of interest collected at different city points. For example, regulating city traffic in pick time such that pollution levels at city squares do not cross a marked threshold. Such applications need processing of huge data that emerge at instant of time. Conducting business today unlike before needs intelligent decision makings. More to it, decision-making now demands instant actions as business scenario unfolds itself at quick succession. This is so for digital connectivity that makes business houses, enterprises, and their stakeholders across the globe so closely connected that a change at far end instantly gets transmitted to another end. So, the business scenario changes in no time. For example, a glut in crude oil supply at a distributor invites changes in status of oil transport, availability at countries sourcing the crude oil; further, this impacts economy of these countries as the productions of its industries are badly affected. It shows an event in a business domain can quickly generate a cascade of events in other business domains. A smart decision-making for a situation like this needs quick collection as well as processing of business data that evolve around. Internet connectivity has led to a virtual society where a person at far end of the globe can be a person like your next-door neighbour. And number of people in one's friend list can outnumber to the real number of neighbours one actually has. Social media such as Twitter, Facebook, Instagram and many such platforms provide connectivity for each of its members for interaction and social exchanges. They exchange messages, pictures, audio files, etc.

Big data looks for techniques not only for storage but also to extract information hidden within. This becomes difficult for the very characteristics of big data. The typical characteristics that hold it different than traditional database systems include volume, variety, velocity and value. The term volume is misnomer for its vagueness in quantifying the size that is fit to label as big data. Data that is not only huge but expanding and holding patterns to show the order exist in data, is generally qualifying volume of big data. Variety of big data is due to its sources of data generation that include sensors, smartphones or social networks. The types of data emanate from these sources include video, image, text, audio, and data logs, in either structured or unstructured format. Historical database dealing with data of past has been studied earlier, but big data now considers data emerging ahead along the timeline and the emergence is rapid so Velocity of data generation is of prime concern. For example, in every second large amount of data are being generated by social networks over internet. So in addition to volume, velocity is also a dimension for such data. Value of big data refers to the process of extracting hidden information from emerging data. A survey on generation of big data from mobile applications is presented in.

Big Data Processing

Big data offers a bountiful of opportunities. But, opportunities always come with challenges. The challenge with big data is its enormous volume. But, taming the challenges and harnessing benefit always have been with scientific tamper. The volume of big data looks like a data avalanche posing several challenges. Big data service faces challenges for its very characteristics and has generated enormous expectations. First, we will discuss on a broad outline of data service and then refer to some important challenges the service faces.

Big data service process has few steps starting from Data acquisition, Data staging, Data analysis and application analytics processing and visualisation. A framework for big data processing that models at higher level, the working of such a system. Source of data could be internet-based applications and databases that store organisational data. On acquiring data, preprocessing stage called data staging includes removal of unrequired and incomplete data. Then, it transforms data structure to a form that is required for analysis. In the process, it is most important to do data normalisation so that data redundancy is avoided. Normalised data then are stored for processing. Big users from different domains such as social computing, bioscience, business domains and environment to space science look forward information from gathered data. Analytics corresponding to an application are used for the purpose. These analytics being invoked in turn take the help of data analysis technique to scoop out information hiding in big data. Data analysis techniques include machine learning, soft computing, statistical methods, data mining and parallel algorithms for fast computation.

Big Data Architecture

Big data is a broad descriptive term for non-transactional data that are user-generated and machine-generated. Data generation evolved from transactional data to first interaction data and then sensor data. Weblog was the first step in this evolution. These machines generated logs of internet activity caused the first growth of data. Social media pushed data production higher with human interactions. Automated observations and wearable technologies make the next phase of big data. Data volumes have been the primary focus of most big data discussions. Architecture for big data often focuses on storing large volumes of data. Dollars per TB (Terabyte) becomes the metric for architecture discussions. We argue this is not the right focus. Big data is about deriving value. Therefore, analytics should be the goal behind investments in storing large volumes of data. The metric should be dollars per analytic performed. There are three functional aspects to big data—data capture, data R&D, and data product. These three aspects must be placed in a framework for creating the data architecture. The goal of big data is data-driven decision making. Decisions should not be made with data silos. When context is added to data items they become meaningful. When more contexts are added more insight is possible. Deriving insight from data is about reasoning with all data and not just big data. We show examples of this and argue big data architecture must provide mechanisms to reason with all data. Big data analytic requires all forms of different technologies including graph analytics, statistical analytics, path analysis, machine learning, neural networks, and statistical analysis be integrated in an integrated analytics environment. Big data architecture is an architecture that provides the framework for reasoning with all forms of data.

The focus of a architecture is the data layer and everything else is pushed off to the side. A complete architecture needs all the access tools, data acquisition tools, and all visualization tools. It requires multiple mechanisms to transport and load data in parallel. It requires all the client tools that interact with each of these three platforms.

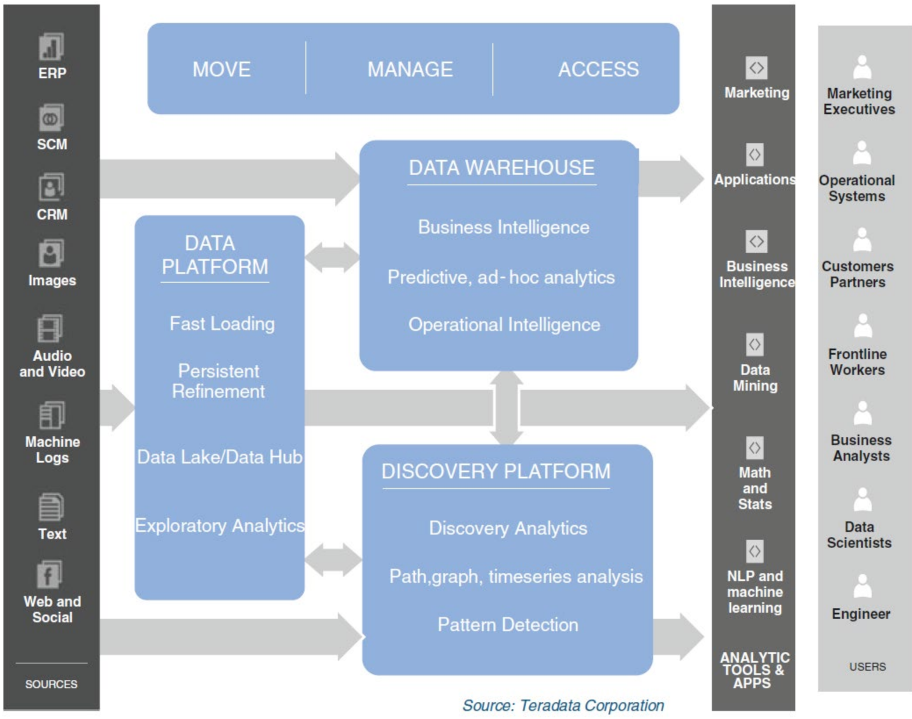

Figure 4: Figure Integrated analytics architecture

Applications in Manufacturing

All the major corporations face a highly competitive environment with constant pressure to increase the profitability by identifying avenues for operational efficiencies and at the same time keeping the business risk to a minimum. All of the big businesses have realized the importance of analyzing loads of historical data that they have collected over the years, and analysis of this data has become an integral part of making strategic business decisions for these corporations. There is a big push to setup an integrated data management systems and utilize the business intelligence and analytic techniques for improving their businesses. Over the recent past, big data analytics has found its ways into multiple applications in diverse areas with widespread interest from both the academia and industry. Although this area has made significant progress over the last decade or so, many more challenging problems still exist and finding avenues to new and complex problems in this growing market is ongoing. Various techniques in modeling, statistical analysis, data mining, and machine learning are used to forecast the future events and predict customer behaviours and then proactively act on them to safeguard and enhance business objectives.

Manufacturing companies have become highly competitive across the world with the margins of doing business going down every day. The manufactures are always on the lookout for optimizing costs in running factories thereby increasing the margins.

In the automated world of manufacturing, sensors are used everywhere in monitoring the assembly line so that the failures can be quickly identified and fixed to minimize the downtime. The root cause of plant failure could be due to one or more of the numerous possible parameters spread across different subsystems linking the assembly line. Huge amount of sensor data, all unstructured data, is accumulated over the running of the manufacturing plant. Historical maintenance records for the various subsystems are also gathered in the semi-structured format. And logs related to the productivity relative to the peak capacity are also gathered along with the maintenance records and sensor data. Time series analysis of the various subsystems based on their respective sensor data and performing pattern matching against the failure case is used for catching the potential failures. Also, path analysis and sessionization techniques are used to capture the critical events based on correlations between the sensor readings, historical maintenance records, and logs to predict the probable failures. This helps take preventative measure to keep the line running for extended period of time without interruptions and also help with improving the safety of running the operations.

The most important factor in businesses which are tied to manufacturing industry is to optimally use the resources where the day-to-day orders keep changing dynamically. Forecasting sales and the time frame when they happen will help plan for timely acquisition of raw materials, ramping up/down production, manage warehousing, and shipping logistics. In the short term, overestimating demand leaves the manufacturer with unsold inventory which can be a financial drain and underestimating implies missed opportunities. In the long term, demand forecasting is required to plan for strategic investments and business growth. Hence, for effective running of a business with maximum profitability requires a solid forecasting system. Time series analysis is a popular forecasting technique used to predict future demand and is based on the historical sales data. This simplistic method in generating future forecast is inaccurate when the environment is dynamic with factors such as changing customer requirements and impact of competition. Predictive modelling is a more advanced and accurate forecasting technique which has the capability to factor in all the variables impacting future demand. The model also facilitates with testing various scenarios and helps understand the relationship between the influencing factors and how they affect the end demand.

3.2.2 Smart connected products

We are surrounded by products that have minds of their own. Computing power, in the form of microcontrollers, microprocessors, sensors, and data storage chips, has become so cheap that manufacturers are building microcomputers and embedded software programs into all types of consumer goods. Extending the power of Internet connectivity to a virtually limitless variety of embedded devices, many of them able to communicate machine-to-machine without human intervention has far-reaching business and personal implications. However, the smart product value proposition for consumers is complex. In some cases industry evangelism for embedded intelligence is not grounded in an understanding of the many challenges presented by smart products and their evolving ecosystems. There are numerous examples of smart products that never captured the consumer market or that fell out of favour when lower-cost, more generic offerings came along. Consumers also have concerns about the potential negative impact of bringing more connected, intelligent products into their lives.

Definition

Even in the realm of consumer products, the feature of connected embedded intelligence and the term "smart product" are used to describe a myriad of objects as disparate as automobiles, mobile phones, and electric utility meters. When applied to home appliances such as refrigerators and dishwashers a decade ago, the smart descriptor typically meant that the appliance was connected to the Internet. Now it is more likely to indicate an interface with a smart utility meter that sends the appliance signals about the cost of electric power at different times of the day and monitors its energy consumption. The smart designation has been applied to so many products so frequently, and in so many different contexts, that it is becoming more of a marketing claim than a well-defined technical description. Which consumer devices should be categorized as smart products? While the rapid growth in embedded computing power and the absolute number of microcontroller chips are well-documented facts, the definition of a smart product is still evolving. Definitions differ considerably depending on the point of view of the writer. We will review some definitions that have particular applicability for products that target the consumer market and then provide a description of the specific product characteristics and capabilities that are most relevant for our analysis. According to Stanford University's Smart Product Design Laboratory, the presence of an embedded microprocessor is the defining technical characteristic of a smart product: "Smart Products are products whose functionality is increased by an embedded microprocessor. It is a superset of the field that has become known as Mechatronics. Embedded microprocessors can already be found in everything from dishwashers to automobiles – and more Smart Products appear every day".

"Smart Products" are real-world objects, devices or software services bundled with knowledge about themselves and their capabilities. These properties make Smart Products not only intelligible to users but also smart to interpret user's [sic.] actions and adopt accordingly. By naming these objects Smart Products, we convey not only the notion of technology available "off-the-shelves", but also the notion of componentized software services and hardware objects required to assemble new, innovative end-user components. Therefore, Smart Products share some key properties: the ability to have multiple uses, be deployed independently, and network with others to augment their individual and collective capabilities [Lyardet and Aitenbichler, 2008].

Business Perspective

In many cases, smart products and services are a clear extension of a company's strategy and business model. Amazon, for example, is a leading online bookseller. It has strategic partnerships with publishers, including negotiated discounts for selling their books online and agreements to offer its online customers glimpses of digitized content as part of the "Inside the Book" feature of its web pages. Amazon has attracted millions of book-buying customers, creating a branded channel for reaching the book-reading market directly, in particular, readers who are comfortable with online purchasing. Amazon's development of the Kindle e-book reader, the company's first foray into branding its own smart product, builds on its existing publisher relationships, customer base and online sales channel. Whether or not Amazon emerges as a long-term e-book leader, the Kindle has invigorated the long-dormant e-reader and e-book market. Amazon customers who have invested in Kindles also have an added incentive to remain loyal to the brand, since Amazon hosts back-up copies of their e-book purchases and uses a proprietary format for Kindle content that is not interoperable with other e-books on the market. The benefits of higher-margin revenue opportunities from linking smart products and services are significant enough to attract many companies to extend into new market sectors. Smart products may also provide bottom-line benefits by lowering the cost of after-sales product service and maintenance. This is especially important for expensive products such as automobiles and home appliances that may be covered by warranties that extend for several years. It is much less costly for the vendor to detect a performance problem and address it proactively than to send out a service representative or accept a product return. Embedded product intelligence, data collection, and connectivity features make it possible for vendors to remotely diagnose and resolve problems faster and more cost-effectively, perhaps in ways that are invisible to the product owner. This same connected access to installed products can provide companies with valuable insights into how customers are actually using their branded smart products. The enterprise can then build on these insights to improve new product design, to supplement its product and services offerings, or to further personalize its services to create a more targeted value proposition and increase customer loyalty. In addition to the direct benefits that smart products and services can provide to companies, they support a variety of strategies for avoiding or diminishing the impact of competitive, social, and legal threats by exercising tighter control on the use of the product and its components and content. Recent trends in business, technology, and society have highlighted the severity of external threats, including billions of dollars in lost revenue from activities such as illegal media downloads and software piracy. These trends are making threat avoidance and customer control an urgent priority for many industry sectors. Economic trends include the recent global downturn and the longer-term tendency of decreasing prices of consumer electronics, accompanied by the commoditization and lackluster consumer adoption of higher-priced, branded consumer products. The relentless downward pressure on prices for consumer electronics has turned already low-margin hardware products into low-cost commodities. It's extremely difficult to maintain brand loyalty when consumers are intent on finding bargains, and relatively few features differentiate a high-end, branded phone, computer, or electronics device from a generic clone. Linking smart products to subscription-based services or requiring that customers buy replacement components only from the original brand provide some defence against these trends.

Risks

With a combination of business drivers motivating companies to embrace smart product strategies, it is important to consider some of the risks that such strategies entail. Many of the manufacturers of hardware products have little experience in developing software and linking it to services or data-collection features. Sometimes these software capabilities are outsourced and integrated into the product during manufacturing. In any case the new software adds complexity to the design and manufacturing process, increasing the risk of product malfunction or failure to operate as expected. Because of their complexity and mix of software, firmware, and hardware, smart products have become a favourite target of hackers and criminals who are seeking to crack these systems for their own reputation or for financial gain. As such, smart products carry a high-security risk, and manufacturers must continually monitor and upgrade security in response to targeted attacks. Complex software development projects, in general, have a significant risk of outright failure. Even when development projects turn out products that are ready for commercial distribution, most newly issued software programs include numerous bugs. There is an especially large risk associated with the increased reliance on smart software-enabled components in complex systems such as today's automobiles, one of the most intelligent of consumer products as measured by their use of computer chips and embedded software. In fact, many automotive recalls and malfunctions are associated with faulty electronics and software, in essence a malfunctioning of some smart component.

Smart product ecosystems

Applying product platform strategies to computer component design and software development gained favour in the 1990s as a way to keep up with rapid-fire technological advances and accelerating software-update cycles. Platform strategies allowed technology companies to attract more developers and component partners, to create more coherent product roadmaps, and to assure their technical and channel partners that the next generation of products would complement current development and sales plans and be compatible with their growing base of customer installations. The earliest technology product platforms and ecosystems aimed to streamline innovation and facilitate interoperability. The company that owned the core technology remained at the centre of the ecosystem. If that company's strategy was successful, it attracted a variety of partners who then built the products, applications, components, and peripherals that provided value-added features for the core technology. The PC partnership of Intel with Microsoft is the canonical example.

The next generation of electronic products won't be stand-alone devices, as they have been in the past. Rather, devices will be an intelligent part of an interconnected system – a product "ecosystem" – that will offer far more than the metal, silicon and plastic from which the devices themselves are made. In essence, electronic devices are moving away from the centre of the electronics design universe and becoming satellites of a much bigger device ecosystem. The devices and the ecosystems behind them are intimately linked, and both go to make up the total user experience.

The core elements that make up a smart product ecosystem are:

- intelligent, connected devices
- closely aligned and interconnected enterprise partners who build components, applications, services, and infrastructure for these devices
- a core technology platform
- data generation and management
- a clear value proposition for ecosystem participants and smart product end-users
- participatory and user-friendly applications and services.

Although smart, connected devices have proliferated in the past decade, the other elements of smart ecosystems remain at an early stage of development. Many consumer product companies are still following an ecosystem game plan that has barely adjusted to the impact of the Internet on enterprise channel strategies. Others simply partner with the already well-established product ecosystem of a global brand like Microsoft to jump-start adoption of their own smart products or applications. But just thinking in terms of current partners and ecosystem models will limit the potential value proposition of a connected smart product for the company and for its potential customers. To take advantage of the embedded connected intelligence of smart products, smart ecosystems must create dynamic, scalable services that can extend their value proposition far beyond that offered by more traditional products and services in the market. Smart products need an ecosystem strategy that aligns decisions about product connectivity, content, applications, product extensions, and channels for sales and support. This chapter will analyze the features of selected smart product ecosystems to provide a general framework for understanding the pros and cons of contrasting smart ecosystem models and strategies. It will discuss examples of companies that are using each model and review the benefits and risks associated with certain ecosystem decisions. The chapter concludes with a discussion of the role of the customer in smart ecosystem models as an essential and often overlooked aspect of ecosystem strategy.

The strategy of evolving a smart ecosystem around a company's existing products and value chain relationships has obvious appeal for established market leaders. It keeps the company in control, positioning their own products, services, and technology roadmap at the centre of the new ecosystem. The lead brand can stage the rollout of interoperable services to avoid disruption or cannibalization of its current business model. It is also very tempting for large companies to try to capture the lion's share of any new revenues that may be generated by future growth of the smart ecosystem and to exclude potential competitors from any meaningful participation

Connected machines

M2M systems designed for the enterprise feature components such as remote cameras, motion detectors, location-tracking GPS chips, and sensors that can monitor changes in temperature, moisture, vibration, and other environmental conditions. These components are connected to each other and to wide area wireless networks, extending an enterprise customer's eyes and ears to remote locations. Connected M2M modules keep a virtual eye on enterprise resources twenty-four hours a day, seven days a week without the need for costly personnel or supervision. Each module logs the data it has been designed to monitor and sends it through the network to a central point for real-time analysis, aggregation, and storage. If something out of the ordinary occurs, or if the equipment being monitored stops operating, the system can be programmed to trigger an alert. Freight companies and fleet operators, for example, can monitor the temperature of cargo that requires refrigeration and respond immediately if a refrigeration unit breaks down. They can also route freight shipments and schedule drivers much more efficiently when all vehicles and cargoes are M2M enabled, getting the cargo to its destination faster or more economically. Once an M2M installation is in place it enables enterprises to manage complex equipment and transportation logistics, to detect intruders, to monitor lights-out operations inside physically secure installations, to improve the efficiency of far-flung operations, or all of these things at once. Managers can immediately send a response team to the precise location of the problem when equipment malfunctions or leaks are detected. Even when everything seems to be operating normally in the field, analysis of the data collected from multiple M2M modules may reveal a weakness in the system or detect early symptoms of a pending breakdown.

Lower prices and better-quality wireless coverage will address some of the barriers to M2M growth. Vendors are also hoping that delivering strategic services based on the data that connected machines are collecting and reporting will provide higher revenue margins for them and encourage their enterprise customers to invest more in M2M installations. Vendors are expanding their solutions beyond simply implementing M2M connections to providing data aggregation and data-mining services for enterprise customers.

Smart Services

The smart services term has been used in a number of different ways to describe a variety of business service offerings. Even M2M service providers who have recently adopted the term apply it to different types of activities. M2M Premier defines smart services in the context of specific benefits that an M2M customer would receive, describing it as the process of networking equipment and monitoring it at a customer's site so that it can be maintained and serviced more effectively. At their core, Smart Services are differentiated post-sales product support, enabled by wirelessly capturing and analyzing timely product performance information. Usually, these services are delivered by manufacturers or service providers to the owners/ operators of the serviceable equipment or machinery. Smart Services represent a way of doing business where the relationship a manufacturer cultivates with its customers after the initial product sale is just as financially relevant – if not more so – than the sale itself.

Smart services are a wholly different animal from the service offerings of the past. To begin with, they are fundamentally preemptive rather than reactive or even proactive. Preemptive means your actions are based upon hard field intelligence; you launch a preemptive strike to head off an undesirable event when you have real-world evidence that the event is in the offing. Smart services are thus based upon actual evidence that a machine is about to fail, that a customer's supply of consumables is about to be depleted, that a shipment of materials has been delayed, and so on. For customers, smart services create an entirely new kind of value – the value of removing unpleasant surprises from their lives. Meanwhile, because the field intelligence makes product performance and customer behaviours visible as never before, manufacturers gain unprecedented R&D feedback and insight into customers' needs and can provide even greater ongoing value.Finally, because it is impractical to deploy humans to gather and analyze the real-time field data required, smart services depend on "machine intelligence." In a smart services environment, reliable and blindingly fast microprocessors do what they are very good at doing: digesting billions of data points, talking to one another about the data, controlling one another based upon the state of the data – all in a matter of nanoseconds. Humans cannot do this, nor should they; this incessant stream of business information should be invisible to people. At the same time, all this background activity gives managers and decision-makers much more visibility into a business's assets, costs, and liabilities – precisely when they need or want it.

Smart services such as optimizing equipment performance and making pre-emptive repairs map very well into typical enterprise goals and objectives. The enterprise is committed to improving productivity and maximizing profitability in order to deliver value to owners, shareholders, and customers – and to survive in challenging and competitive economic periods. M2M implementation and the resulting smart services contribute directly to this overarching objective. To the extent that M2M data collection, reporting, and analysis can be rendered invisible in the sense that it is carried out autonomously without the need for man-in-the-loop decision making, this is a positive benefit for the enterprise. M2M components surface alerts when action is needed; otherwise, they remain in the background, avoiding a barrage of routine information that would distract managers. The long-term data are aggregated and stored until the M2M vendor compiles an analysis of the data and draws some inferences about how to improve productivity and performance even further. These insights can be packaged for the enterprise decision-makers in the form of strategic recommendations, or in the words of Allmendinger and Lombreglia, they can be delivered “preemptively” to the customer to enhance performance and head off problems before they happen. This can create a positive feedback loop in a well-designed M2M installation, where the customer becomes more productive and more profitable thanks to the constant monitoring and pre-emptive services provided by the M2M vendor. In the preemptive model, reports on problems avoided and increased productivity can contribute to the calculation of return on investment (ROI) from optimizing the company’s equipment and operations.

3.2.3 Artificial intelligence

Artificial Intelligence (AI) is changing from a hype and marketing trend of Internet companies to an essential parameter for the competitive strength and profitability of many companies. After years in the academic niche, AI is experiencing a new, and so far unknown, phase of innovation and growth. Artificial Intelligence has left the research labs and is rapidly entering our everyday world in the form of talking devices and digital assistants. It is becoming increasingly difficult for us to distinguish bots from human beings in digital media, and more and more routine tasks are also being automated at the office. Autonomous driving and early detection of diseases are just a few more prominent examples of AI applications. This is made possible by increasing computing power, cloud applications and the growing availability of huge amounts of data.

Numerous surveys of experts indicate that every industry will be affected by AI applications in the foreseeable future. It will take several years before companies will be able to leverage the AI technology for the creation of added value. But this also requires investments and efforts to adapt the technology for the company, to overcome hurdles and to develop application scenarios for its own business.

In the future, the performance spectrum of AI applications will expand significantly. This raises a number of political, social and ethical questions.

The objective of this overview is to identify possible drivers, benefits, barriers and challenges based on literature research in order to support companies in adapting the technology and implementing AI potentials. Drivers were also worked out to make the current hype of the topic comprehensible.

By analyzing the researched sources and their definitions it appears that there is no coherent definition for AI. Each definition has individual focus areas, which often overlap with other definitions. Another issue, mentioned in the literature, is the missing common understanding of the terms “artificial” and “intelligence”. Thereby the term artificial can be understood as the imitation of something that is not natural, which was modelled, manufactured or created according to a natural model by the use of technical means. Moreover, the word art can be derived from the artist or creator and cannot exist without him. The term intelligence derives from the Latin “intelligentia” and "intellergere" and means insight, cognitive ability or understanding. It also describes the ability to act abstractly and reasonably and to derive appropriate action from it. Intelligence also stands for the characteristics of learning ability, abstraction ability, adaptability and logical thinking. The characteristics of intelligence are mostly attributed to biological beings. In the human context, intelligence usually describes the ability to consciously adapt thinking to new demands, tasks and conditions of life.

According to the identified sources and the definitions contained therein, certain key topics can be identified. These include the assignment to a scientific research area, imitation of human-like intelligence and the solution of complex problems, as well as learning from preceding experiences. Furthermore, the applications generally involve computer programs or machines (especially robots).

For this reason, a novel definition was formulated for this paper, which covers the identified main focuses and is intended to provide a general understanding of AI:

Artificial Intelligence is a research field with the aim of creating artefacts, such as computer programs or machines. The objective of most applications is to solve problems by applying algorithms. Applications can address the imitation or extension of human intelligence. Another possible focus of AI applications can be the learning from complex problem solutions and the extension of the functionalities of existing applications.

The following subchapters will describe several types of AI and their functionalities.

Types of AI

In principle, Artificial Intelligence can be divided into two general sub-areas: the "weak" and the "strong" AI. When using "weak" AI it is sufficient if only a few characteristics connected with the idea of human intelligence are used to solve concrete application examples and to support people in their specific tasks. In contrast, a "strong" AI is expected to act truly intelligently. Attempts are made to create intelligence that is equal to or even better than human intelligence. However, the basis for this are skills such as logical thinking, making independent decisions in the event of uncertainty and independent learning. Turning these characteristics into reality is still one of the greatest challenges today. The highest form of Artificial Intelligence is Artificial Super Intelligence (ASI). Super Intelligence is currently only a hypothesis, and no one can be sure whether there will be superintelligence or when the first superintelligence application will appear.
The following figure shows three consecutive types of Artificial Intelligence.

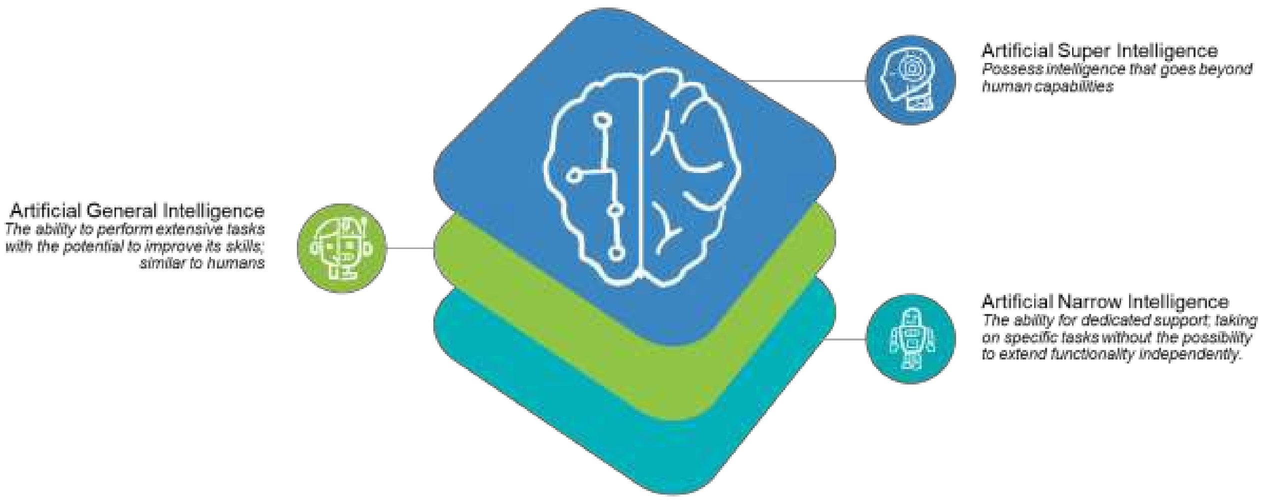

Figure 5: Types of Artificial Intelligence

Artificial Narrow Intelligence (ANI)

Today we are already surrounded by numerous intelligent machine systems. This includes object-oriented programming languages and graphical user interfaces. Every smartphone offers numerous intelligent applications. For example, personalized public transportation timetables can be created in seconds, a task that took a lot of time and effort just a few decades ago. Digital assistants, such as Apple's Siri, Amazon's Alexa and Microsoft's Cortana, can understand, process and interpret spoken human language. Questions can be answered, online purchases made and entire texts translated. Further possible applications in which human tasks can be performed are manifold and will grow in the near future. All examples mentioned so far are Artificial Narrow Intelligence (ANI), also known as weak AI.

Artificial Narrow Intelligence focuses on one or more specialized areas. Thereby weak does not necessarily mean that this type of AI lacks skills. It only emphasizes the characteristics of specialization. This kind of Artificial Intelligence is characterized by the fact that it can solve certain tasks in a specific area very quickly and/or precisely.

This special form of AI is thus limited to a single field of activity or rather to a particular problem to be solved and should support human thinking in particular. If an AI system is trained in a specific field, it may be able to solve selected tasks as well as or better than a human being. The training is usually done by machine learning.

Artificial General Intelligence (AGI)

Artificial General Intelligence (AGI) is also known as Human-Level AI or strong AI. Kurzweil defined strong AI as machine intelligence with the entire spectrum of human intelligence. Such systems are intellectually equal to humans and are therefore not limited to individual fields of activity. Typically, these machines are equipped with human-like cognitive abilities and are therefore able to plan, solve problems, think abstractly or learn independently.

Thus, a strong AI describes IT systems that are able to "think" and act in a human-like interconnected manner in many different areas at the same time. It is generally accepted that an AGI is not yet feasible and is currently the subject of controversial discussion.

Both AI approaches, ANI and AGI, have a right to exist in AI research. It is advantageous to have specialized AI systems that solve certain tasks, as well as systems that have the ability to tackle new problems they have never faced before. The distinction between the two systems should emphasize the need for different evaluation procedures for ANI and AGI. Specialized AI applications should receive a task-oriented evaluation. On the other hand, multi-purpose AI applications require a performance-oriented evaluation.

Artificial Super Intelligence (ASI)

The ultimate form of Artificial Intelligence is Artificial Super Intelligence (ASI). Nick Bostrom defines such a Super Intelligence as one that is superior to even the brightest mind in all aspects . Especially the scientific creativity, general wisdom and social skills are decisive for this. Super Intelligence is currently only a hypothesis, and it is not certain whether there will be superintelligence or when the first application of superintelligence will appear.

As soon as such a Super Intelligence system begins to continuously improve itself, the state of singularity is reached, where machine intelligence as a whole exceeds human cognitive performance.

According to a survey conducted by Müller & Bostrom, most experts believe that such a Super Intelligence could only be developed about 30 years after the development of the strong AI. In order to meet the requirement of the designation as ASI it is sufficient if the system is only slightly superior to humans. Müller & Bostrom, however, assume a Super Intelligence that is many times superior to all of humanity and whose structure can no longer be understood and comprehended by people. Tim Urban provides a detailed description of this classification. This development is based on an insight that Kurzweil describes, which states that technological developments are increasing exponentially and thus the frequency at which new technologies emerge is increasing. This assumption also corresponds to Moores Law, which had already predicted the development of the performance of integrated circuits (ICs) in the 1960s. Based on research on technological development, Barrat assumed that a strong AI could possibly be developed as early as 2030. If this assumption is correct, a first Super Intelligence application could be introduced around the year 2060 at the earliest.

Functionalities of AI

The term Artificial Intelligence includes a wide range of techniques of varying complexity. AI is characterized by its systems and their performance, as well as outcomes and results. The way those findings are generated have usually no high importance since the internal processes of an AI system are not always traceable and can, therefore, represent a black box.

The following sections describe the functionalities of artificial intelligence. These include Machine Learning, Deep Learning and Cognitive Computing. The three areas presented differ strongly in the clarity of the application purpose and the degree of autonomy. The clearer the purpose of such a functionality is, the less autonomy it allows. This also applies the other way round. Likewise, the degree of innovation of the functionalities rises with the increasing degree of autonomy of the application. Following this argumentation, a strong AI would have the highest degree of innovation and autonomy, but there would be less clarity of purpose.

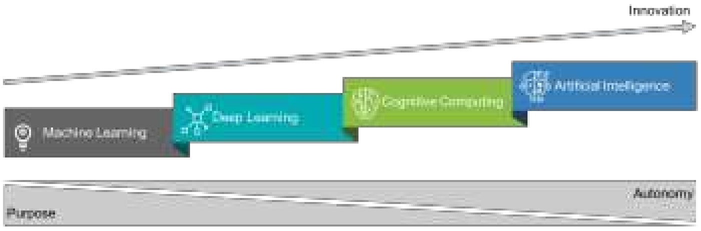

Figure 6: AI functionalities and their categorization

Machine Learning

Machine Learning (ML) is an important technical approach of AI. ML forms the basis for the development of new solutions for a wide range of applications.

Machine Learning is of importance because it facilitates the meaningful processing of large amounts of data since traditional rule-based systems are already reaching their limits.

ML is, therefore, a partial aspect of AI, which generates new knowledge from existing experience. Based on data or examples, an artificial system is trained to recognize patterns or repetitive characteristics. These are then used for an analysis of new, previously unknown data in order to draw the right conclusions for solving specific tasks.

With Machine Learning, a system learns from existing data and examples. Neural networks are a special form of these approaches. This AI technology uses simulated artificial neural networks in computers to understand the functioning of the human brain or to solve concrete application problems in statistics, economics and technology.

The success of a neural network often depends on so-called training data sets. Here, for example, the contents of images are previously described by machines or people and assigned to the image. If a sufficient number of these training data sets are fed into a neural network, the machine learns independently whether an image is a dog or a cat.

Neural networks are based on a very simplified reproduction of the structure and function of the human brain. Essential mathematical elements are neurons that act as nodes and pass on information depending on the input data and subsequent activation. Synapses represent a weighted connection between the neurons. The neurons are additionally arranged in different layers (input layer, hidden layer, output layer) and compress the input data to ever higher knowledge until a result is finally available in the output layer.

A major advantage of Machine Learning is that results can be achieved with a low data volume and low computing power without having to produce a special code.

Furthermore, three techniques of Machine Learning can be distinguished. Those are Supervised Learning, Unsupervised Learning and Re-enforcement Learning.

Applications for ML include spam detection, content personalization, document classification, customer migration prediction, automated solution recommendation for customer service, transaction fraud detection, diagnostic systems, traffic jam prediction, medical diagnostics, chatbot applications and personal assistants like Siri, Alexa, Cortana and Google now.

Deep Learning

Deep Learning, also known as Deep Network Learning, is a specialized form of Machine Learning that uses statistical data analysis rather than an algorithm for input evaluation. The goal of DL is for a computer to learn an ability that people already own.

Deep Learning is based on neural networks, which allow machines to understand more complex structures and complicated solutions through new applications than it is possible with ML.

Simulated neurons, which are supposed to resemble the human brain, are modelled and arranged in many layers one behind the other or one above the other. Each level of the network performs a single task, such as edge detection. This extraction of characteristics takes place separately within the individual layers.

The output of the individual layers then serves as input for the next layer. In combination with many high-quality training data, the network then learns to perform certain tasks. Existing applications brought initial success, especially in the medical field, as the machines were able to diagnose cancer cells in images quick and efficient. Similar to Turing's description, these methods of Artificial Intelligence do not give people an insight into the layers of the network. The decision is made solely by the trained machines. Deep learning-based systems therefore already have a significantly higher degree of autonomy and offer a variety of application possibilities. The principles of DL operations are currently difficult to understand from the outside since the next generation of neural networks learns independently after initiation and decision-making.

These intelligent systems are used in particular for more complex problems, which are also associated with a large amount of data. These data records can contain both structured and unstructured data. They support decision-making, interpret patterns, control processes or move autonomously in unknown use cases. Other known areas of application are the recognition of objects in images and videos, as well as speech recognition.

Cognitive Computing

In recent years, the AI has increasingly turned back to the original orientation of the pioneers of the field, which is the reproduction of cognitive functions in the human brain. Algorithmic implementation using neural networks is already well advanced. Now the focus is moving more towards the architecture of cognitive structures.

Cognitive computing refers to systems that take on tasks or decisions that are currently mainly carried out by humans. This is the case, for example, with insurance claim management, on the service hotline or in hospital diagnostics. Cognitive systems are primarily characterized by their ability to adopt certain "human" characteristics and to deal with ambiguity and blurriness. The degree of autonomy can be high with these systems. The term Artificial Intelligence is used when machines have complete cognitive abilities. Thereby it is no longer possible to distinguish man and machine from each other from the outside. In an advanced stage of development, these systems of Artificial Intelligence have achieved a very high degree of independence. They make their own decisions, define their own strategies and determine the way in which they learn and communicate. Such systems are currently the focus of many researchers, while companies and their use cases refer to simpler functionalities of artificial intelligence.

3.2.3.1 Influential Factors – drivers, benefits, barriers

The field of AI is influenced by numerous factors. In recent years, technological progress has encouraged development. Current and potential applications have advantages as well as disadvantages for stakeholders, which have an impact on the general acceptance of the technology. Especially negative influences cause challenges, which have to be solved in order to be able to utilize the full potential. In this context, it is necessary to consider all stakeholders concerned in order to achieve broad acceptance of the technology.

Drivers

Drivers are relevant developments or technologies that promote future changes of a technological, social or other nature. For the subject area AI the following drivers are mentioned in the literature: Big Data, Internet of Things (IoT), Cloud Computing and Cloud Storage, Higher Processor Speed, and Algorithms.

Big Data

One of the most frequently mentioned drivers for the strong increase in interest in AI is the large amount of data that is available everywhere nowadays. This data is routinely generated, collected and stored by digital systems. The amount of data generated worldwide doubles every two years. Large amounts of data are essential for AI, as big training data sets are currently the basis for many AI applications. They are also needed to continuously improve the system. With the AI it is now possible to process large amounts of data that previously required extremely expensive hardware and software. The input data are an essential element for the quality of the output results.

Internet of Things (IoT)

In recent years, communication networks have gained speed so that large amounts of data can be quickly distributed between servers and devices. Broadband, as well as 4G and 5G communication networks and communication technologies for nearby areas, serve as the technological basis. The IoT also allows more data to be generated by the large number of communication- enabled devices. For the AI, this means that most of the intensive real-time data processing can be performed on servers in data centres. Furthermore, AI systems can be connected via networks if required to share experience and benefit from the new data.

Cloud Computing

Cloud computing is a network of remote servers hosted on the Internet. Thus, data can be stored, managed and processed in the cloud without using a local server for these tasks. Increasing availability and consistency of fast connections to the Internet also mean that large amounts of data can be quickly transferred to cloud servers and stored by cloud service providers. Cloud computing is therefore a key factor for AI technology. The increased use of cloud computing has reduced cost of storing data in the cloud, which in turn reduces the cost barriers for companies using this technology.

Processor Performance

The data volumes described above are a relevant driver for the AI. The increasing collection of data requires an extension of the ability to perform calculations. This increase in computing power is made possible, for example, by Graphical Processing Units (GPUs) used in Machine Learning. Faster processors mean

that more complex problems requiring more data and more computing operations can be solved. Processing and managing all this data takes time, and even relatively simple training sessions can take from a few hours to several days. Any improvement in processor performance therefore helps in the use of AI applications.

Algorithms

In general, algorithms are guidelines for solving problems that consist of defined individual steps and are implemented in a computer program. AI algorithms have improved significantly in recent years. Faster calculations and improved data quality allow algorithms to be trained to work with better accuracy and inference. Experiments based on the Minimal Viable Product (MVP) model are also made easier by improved algorithms and higher available computing power.

Benefits

Benefits are factors, which favour and promote the adoption and application of a Technology. The following list shows identified benefits of AI.

- Increase in productivity
- Increase in efficiency in the production area
- Forecasts are improved, processes optimized and the user experience improved
- Processing of large data sets
- Introduction of new business models
- Expand human abilities and possibilities of learning and exploring
- Solving complex problems
- Competitive edge
- Higher profit margins
- Replacement of human labour
- Better decision making

Increase in productivity

In the production area, an increase in productivity of up to 40 per cent is to be reached through the use of cognitive machines. During the entire production chain - from design, logistics and production to reengineering - an intelligent human-machine interface should collect data volumes through interaction with the user and their environment and is able to make data-driven predictions in real-time and adapt processes and behaviour with foresight. AI thus encourages the improvement of the value chain. This is only made possible by the improved connectivity of the systems and products on the Internet of Things and enhanced by advances in machine learning.

Increase in efficiency in the production area

The basis for the factory of the future is a modern infrastructure combined with a wide variety of AI technologies. These enable the introduction of new types of cognitive machines into the factories, which are supposed to generate an increase in productivity. These intelligent information and assistance systems are intended to ensure more user-friendly and efficient work in the production area. These include intelligent user interfaces that adapt to the user, or intelligent data glasses with augmented reality applications that provide visual support for various production steps.

Forecasts are improved, processes optimized and the user experience improved

AI helps to improve forecasting and procurement, optimize and automate processes, and develop targeted marketing and pricing. These measures lead to the improvement of the holistic customer satisfaction.

Processing of large data sets

Companies nowadays possess a high quantity of structured and unstructured data, which is constantly multiplying. The quality of Artificial Intelligence applications depends on the input data used for training. The more data available as a basis, the more extensive are the possibilities to link new information and connections and to process them by means of AI.

Introduction of new business models

Artificial Intelligence influences the way the economy operates, for example by influencing the way decisions are made. By adding new sources of value creation, existing business models are questioned and disturbed, but completely new ones can be also created. This new markets or services leads to cost reduction and sales increase.

Expand human abilities and possibilities of learning and exploring

Artificial Intelligence expands human abilities and possibilities of teaching, learning and research. Advances in sensors and networking as well as in computing and storage performance increase the number of available data. This also enhances the number of possible intervention points. This expands the application possibilities of machines, devices and software. Only through these developments can the actual potential of AI technology be unlocked.

Solving complex problems

Machines today still have difficulties understanding and interpreting real-world situations. However, with the help of artificial intelligence, machines are already able to solve combinatorial problems better than humans. So machines can imitate human cognitive abilities to understand our feelings and thoughts and strengthen human-machine interaction.

Competitive advantage

Artificial Intelligence creates a competitive advantage for companies at an early stage of use. This advantage is growing steadily and is difficult to compensate later on. Successful applications include many elements of a digital and analytical transformation: identifying the business field, setting up the right data ecosystem, using adequate AI tools, and implementing appropriate workflow processes. This change also depends on the willingness to adapt one's own corporate culture and to break new ground. Key factors here are leadership skills and technical understanding, as well as seamless data access.

Higher profit margins

AI techniques will play an important role in the future, especially in the areas of marketing and sales. "Next product to buy" recommendations addressed to individual customers - as already successfully implemented by companies such as Amazon and Netflix - can lead to a significant increase in sales. Individual pricing and promotion is also applied across a wide range of industries. Higher profit margins can be achieved by combining advanced digital capabilities with pro-active strategies.

Replacement of human labour

In the past, technological progress has been a medium to eliminate dirty and dangerous jobs and improve human quality of life. New technological developments have led to the takeover of monotonous and repetitive tasks. This results in a re-allocation of the time available for more demanding activities, but also more freedom for creative or leisure activities. Nowadays robots are already capable of performing many tasks quickly, reliably and in the highest quality - and all this without breaks and finish work. Up to now, however, the acquisition and configuration of such robots has only been worthwhile in mass production or in highly repetitive processes. AI will enable robots to perform a wide range of activities in the future, even in such environments, and to adapt continuously. This would make them more versatile and, due to an increasing range of products, more affordable to buy.

Better decision making

Artificial Intelligence provides a better basis for decision making, taking into account a higher amount of information, looking to the future, and performing rigorous analysis. Likewise, there are no potential heuristics and distortions by humans that could have a negative impact on decision making.

Barriers

Barriers are issues that may occur before or during AI application and which hinder a successful implementation or usage of AI. The following list shows currently discussed barriers of AI.

- Liability: who is responsible if something goes wrong?
- Part of the human labour force can be replaced by AI
- Users no longer have control over the use of their data
- Lack of system verifiability due to lack of transparency (security)
- Increased default risk of the new systems
- High investment costs
- Increased risk of arming AI (both physical and cyber)
- Data manipulation
- Misuse of AI systems
- Difficulty of AI to recognize emotions
- Very large amount of training data required
- Data protection
- AI systems have difficulty transferring their experience in changing circumstances

Liability - who is responsible if something goes wrong?

One of the advantages of AI is that the system works with a certain autonomy and can make decisions independently up to a certain degree. This also raises the question of who is liable if an activity carried out by the AI is performed incorrectly or does damage. This question is particularly of relevance in the field of autonomous vehicles, which contain components from a large number of suppliers. In the event of damage, the question arises which party is to blame. Is it the driver, the manufacturer or, for example, the supplier of AI relevant components or the software? Similarly, this example can also be applied to many different industries. The question of liability is, therefore, a very important one.

Part of the human labour force can be replaced by AI

On the one hand, there is the view that if robots start to replace people in all fields, it leads to unemployment. Thus many people would remain without employment and the empty time could end in their destructive uses. On the other hand, sources highlight the view that the forecasted change will be less disruptive and slower. This would give the labour market more time to adapt to the changes, which in the long run would lead to new fields of activity. Available applications indicate, that repetitive and rule-based tasks like e.g. administrative tasks can be replaced by AI. Therefore, the literature recommends to prepare employees for lifelong retraining, during which they should be able to adapt to changing working conditions.

Furthermore, Heinen et al. argue, that some pessimistic studies have questionable data quality and methodology.

Lack of user data control and transparency

AI is very good at personalizing product recommendations based on aggressive customer data and understanding customers' individual preferences. However, customers have reservations about services that deliberately invade their privacy, even if this improves the customer experience. In addition, AI is a black box for many outsiders, whose internal processes are difficult even for experts to understand and decisions that used to be based on human reflection are made in seconds using algorithms. Thus, there is the fear that those who control the algorithms now also have comprehensive influence on people and many areas of society.

Increased default risk of the new systems

In complex AI systems, which consist of many applications and where algorithms have to work together at high speeds, there is a risk that these systems may unexpectedly break down due to internal errors or external influences.

High investment costs

Large internet companies and other tech firms have invested billions of USD in R&D of AI solutions in recent years. However, survey-based results show that many companies using AI are not sure whether the business case is working and whether there will be a near-time Return on Inverst (ROI) for it. Especially the development of higher levels of AI will be difficult to realize and will therefore be costly.

Misuse of AI Systems

Fears about the use of the AI as a weapon have been identified in various sources. This applies to both the physical and the cyber world. Furthermore, there are fears that existing social and economic inequalities may be exacerbated by inequalities in access to AI systems. Uneven access to AI benefits can also result in economic benefits that are not equally beneficial to all people.

Data manipulation

Aspects of AI such as Machine Learning are based on data that are made available to the AI system for training purposes. During the training phase the algorithms try to find systematic structures and rules. Thus AI systems are vulnerable during the training phase. If an attacker succeeds in manipulating the training data, the output of the training phase is modified and the system does not function as planned.

Challenges

Challenges are based on the known barriers of a topic area and must be at least partially overcome for the successful adaptation of a technology. This work identified several challenges, including fear of change, algorithm comprehensibility, technology, cost-benefit ratio, legal framework and security. These challenges are described below.

Artificial Intelligence is a universally usable technology that will fundamentally change all aspects of life. The idea is compared with the invention of electricity or the steam engine. Already today AI has become an important part of everyday life and can be found in various applications, private as well as public. Technologies based on machine learning, such as text and speech recognition or translation, have become an integral part of our everyday lives. Algorithmic calculations provide product suggestions for those who surf the Internet or customized messages for those who browse their social media account. The number of possible AI applications is not yet exhausted.

One of the main barriers to the implementation of AI applications is the general fear of what changes can result from this technology. This fear occurs especially when the AI fundamentally reforms the way people work. Up to now, there have already been many changes in the way of working, which could increase drastically due to the AI developments. Automation of factories, offices, administration, traffic, household and many other areas has for many years ensured that more and more heavy, dirty and unhealthy work is taken over by computers, machines and robots. Speculative reports by academics and institutions repeatedly report job losses. Some authors go one step further and also address existential threat scenarios as a consequence of Artificial Super Intelligence. Artificial Intelligence does not necessarily lead to job losses. Instead, expectations and types of jobs will be transformed in the future. The fear that these predictions will come true, however, leads to a natural resistance from those who might be affected.

A possible advantage of AI systems is their autonomous operation, which is the key attraction of this technology. Nevertheless, AI systems often work as so-called black boxes. A large part of the computing work done by an AI system is unknown to the developer or user. This means that there is no traceable path to determine how a decision was made. This poses challenges in the areas of liability and negligence in the case of complications. Especially with larger and more complex models, it is difficult to understand why a certain decision was taken. This makes it clear why the acceptance of some AI instruments in certain areas of application in which much explanation is needed is not provided. This is especially true where predictions or decisions directly influence human beings. For example, an AI system cannot always explain why a particular applicant was accepted or rejected for a job or why a particular medication was recommended. For this reason, AI users need to be confident that the content of the black box makes decisions in their own interest. Since this trust is not often given by society, this is an obstacle to the implementation of AI applications.

Despite major advances in data management and cloud infrastructures, AI systems are primarily monolithic systems that require a critical amount of data to train and learn skills. Companies face challenges in the development of such systems. One of the main reasons why tech companies such as Google, Microsoft, Amazon or IBM are successful with this topic is their access to a large amount of data with which they can work and experiment. Companies that want to deal with AI and enter this market usually do not have the necessary data available in the required quantity, structure and form. This hurdle is also referred to in the literature as the so-called data wall, which denies companies an easy entry into this field.

After successfully overcoming the data wall, companies face further challenges in the development of AI systems. This includes the necessary personnel expertise, prioritization of competing AI applications and their financing, as well as the technological challenges. For the training of AI systems, the training data are essentially responsible for the learning success. Hence, a massive amount of data is necessary. The more extensive and detailed the information in the training data is, the better it can be used for training the AI. This is one of the reasons why companies have been keen to pursue the subject of big data in recent years. The desire of companies to possess comprehensive, coherent and as valid as possible data sets of their customers can easily come into conflict with the provisions of the European General Data Protection Regulation, which has been in force since May 2018. For this purpose, Article 5 is relevant, which deals with the principles for processing personal data. An example for this is the principle of data minimization (Article 5.1c), which aims primarily at the collection and processing of personal data. This means that data for AI applications can be used either only without personal reference or with explicit permission. Furthermore, Article 5.1b regulates the appropriation of data. In most cases, this means that the data collected would not correspond to the original purpose if it were used for training purposes and hence to obtain new information. Such regulations intent to protect personal data, but from an AI point of view, it seems to get harder to get relevant data without destroying its usefulness.

Further challenges for companies are competing investment priorities and the high investment costs in relation to the benefits gained. This raises the question of a cost-benefit ratio. High initial costs arise for the development and implementation of AI applications. It can be assumed that the advantages of AI technology will predominate in the future, but these cannot yet be reliably estimated. Based on the current state of AI research, it is not yet clear when the technology can be used to create added value.

3.2.4 Blockchain

Originally, blockchain was just the computer science term for how to structure and share data. Today blockchains are hailed the “fifth evolution” of computing. Blockchains are a novel approach to the distributed database. The innovation comes from incorporating old technology in new ways. You can think of blockchains as distributed databases that a group of individuals controls and that store and share information. There are many different types of blockchains and blockchain applications. Blockchain is an all-encompassing technology that is integrating across platforms and hardware all over the world.

A blockchain is a data structure that makes it possible to create a digital ledger of data and share it among a network of independent parties. There are many different types of blockchains.

- Public blockchains: Public blockchains, such as Bitcoin, are large distributed networks that are run through a native token. They're open for anyone to participate at any level and have open-source code that their community maintains.
- Permissioned blockchains: Permissioned blockchains, such as Ripple, control roles that individuals can play within the network. They're still large and distributed systems that use a native token. Their core code may or may not be open source.
- Private blockchains: Private blockchains tend to be smaller and do not utilize a token. Their membership is closely controlled. These types of blockchains are favoured by consortiums that have trusted members and trade confidential information.

All three types of blockchains use cryptography to allow each participant on any given network to manage the ledger in a secure way without the need for a central authority to enforce the rules. The removal of central authority from database structure is one of the most important and powerful aspects of blockchains. Blockchains create permanent records and histories of transactions, but nothing is really permanent. The permanence of the record is based on the permanence of the network. In the context of blockchains, this means that a large portion of a blockchain community would all have to agree to change the information and are incentivized not to change the data. When data is recorded in a blockchain, it's extremely difficult to change or remove it. When someone wants to add a record to a blockchain, also called a transaction or an entry, users in the network who have validation control verify the proposed transaction.

Intention of Blockchain

A blockchain is a peer-to-peer system with no central authority managing data flow. One of the key ways to removing central control while maintaining data integrity is to have a large distributed network of independent users. This means that the computers that make up the network are in more than one location. These computers are often referred to as full nodes.

To prevent the network from being corrupted, not only are blockchains decentralized but they often also utilize a cryptocurrency. A cryptocurrency is a digital token that has a market value. Cryptocurrencies are traded on exchanges like stocks. Cryptocurrencies work a little differently for each blockchain. Basically, the software pays the hardware to operate. The software is the blockchain protocol. Well-known blockchain protocols include Bitcoin, Ethereum, Ripple, Hyperledger, and Factom. The hardware consists of the full nodes that are securing the data in the network.

Importance of Blockchain

Blockchains are now recognized as the "fifth evolution" of computing, the missing trust layer for the Internet. This is one of the reasons that so many people have become excited about this topic. Blockchains can create trust in digital data. When information has been written into a blockchain database, it's nearly impossible to remove or change it. This capability has never existed before. When data is permanent and reliable in a digital format, you can transact business online in ways that, in the past, were only possible offline. Everything that has stayed analogue, including property rights and identity, can now be created and maintained online. Slow business and banking processes, such as money wires and fund settlements, can now be done nearly instantaneously. The implications for secure digital records are enormous for the global economy. The first applications created were designed to piggyback on the secure digital value transfer that blockchains enable through the trading of their native tokens. These included things like the movement of money and assets. But the possibilities of the blockchain networks go far beyond the movement of value.

The Structure of Blockchains

Blockchains are composed of three core parts:

- Block: A list of transactions recorded into a ledger over a given period. The size, period, and triggering event for blocks is different for every blockchain. Not all blockchains are recording and securing a record of the movement of their cryptocurrency as their primary objective. But all blockchain do record the movement of their cryptocurrency or token. Think of the transaction as simply being the recording of data. Assigning a value to it (such as happens in a financial transaction) is used to interpret what that data means.
- Chain: A hash that links one block to another, mathematically "chaining" them together. This is one of the most difficult concepts in blockchain to comprehend. It's also the magic that glues blockchains together and allows them to create mathematical trust. The hash in blockchain is created from the data that was in the previous block. The hash is a fingerprint of this data and locks blocks in order and time. Although blockchains are a relatively new innovation, hashing is not. Hashing was invented over 30 years ago. This old innovation is being used because it creates a one-way function that cannot be decrypted. A hashing function creates a mathematical algorithm that maps data of any size to a bit string of a fixed size. A bit string is usually 32 characters long, which then represents the data that was hashed. The Secure Hash Algorithm (SHA) is one of some cryptographic hash functions used in blockchains. SHA-256 is a common algorithm that generates an almost-unique, fixed-size 256-bit (32-byte) hash. For practical purposes, think of a hash as a digital fingerprint of data that is used to lock it in place within the blockchain.
- Network: The network is composed of "full nodes." Think of them as the computer running an algorithm that is securing the network. Each node contains a complete record of all the transactions that were ever recorded in that blockchain. The nodes are located all over the world and can be operated by anyone. It's difficult, expensive, and time-consuming to operate a full node, so people don't do it for free. They're incentivized to operate a node because they want to earn cryptocurrency. The underlying blockchain algorithm rewards them for their service. The reward is usually a token or cryptocurrency, like Bitcoin

The terms Bitcoin and blockchain are often used interchangeably, but they're not the same. Bitcoin has a blockchain. The Bitcoin blockchain is the underlying protocol that enables the secure transfer of Bitcoin. The term Bitcoin is the name of the cryptocurrency that powers the Bitcoin network. The blockchain is a class of software, and Bitcoin is a specific cryptocurrency.

Blockchain Applications

Blockchain applications are built around the idea that network is the arbitrator. This type of system is an unforgiving and blind environment. Computer code becomes law, and rules are executed as they were written and interpreted by the network. Computers don't have the same social biases and behaviours as humans do. The network can't interpret intent (at least not yet). Insurance contracts arbitrated on a blockchain have been heavily investigated as a use case built around this idea. Another interesting thing that blockchains enable is impeccable record keeping. They can be used to create a clear timeline of who did what and when. Many industries and regulatory bodies spend countless hours trying to asses this problem. Blockchain-enabled record keeping will relieve some of the burdens that are created when we try to interpret the past.

The Driving Force of Blockchains

Blockchains are correct without the need for a third party to enforce the rules. They accomplish the enforcement of rules through their consensus algorithm. In the blockchain world, consensus is the process of developing an agreement among a group of commonly mistrusting shareholders. These are the full nodes on the network. The full nodes are validating transactions that are entered into the network to be recorded as part of the ledger.

Each blockchain has its own algorithms for creating agreement within its network on the entries being added. There are many different models for creating consensus because each blockchain is creating different kinds of entries. Some blockchains are trading value, others are storing data, and others are securing systems and contracts.

Bitcoin, for example, is trading the value of its token between members on its network. The tokens have a market value, so the requirements related to performance, scalability, consistency, threat model, and failure model will be higher. Bitcoin operates under the assumption that a malicious attacker may want to corrupt the history of trades in order to steal tokens. Bitcoin prevents this from happening by using a consensus model called "proof of work" that solves the Byzantine general's problem: "How do you know that the information you are looking at has not been changed internally or externally?" Because changing or manipulating data is almost always possible, the reliability of data is a big problem for computer science. Most blockchains operate under the premise that they will be attacked by outside forces or by users of the system. The expected threat and the degree of trust that the network has in the nodes that operate the blockchain will determine the type of consensus algorithm that they use to settle their ledger. For example, Bitcoin and Ethereum expect a very high degree of threat and use a strong consensus algorithm called proof of work. There is no trust in the network. On the other end of the spectrum, blockchains that are used to record financial transactions between known parties can use a lighter and faster consensus. Their need for high-speed transactions is more important. Proof of work is too slow and costly for them to operate because of the comparatively few participants within the network and immediate finality need for each transaction.

Future blockchain applications

Most up-and-running blockchain applications revolve around moving money or other forms of value quickly and cheaply. This includes trading public company stock, paying employees in other countries, and exchanging one currency for another.

Larger and longer-run blockchain projects that are being explored now include government-backed land record systems, identity, and international travel security applications. The possibilities of a blockchain-infused future have excited the imaginations of business people, governments, political groups, and humanitarians across the world. Countries such as the UK, Singapore, and the United Arab Emirates see it as a way to cut cost, create new financial instruments, and keep clean records. They have active investments and initiatives exploring blockchain. Blockchains have laid a foundation where the need for trust has been taken out of the equation. Where before asking for "trust" was a big deal, with blockchains it's small. Also, the infrastructure that enforces the rule if that trust is broken can be lighter. Much of society is built on trust and enforcement of rules. The social and economic implications of blockchain applications can be emotionally and politically polarizing because blockchain will change how we structure value-based and socially based transactions.

Blockchain 2.0 is the next big tier in the development of the blockchain industry. Because the Blockchain 2.0 space is in development, there are many different categories, distinctions, and understandings of it, and standard classifications and definitions are still emerging. Some of the terminology that broadly refers to the Blockchain 2.0 space can include Bitcoin 2.0, Bitcoin 2.0 protocols, smart contracts, smart property, Dapps (decentralized applications), DAOs (decentralized autonomous organizations), and DACs (decentralized autonomous corporations). Whereas Blockchain 1.0 is for the decentralization of money and payments, Blockchain 2.0 is for the decentralization of markets more generally and contemplates the transfer of many other kinds of assets beyond currency using the blockchain, from the creation of a unit of value through every time it is transferred or divided. An approximate technological metaphor for Bitcoin is that it is analogous to the protocol stack of the Web. After the underlying Internet technology and infrastructure was in place, services could be built to run on top of it—Amazon, Netflix, and Airbnb—becoming increasingly sophisticated over time and always adding new ways to take advantage of the underlying technology. Blockchain 1.0 has been likened to the underlying TCP/IP transport layer of the Web, with the opportunity now available to build 2.0 protocols on top of it (as HTTP, SMTP, and FTP were in the Internet model). Blockchain 2.0 protocols either literally use the Bitcoin blockchain or create their own separate blockchains, but are in the same cryptocurrency decentralized technical architecture model of the three-layer stack: blockchain, protocol, and currency. However, it is important to note that these "new Internet plumbing layers" are very much still in development and any metaphor might become quickly outdated. These analogies might be like calling Chrome a "Napster 2.0," or Facebook or AdBlock a "Web Browser 3.0." The key idea is that the decentralized transaction ledger functionality of the blockchain could be used to register, confirm, and transfer all manner of contracts and property. The following table lists some of the different classes and examples of property and contracts that might be transferred with the blockchain. Satoshi Nakamoto started by specifying escrow transactions, bonded contracts, third-party arbitration, and multiparty signature transactions. All financial transactions could be reinvented on the blockchain, including stock, private equity, crowdfunding instruments, bonds, mutual funds, annuities, pensions, and all manner of derivatives (futures, options, swaps, and other derivatives).

Class	Examples
General	Escrow transactions, bonded contracts, third-party arbitration, multiparty signature transactions
Financial transactions	Stock, private equity, crowdfunding, bonds, mutual funds, derivatives, annuities, pensions
Public records	Land and property titles, vehicle registrations, business licenses, marriage certificates, death certi�cates
Identification	Driver's licenses, identity cards, passports, voter registrations
Private records	IOUs, loans, contracts, bets, signatures, wills, trusts, escrows
Attestation	Proof of insurance, proof of ownership, notarized documents
Physical asset keys	Home, hotel rooms, rental cars, automobile access
Intangible assets	Patents, trademarks, copyrights, reservations, domain names

Public records, too, can be migrated to the blockchain: land and property titles, vehicle registrations, business licenses, marriage certificates, and death certificates. Digital identity can be confirmed with the blockchain through securely encoded driver's licenses, identity cards, passports, and voter registrations. Private records such as IOUs, loans, contracts, bets, signatures, wills, trusts, and escrows can be stored. Attestation can be executed via the blockchain for proof of insurance, proof of ownership, and notarized documents. Physical asset keys can be encoded as digital assets on the blockchain for controlled access to homes, hotel rooms, rental cars, and privately owned or shared-access automobiles (e.g., Getaround). Intangible assets (e.g., patents, trademarks, copyrights, reservations, and domain names) can also be protected and transferred via the blockchain. For example, to protect an idea, instead of trademarking it or patenting it, you could encode it to the blockchain and you would have proof of a specific cargo being registered with a specific datetime stamp for future proof.

Challenges

The blockchain industry is still in the early stages of development, and there are many different kinds of potential limitations. The classes of limitations are both internal and external and include those related to technical issues with the underlying technology, ongoing industry thefts and scandals, public perception, government regulation, and the mainstream adoption of technology.

Technical Challenges

A number of technical challenges related to the blockchain, whether a specific one or the model in general, have been identified. The issues are in clear sight of developers, with different answers to the challenges posited, and avid discussion and coding of potential solutions. Insiders have different degrees of confidence as to whether and how these issues can be overcome to evolve into the next phases of blockchain industry development. Some think that the de facto standard will be the Bitcoin blockchain, as it is the incumbent, with the most widely deployed infrastructure and such network effects that it cannot help but be the standardized base. Others are building different new and separate blockchains (like Ethereum) or technology that does not use a blockchain (like Ripple). One central challenge with the underlying Bitcoin technology is scaling up from the current maximum limit of 7 transactions per second (the VISA credit card processing network routinely handles 2,000 transactions per second and can accommodate peak volumes of 10,000 transactions per second), especially if there were to be mainstream adoption of Bitcoin.

Challenges:

- **Throughput:** The Bitcoin network has a potential issue with throughput in that it is processing only one transaction per second (tps), with a theoretical current maximum of 7 tps. Core developers maintain that this limit can be raised when it becomes necessary. One way that Bitcoin could handle higher throughput is if each block were bigger, though right now that leads to other issues with regard to size and blockchain bloat. Comparison metrics in other transaction processing networks are VISA (2,000 tps typical; 10,000 tps peak), Twitter (5,000 tps typical; 15,000 tps peak), and advertising networks (>100,000 tps typical).
- **Latency:** Right now, each Bitcoin transaction block takes 10 minutes to process, meaning that it can take at least 10 minutes for your transaction to be confirmed. For sufficient security, you should wait more time—about an hour—and for larger transfer amounts it needs to be even longer, because it must outweigh the cost of a doublespend attack (in which Bitcoins are double-spent in a separate transaction before the merchant can confirm their reception in what appears to be the intended transaction). Again, as the comparison metric, VISA takes seconds at most.
- **Size and bandwidth:** The blockchain is 25 GB, and grew by 14 GB in the last year. So it already takes a long time to download (e.g., 1 day). If throughput were to increase by a factor of 2,000 to VISA standards, for example, that would be 1.42 PB/year or 3.9 GB/day. At 150,000 tps, the blockchain would grow by 214 PB/year. The Bitcoin community calls the size problem “bloat,” but that assumes that we want a small blockchain; however, to really scale to mainstream use, the blockchain would need to be big, just more efficiently accessed. This motivates centralization, because it takes resources to run the full node, and only about 7,000 servers worldwide do in fact run full Bitcoin nodes, meaning the Bitcoin daemon (the full Bitcoin node running in the background). It is being discussed whether locations running full nodes should be compensated with rewards. Although 25 GB of data is trivial in many areas of the modern “big data” era and data-intensive science with terabytes of data being the standard, this data can be compressed, whereas the blockchain cannot for security and accessibility reasons. However, perhaps this is an opportunity to innovate new kinds of compression algorithms that would make the blockchain (at much larger future scales) still usable, and storable while retaining its integrity and accessibility. One innovation to address blockchain bloat and make the data more accessible is APIs, like those from Chain and other vendors, that facilitate automated calls to the full Bitcoin blockchain. Some of the operations are to obtain address balances and balances changes, and notify user applications when new transactions or blocks are created on the network. Also, there are web-based block explorers (like https://blockchain.info/), middleware applications allowing partial queries of blockchain data, and frontend customer-facing mobile ewallets with greatly streamlined blockchain data.
- **Security:** There are some potential security issues with the Bitcoin blockchain. The most worrisome is the possibility of a 51-per cent attack, in which one mining entity could grab control of the blockchain and double-spend previously transacted coins into his own account. The issue is the centralization tendency in mining where the competition to record new transaction blocks in the blockchain has meant that only a few large mining pools control the majority of the transaction recording. At present, the incentive is for them to be good players, and some (like Ghash.io) have stated that they would not take

over the network in a 51-per cent attack, but the network is insecure. Double-spending might also still be possible in other ways—for example, spoofing users to resend transactions, allowing malicious coders to double-spend coins.

- **Wasted resources:** Mining draws an enormous amount of energy, all of it wasted. The earlier estimate cited was $15 million per day, and other estimates are higher. On one hand, it is the very wastefulness of mining that makes it trustable—that rational agents compete in an otherwise useless proof-of-work effort in hopes of the possibility of reward—but on the other hand, these spent resources have no benefit other than mining.
- **Usability:** The API for working with Bitcoind (the full node of all code) is far less user-friendly than the current standards of other easy-to-use modern APIs, such as widely used REST APIs.
- **Versioning, hard forks, multiple chains:** Some other technical issues have to do with the infrastructure. One issue is the proliferation of blockchains, and that with so many different blockchains in existence, it could be easy to deploy the resources to launch a 51-per cent attack on smaller chains. Another issue is that when chains are split for administrative or versioning purposes, there is no easy way to merge or cross-transact on forked chains.

Business Model Challenges

Another noted challenge, both functional and technical, is related to business models. At first traditional business models might not seem applicable to Bitcoin since the whole point of decentralized peer-to-peer models is that there are no facilitating intermediaries to take a cut/transaction fee (as in one classical business model). However, there are still many worthwhile revenue-generating products and services to provide in the new blockchain economy. Education and mainstream user-friendly tools are obvious low-hanging fruit (for example, being targeted by Coinbase, Circle Internet Financial, and Xapo), as is improving the efficiency of the entire worldwide existing banking and finance infrastructure like Ripple—another almost "no brainer" project when blockchain principles are understood. Looking ahead, reconfiguring all of business and commerce with smart contracts in the Bitcoin 2.0 era could likely be complicated and difficult to implement, with many opportunities for service providers to offer implementation services, customer education, standard-setting, and other value-added facilitations. Some of the many types of business models that have developed with enterprise software and cloud computing might be applicable, too, for the Bitcoin economy—for example, the Red Hat model (fee-based services to implement open-source software), and SaaS, providing Software as a Service, including with customization. One possible job of the future could be smart contract auditor, to confirm that AI smart contracts running on the blockchain are indeed doing as instructed, and determining and measuring how the smart contracts have self-rewritten to maximize the issuing agent's utility.

3.3 Service innovation

The *Smart Guide to Service Innovation* (2012) has been produced by the Clusters and Support for SMEs unit of the European Commission's Enterprise and Industry Directorate-General in consultation with the Smart and Sustainable Growth unit of the Directorate-General for Regional Policy. It defines service innovation and its transformative power as follows:

"**Service innovation** comprises new or significantly improved service concepts and offerings as such, irrespective of whether they are introduced by service companies or manufacturing companies, as well as innovation in the service process, service infrastructure, customer processing, business models, commercialisation (sales, marketing, delivery), service productivity and hybrid forms of innovation serving several user groups in different ways simultaneously.

The **transformative power of service innovation** is understood as the process when services "disrupt traditional channels to market, business processes and models, to enhance significantly customer experience in a way which impacts upon the value chain as a whole". In this way, service innovation is shaping emerging sectors, industries and markets and contributes to structural change and industrial modernisation."

This transformative power of service innovation contributes to fundamentally change some value. An example given in the *Smart Guide to Service Innovation* is the music industry. Since then such changes are ongoing on a constant basis.

In the following, according to the priorities of the CHAIN REACTIONS project, we describe how service innovation have the potential to transform value chains originally building on products.

3.3.1 Product service systems

Definition

The changes brought about by digitization dominate often the entrepreneurial discourse. The focus of this innovation brief is on the question of how companies can successfully shape change for themselves and tap into new business potential. The combination of **digitized products (smart products) in combination with services** opens up new opportunities for companies to secure and improve their market and competitive position in the future.

Product Service Systems (PSS) are hybrid products composed of a material good, the product, as well as one or more services. Information technologies often play a decisive role in these services or are what makes them possible in the first place. Depending on the PSS, there may be different proportions of service and product, the ratio of which may change over time, for example, due to technological developments or changing customer needs.

The driving role of digitization

The speed of digitization is advancing rapidly. At the centre of this digital transformation is the customer with fundamentally changed expectations. Companies must meet the demand for immediate availability of the individualized complete solution and continuous access to digitally networked products and services at all times. In general, public perception of the digital transformation has increased recently. In some countries, the focus is on industry 4.0, in others on the Internet of Things (IoT). While the focus in Industry 4.0 is on the use of digital technologies, especially in production to increase efficiency and optimize costs, the IoT concept is much broader. This not only deals with production but is also considered across industries and divisions and addresses, for example, changes in customer access. This broader understanding ultimately also shows the need for change in single companies. Not only production and in particular value creation are considered, but also completely new business opportunities and models are discussed as shown in figure 7.

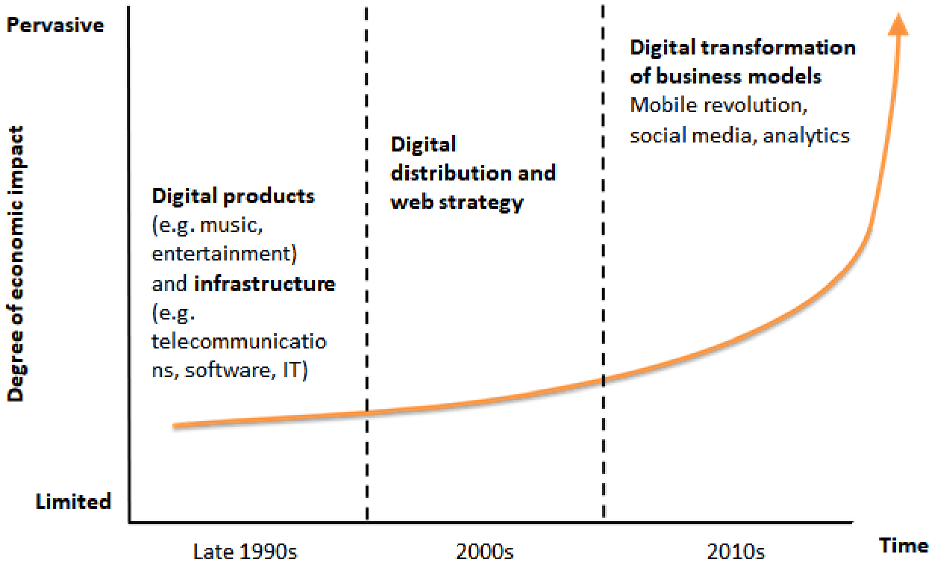

Figure 7: Development of digital transformation
Source: Berman and Bell (2011), p. 2.

This not only changes the demands of customers but also the way classic products have to be offered to customers. In the context of IoT, each physical product will in future receive a digital shell in addition to a digital twin, giving the product itself the opportunity to interact with the outside world. The exponential increase in the number of Internet-enabled objects simultaneously results in immense amounts of data, which, through the application of powerful analytical methods and technologies, enable completely new, digital approaches to solutions for customers. Overall, the digital transformation will in future shift the focus from the classic product to integrated services to a comprehensive PSS. By developing and selling such networked products and services, companies can leverage the opportunities of digital transformation to create unique solutions and continue to successfully differentiate themselves from the competition.

From product to product-service system

One trend is that more and more manufacturing companies are developing from a product to a service or solution provider. In this context, the company must know and analyse the needs and problems of its customers in order to offer a service at any time and in any place. The company no longer acts as a product seller but offers solutions that include comprehensive services for the customer. (cf. Kagermann and Österle 2007; p. 14). PSS are suitable for providing such a complete solution. They consist of a traditional product component, which is supplemented by services during the product life cycle. Ideally, both merge to form an innovative overall solution. In the design of such combinations, the possibilities offered by digitisation are of central importance and in many cases, they are what makes them possible. The basic idea behind this model is to combine intelligent products with physical and digital services to create so-called smart services that satisfy customer needs and thus focus on the customer. These services can then be made available to the customer independent of location and time.

The following figure shows the PSS classification according to Tukker (2004). PSS is divided into three categories, ranging from product-oriented to benefit-oriented to result-oriented. With a product-oriented PSS, the share of the product in the total range is high. In addition, such a solution includes either a product-related service or consulting and training. A relatively balanced relationship between product and service exists with a benefit-oriented PSS. This includes concepts such as the leasing of vehicles or Car-Sharing. If the offer has a high service share, it is a result-oriented PSS. As an example, one payment per service unit can be cited. Likewise, agreeing on a specific result, e.g. a pleasant indoor climate, which can be provided by the manufacturer in any way, as long as the result is correct, is a result-oriented PSS.

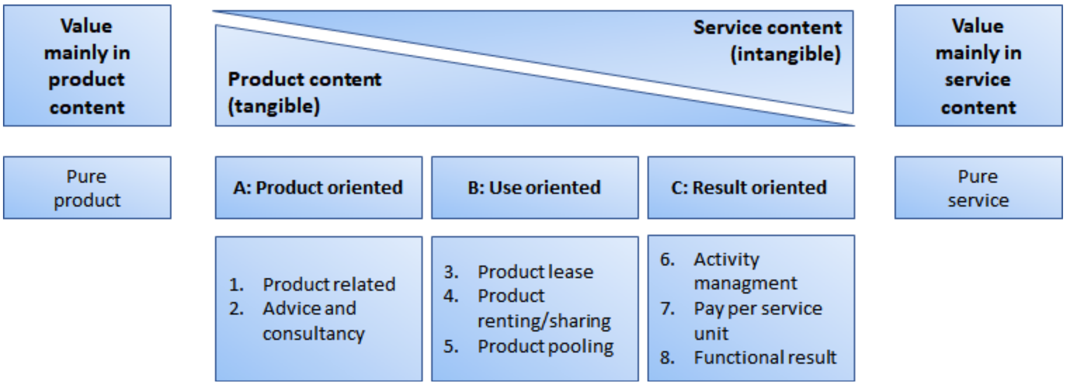

Figure 8: Modified representation of Tukker

An example of a PSS in which the customer pays per service unit received is the "Power by the Hour" concept. The term was coined in the 1960s by the engine manufacturer Bristol Siddeley. He realized that his customers were not interested in the actual product - the engine - but in its performance and offered them a payment per flight hour. Following Rolls Royce's acquisition of this engine manufacturer, the company took up the approach again after several years and developed the "TotalCare" offer. The engine remains the property of Rolls Royce after delivery of the aircraft. The airlines pay a certain amount and receive services such as complete engine overhauls, repairs or the replacement of wearing parts. (cf. Baines et al. 2007, p. 1 ff.).

Traditional business model:

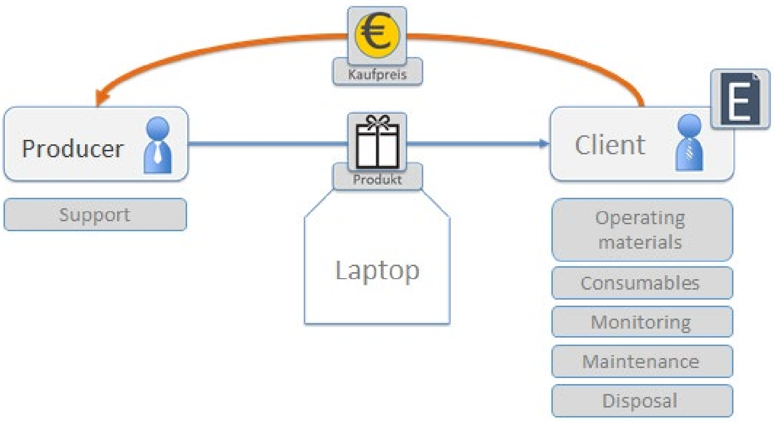

Figure 9: Traditional Business Model for a Laptop
Source: BWCON

The following chart shows the business model described above. The manufacturer (Rolls Royce) leaves the product to the customer (airline) for use and invoices the performance per unit of performance, in this example per flight hour. The ownership of the product remains with the manufacturer, only the owner changes. In this example, the manufacturer ensures the operational readiness of the product, takes care of maintenance, modernization, upgrades and guarantees the customer a certain degree of availability for the product. The customer merely provides feedback on the product and determines the usage requirement prior to procurement.

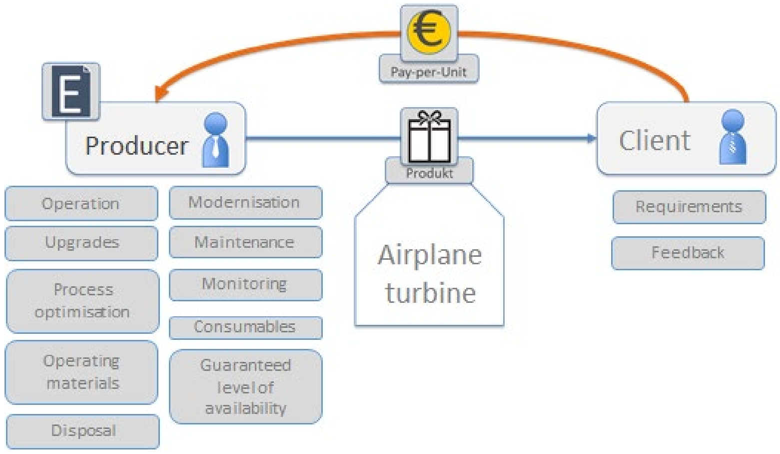

Figure 10: Illustration of the business model "Pay-per-Unit" for aircraft turbines
Source: BWCON

The emergence of new business models and value chains
In order to meet customer needs in the long term and not to miss out on competitors, companies have to react to the far-reaching developments of advancing digitization (cf. figure 11). Most companies are still facing this transformation. The great challenge they face is how to sensibly transfer new and innovative business models to traditional business. This requires companies to analyze existing product and service portfolios, radically re-think and revise them, abandon obsolete products and services at an early stage and develop new business areas and customers.
Another phenomenon of digital transformation is the convergence of previously separate industries. For example, IT is becoming increasingly important in the automotive sector in the direction of autonomous driving or in the field of building services in the direction of smart buildings. This leads to the alignment of products and services, the development of integrated solutions and the **break-up and redesigning of previously known value chains.**
The following picture illustrates the stepwise transformation of business models and value chains for a producer of industrial products according to the level of servitization:

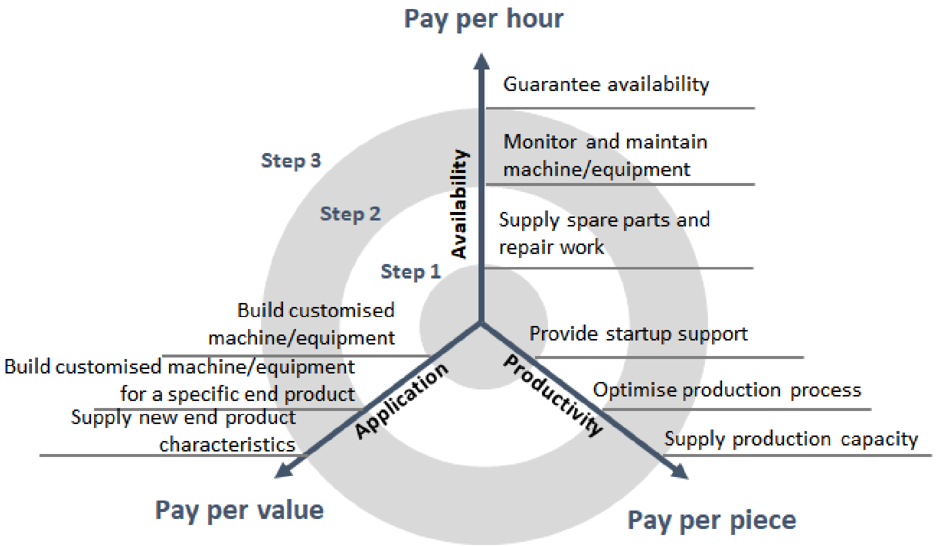

Figure 11: New billing models according to customer outcome
Source: Representation based on Ministry of Finance and Economics Baden-Württemberg and Fraunhofer Institute for Manufacturing Engineering and Automation IPA

The following figures provide two specific examples of new business models and value chains based on PSS:

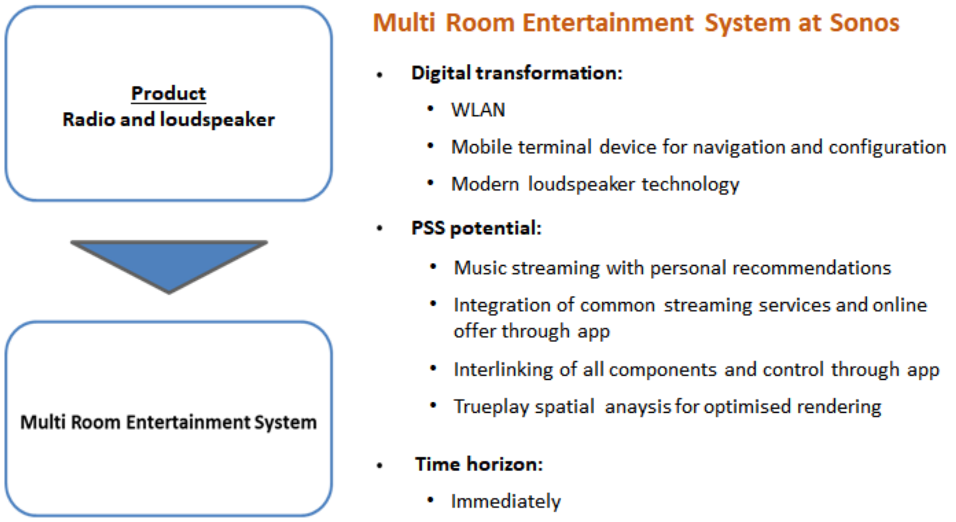

Figure 12: From product to PSS using the example of a loudspeaker manufacturer
Source: BWCON

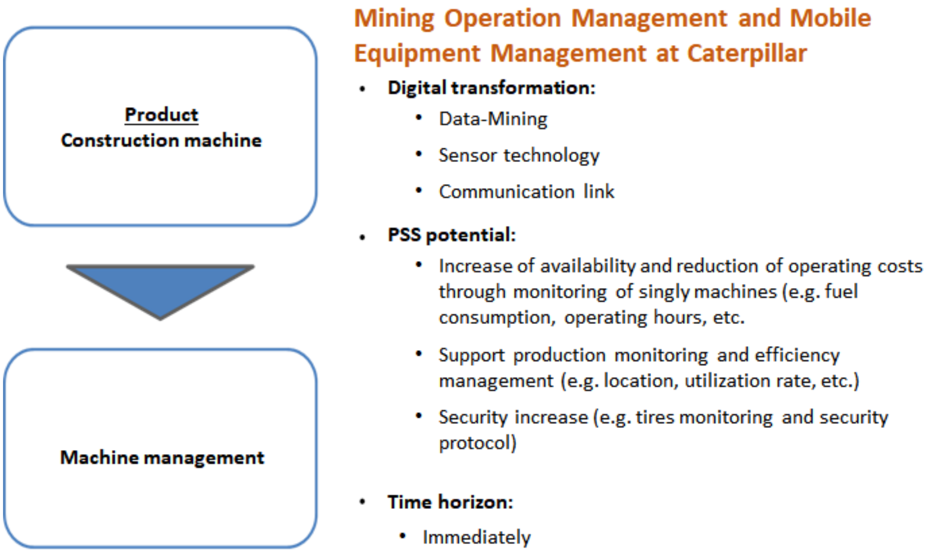

Figure 13: From product to PSS using construction machinery as an example
Source: BWCON

Benefits and challenges of PSS

The trend towards servitization of businesses is growing in importance. But most traditional businesses have difficulties to adopt this new paradigm of the value of services and the importance of a product service offering. The following figure provides an overview of the benefits and challenges of PSS from the point of view of an industrial company:

Benefits	Challenges
Sustainability Increase of market barriers to competition and product differentiation Intensified customer relationship and loyalty Financial benefits Innovation through attachment of additional value to traditional products Growth strategy in mature industry Better monitoring of products and customer data use	No existing market yet Close cooperation required Sustainability trade-off Sustainability is seen as slowing down time to market Change from short-term to long-term profit Extended involvement with a product beyond point-of-sale A shift in corporate culture and market engagement required Ownerless consumption Lack of knowledge about life cycle costs of product ownership High labour costs Integration problems Lack of care (customer side) Opposition of the personnel (provider/customer)

Figure 14: Benefits and challenges of PSS
Source: Richter, A.; Schoblik, J.; Kölmel, B.; Bulander, R. (2018)

3.4 Resource efficiency

Resource efficiency is a very broad topic, which cannot be treated in an exhaustive manner in the framework of CHAIN REACTIONS. Addressing the topic with the perspective of value chain innovation, we decided to focus on the transformative power of circular economy.

3.4.1 Circular economy

The concept of the circular economy has been studied for many years. However, it only became a mainstream concept in the European Union with the adoption of the EU Circular Economy Package in 2015. Before that time the notion of 'greening the economy', 'greening different economic sectors' was much more common. One of the proofs for that is that circular economy was missing in all documents associated with the Programming Period 2014-2020 of the European Structural and Cohesion Funds (ESIF).

The ambition of the **Circular Economy Package** was to "help European businesses and consumers to make the transition to a stronger and more circular economy where resources are used in a more sustainable way". The package includes new and revised legislation with focus on waste prevention and management, with clear timeframe for implementation and financing. The actions aim to contribute to "closing the loop" of product lifecycles through greater recycling and re-use. The Circular Economy Package[1] refers to five priority areas to be addressed in a targeted way: plastics, food waste, critical raw materials, construction and demolition, as well as biomass and bio-based products.

Since the adoption of the Circular Economy Package circular economy has gained enormous traction in EU discourse but also in national, regional and urban policymaking. Circular economy strategies and action plans are mushrooming on all governance levels. Businesses are also exceedingly considering 'going circular'.

Value optimization principle

According to this principle, companies have to keep all products, components and materials at their highest value and utility at all times, such as recirculation to be done with minimal energy consumption. Recirculation, in any form, is not the goal of circular economy. Recirculation is only a mean to create new value in the system from elements that are considered loss or waste. Value added is in cost-saving, in lower environmental impact, in higher business resilience, in new revenue streams and in better relationships with customers. Optimization is reached when the normalized impact (value weight) of each business activity in the value chain and each component from the product is of the same magnitude with their normalized costs. Thus, according to circular economy, the goal is not to optimize profit but rather the value.

Optimization of value is about finding an alternative (a solution) with the highest possible performance under given constraints (e.g. human, financial, natural, technological), by maximizing useful and desirable factors while minimizing harmful factors. Materials that are seen as waste in production or post- consumption can become valuable resource inputs in new products and applications. In this case, optimization is about minimizing the waste generation and maximizing the reuse of the resulted waste. Moreover, value can be increased by using products langer (prolonging their life-time) or recirculating them in multiple cycles (e.g. second hand refurbished industrial robots) with minimal modifications.

[1] http://ec.europa.eu/environment/circular-economy/index_en.htm

This approach requires cooperation across the value chain to enable changes in the design of products and the development of reverse logistics and reconditioning processes. New types of business models such as leasing or servitization can enable all stakeholders (producers, intermediaries, end-users) to capture a share of value.

In addition, a new value stream that can be optimized, specifically the spare capacity. There are spaces and equipments that are heavily underutilized by a single organization, indicating low returns on investment. By smart partnerships, such capital can be better exploited, sometimes with a neutral management of a third party. Sharing of facilities can be considered in all dimensions: business-to-business (B2B). business-to-customer (B2C). and customer-to-customer (C2C).

Value optimization principle is also about many interlinked outcomes. For example. the output of reducing C02 emissions generates. as a first layer outcome. improvement of air quality. A better air quality leads to an improved natural environment and better health of population. This reduces costs with health systems and environmental interventions: thus. public money can be redirected to other areas. such as education and social security. In fact. reduction of C02 emissions is an important aspect that encourages adoption of circular economy at large scale.

In CHAIN REACTIONS we consider this broad approach of circular economy and its opportunities, building on the model developed by Peter Lacy and Jakob Rutqvist[2], and taking into account some of the most recent approaches to considering circular economy as an opportunity for creating economic and social value:

Types of waste to be eliminated	
	• Wasted resources are materials and energy that cannot be continually regenerated, but instead, are consumed and forever gone when used. • Products with wasted lifecycles have artificially short working lives or are disposed of even if there is still demand for them from other users. • Products with wasted capability sit idle unnecessarily; for instance, cars typically sit unused for 90 per cent of their lives. • Wasted embedded values are components, materials, and energy that are not recovered from disposed of products and put back into use.
Business models	
	• Circular Supply-chain • Recovery and Recycling • Product Life-extension • Sharing Platform • Product as a Service
Technologies	
	• Engineering technologies: modular design, advanced recycling technology, life and material sciences technology… • Digital technologies: big data, machine to machine, mobile technologies… • Hybrid Technologies: Trace and return systems, 3D printing…
Circular capabilities:	

[2] Source: Waste to Wealth. The Circular Economy Advantage, Peter Lacy and Jakob Rutqvist 2015

	Technologies alone will not give companies what they need to excel in their chosen circular business models. They must be paired with a range of new capabilities across the organizations that are vital to developing and institutionalizing new ways of working. • Circular networks/ecosystems • Designing for Many Lifecycles and Users • Circular Supplies • Continuous Customer Engagement • Opportunity-Driven Take-Back

Figure 15: Circular economy framework for businesses
Source: Peter Lacy and Jakob Rutqvist

The following picture illustrates along traditional value chains where the five circular business models named in the table above offer opportunities for value chain innovation.

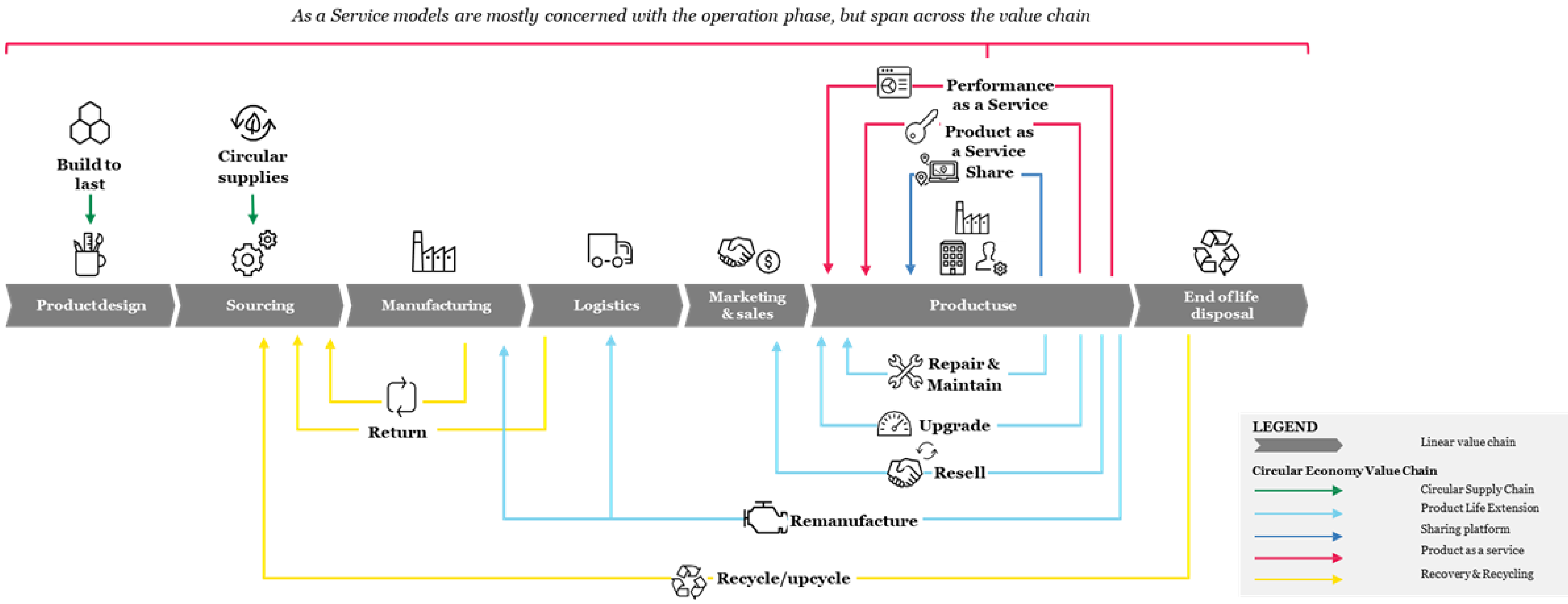

Figure 16: Circular value chains
Source: Accenture

In the following, we provide some further insight into the five circular business models.

Circular Supply-chain

When a company needs resources that are scarce or environmentally destructive, it can either pay more or find alternative resources. The Circular Supply- Chain introduces fully renewable, recyclable, or biodegradable materials that can be used in consecutive lifecycles to reduce costs and increase predictability and control.

Industrial example

Such thinking is the core of CRAiLAR Technologies' business. The company produces renewable and environmentally friendly biomass resources using flax, hemp and other bast fibres that let apparel companies produce a garment that is as soft and durable as cotton, without the environmental risks associated with cotton's cultivation. Similarly, AkzoNobel, a leading global paints and coatings company and a major producer of speciality chemicals, has teamed up with cleantech company Photanol to develop a process for harnessing the power of the sun to make chemicals. The technology mimics the way plants use photosynthesis to produce "green" chemical building blocks that will eventually replace fossil-based linear raw materials.

Key Challenges to Scaling

- Significant costs and lead time

  Shifting to the Circular Supply-Chain model typically involves long research and development cycles and major capital to get to production at scale.

- Collaboration

  Collaborating with R&D institutions, universities, and other sources of innovation is also essential. The Circular Supply-Chain model involves being an active partner in a supportive circular network in which members help each other maximize their resources' profitability. This requires a specific mindset, as information is often shared at levels that many companies initially find uncomfortable.

- Investments

  Companies implementing the Circular Supply-Chain model will likely need to make significant investments to change their linear production systems and supply chains. Given the potentially high cost of switching, it is a major advantage if circular supplies can be used in a company's existing infrastructure as much as possible.

  In cases where renewable material is being introduced as a replacement for non-renewable material (e.g., shifting to bioplastics or plant-based packing material), material suppliers should consider existing production and distribution infrastructure and, as much as possible, avoid asking customers to invest in expensive new equipment or processes to use the new material.

  It's sometimes efficient to generate circular supplies via decentralized, or "distributed," production rather than through the centralized, super-scale production typically used to process linear resources. This is because the input for and output from circular supplies can be more regionally dispersed; consider, for example, biomass resources (forests, land) versus mines, or solar or wind power (solar panels of roofs, windmills) versus oil wells.

- Limited supply of responsibly sourced biomass

Recovery and Recycling

The Recovery & Recycling model creates production and consumption systems in which everything that used to be considered waste is revived for other uses. Companies either recover end-of-life products to recapture and reuse valuable material, energy and components or they reclaim waste and by-products from a production process.

Industrial example

Two leaders in the use of this model are Procter & Gamble and General Motors. P&G has 45 facilities now operating on a zero-waste basis – meaning all of the manufacturing waste at those sites is recycled, repurposed or converted into energy – while General Motors currently recycles 90 per cent of its worldwide manufacturing waste and has landfill-free facilities (and generates $1 billion in revenue annually from by-product recycling and reuse).

Key Challenges to Scaling

- Maintaining the quality of resources and keeping ownership rights to high-quality resources.

  Companies need to find ways to control the return flow (e.g., launching product take-back schemes) and to maximize the quality of recovered resources (e.g., investing in in-house sorting, reprocessing, and refining technology). Simply buying recovered material of the same quality specifications as new or selling untreated waste won't yield much circular advantage.

  Taking back products to recover resources is much easier in B2B markets, where companies can reference their contracts and deal information to track how much in product volume went to each customer and where. That makes it feasible to organize the take-back and closely monitor reverse logistics. In Business-to-Consumer (B2C) markets, customers are much more difficult to corral.

  It's critical for companies to handle returning and reprocessing efficiently to preserve the cost advantage. If these processes cost more than what a company would spend to extract virgin resources, then the model becomes unusable.

- Waste management challenges

  To fully recover materials from products, waste handlers must become partners in their customers' businesses. They can do this by helping to design products for ease of disassembly and material extraction, or by identifying new methods for turning hard-to-recycle waste into high-quality raw material. They may even serve as brokers, buying energy and raw materials from companies with excess and reselling it to others.

Product Life-extension

Consumers discard products they no longer value – because the products are broken, out of fashion or no longer needed. But many of these products still hold considerable value, and the Product Life-Extension model seeks to recapture it. By maintaining and improving products through repairs, upgrades, remanufacturing or remarketing, companies can keep them economically useful for as long as possible. This means shifting from merely selling things to actively keeping them alive and relevant. It also means moving customers from transactions to relationships, tailoring upgrades and alterations to specific needs.

Industrial example

Dell – a global leader in computer technology – is using this business model to serve a wider set of customer segments, increase revenues and keep technology out of the landfill. Through its Dell Outlet and Dell Refurbished businesses, the company takes back and resells unused products (for example, returns), certified refurbished products (for example, ones coming back from leasing) and "scratch and dent" goods with cosmetic blemishes. Construction equipment manufacturer Caterpillar saves itself and its customers considerable money and up to 90 per cent energy use by remanufacturing millions of components each year in a profitable operation employing more than 4,000 people and growing.

Key challenges to scaling

- Design a product for a long lifecycle that includes upgrades, add-ons and, ultimately, take-back.

  Given the focus on continual customer interaction, manufacturers will need to focus as much on customers and users as on products and engineering. That means maintaining and growing customer relationships over time through multiple interaction points, possibly even expanding into retail or services. And they will have to be proficient in conducting predictive maintenance and identifying efficient sales approaches, offering a replacement part to a customer just before something breaks down. Finally, manufacturers will have to knit together an effective network of local field service partners as well as potentially outsourced activities in the return chain.

- Figuring out which situations and products are best suited for product-life extension

  The model is most likely to pay off in B2B industries, where high-value equipment is required – a trait shared by sectors from construction to high-tech. Products with the most potential for product life extension typically have lifecycles exceeding five years. High-quality goods are relatively easier to integrate into this business model than low-end ones.

  Not every product is a good fit for the Product Life-Extension business model. Some can't be designed to accommodate easy disassembly. Others have extensive material requirements. Product life extension is not especially relevant to companies that want to cater to "take-make-waste" markets, where high volumes of cheap, low-quality products are sold. Customers in those markets aren't generally concerned about the total cost of ownership of what they buy as much as they are about having access to a ready quantity of replacement products.

  Companies whose products are susceptible to rapidly shifting consumer tastes – that cannot be addressed through a simple add-on or upgrade – aren't good candidates for this business model, either. That means trendy clothing is probably not a good fit (puns aside), but more standard apparel with relatively timeless appeal, like t-shirts or classic suits, could be.

Sharing Platform

In developed economies, up to 80 per cent of the things stored in a typical home are used only once a month.14 The Sharing Platform model – increasingly enabled by new forms of digital technology – forges new relationships and business opportunities for consumers, companies and micro-entrepreneurs, who rent, share, swap or lend their idle goods. Fewer resources go into making products that are infrequently used, and consumers have a new way to both make and save money.

Industrial example

A number of companies built on this business model have gained millions of members, considerable media attention and in some cases $40 billion-plus valuation. These include Airbnb (home sharing), Uber and Lyft (ride-sharing), Deliv (shipping services sharing) and Peerby (consumer goods sharing). By making it easy for people and companies to use idle products, these businesses are squeezing much more value from the resources used to make them.

Key Challenges to Scaling

Critics of the sharing economy (not specifically the circular economy) have expressed major concerns about its impact on the larger economy and its long-term viability.

- One criticism is that sharing economy companies operate like typical profit-seeking companies when they should be motivated by community-building capitalism and sharing among citizens. The Sharing Platform business model is about finding new ways to access underutilized resources. It offers innovative ways to co-own and co-access products and assets – that's its revolutionary function, regardless of how this new trade is financed. There is no inherent requirement that it should be more or less altruistic than other economic activities. It could be driven by a pure profit motive at the company facilitating the transactions (and the people "sharing") or not. The word "share" does necessarily connote community-based and free exchanges. It can also mean simply providing excess capacity in exchange for some kind of remuneration.
- A second criticism is that the sharing economy is creating a new category of working poor with insecure income and few benefits. This is a valid critique that needs attention. Policymakers and businesses must ensure regulations and business ethics steer clear of exploitation and poor working conditions. Sharing platforms do not create jobs in the traditional employer-sponsored sense. In fact, one could argue that by facilitating greater product utilization, sharing platforms may reduce the need for manufacturing jobs.32 Furthermore, while sharing platforms help micro-entrepreneurs generate income, they don't provide a guaranteed revenue stream or access to benefits that traditional employers provide. But sharing platforms do open up opportunities for people to generate income from underutilized resources. If someone chooses to work through a sharing platform, he or she must feel the payment is worth the effort.
- Finally, some argue that the sharing economy is not competing fairly and is threatening companies and jobs in the formal economy by avoiding taxes and regulation. This is another valid critique. A hotel tax applies when a guest rents a room, but the same tax is not always paid by hosts offering room sharing. Taxes paid by taxi companies are not always paid by those using car sharing. Hotels also must comply with safety standards from which private homes are exempt. As sharing platforms like Uber grow, trade groups, unions, and industry associations are protesting en masse to protect their position. These objections often look more like defensive moves against competition than calls for good regulation. But in some cases, the sharing platforms should compete on a level playing field and ensure compliance with regulation and tax codes.

Product as a Service

What if manufacturers and retailers bore the "total cost of ownership"? Many would immediately adjust their focus to longevity, reliability and reusability. When consumers lease or pay for products by use through the Product as a Service model, the business model fundamentally shifts – in a good way. Performance trumps volume, durability tops disposability, and companies have an opportunity to build new relationships with consumers.

Industrial example

Michelin solutions (www.michelin-solutions.com), a new business launched by Michelin, the tire manufacturer, has embraced this model by enabling fleet customers to lease instead of purchase tires outright – effectively selling "tires as a service," with customers paying per km driven. Similarly, consumer electronics giant Philips is selling "lighting as a service," charging customers not for the LED diodes themselves but for their usage, in a push to improve the customer value proposition.

Key Challenges to Scaling

- Need for local customer interaction

  As long as it's not fully digitalized, a company will need to be able to physically work with customers and products when and where customers need help. To handle geographically dispersed services, a company will need to either team up with local partners or create and deploy mobile service teams that can respond to customer requests.

- Asset management

  The bigger the PaaS operations, the more important it is for a company to keep up-to-date information on the position and status of all assets. When it comes to getting products back, a company might be able to leverage existing return channels. But it also needs to be able to ensure that products are in good working condition and repair them if they're not.

  For take-back and repair, it's not economically viable to have services in every location. Some amount of centralization has to happen. Companies need to strike a balance between establishing adequate local footprints and supplementing them with regional or global capabilities.

- Cost comparison with ownership models

  Companies must be able to clearly articulate the total cost of ownership in a PaaS versus an ownership model. They also need to be able to help customers optimize the performance of their products instead of convincing them to buy new products.

  Because a PaaS model generates value by enhancing products' performance in the market on an ongoing basis as opposed to selling them at a point in time, providers must be able to effectively manage complex and sometimes long-term contracts. They must also be able to define and measure the value of those contracts to ensure the arrangements are profitable. That's especially true when offering a PaaS model requiring no upfront payment and one in which the customer will pay for the product over time.

- Product abuse

  As is the case with the Sharing Platform model, PaaS companies will find that people often aren't as careful with a product they don't own, causing it to wear out more quickly. Landlords who rent out their properties know this all too well. Companies should establish mechanisms that hold a user liable, such as deposits, fines, mandatory insurance, bonuses, and points/reputation. In the long term, educating users on how to properly use the products will help minimize product abuse and promote a longer product life.

4 PORTER'S FIVE FORCES MODEL

Porter's Five Forces analysis is a framework that helps analyzing the level of competition within a certain industry. It is especially useful when starting a new business or when entering a new industry sector. According to this framework, competitiveness does not only come from competitors. Rather, the state of competition in an industry depends on five basic forces: threat of new entrants, bargaining power of suppliers, bargaining power of buyers, threat of substitute products or services, and existing industry rivalry. The collective strength of these forces determines the profit potential of an industry and thus its attractiveness. If the five forces are intense, almost no company in the industry earns attractive returns on investments. If the forces are mild, however, there is room for higher returns. Each force will be elaborated on below with the aid of examples from the airline industry to illustrate the usage.

Figure 17: Porter's five forces model
Source: Porter

4.1 Threat of new entrants

New entrants in an industry bring new capacity and the desire to gain market share. The seriousness of the threat depends on the barriers to enter a certain industry. The higher these barriers to entry, the smaller the threat for existing players. Examples of barriers to entry are the need for economies of scale, high customer loyalty for existing brands, large capital requirements (e.g. large investments in marketing or R&D), the need for cumulative experience, government policies, and limited access to distribution channels. More barriers can be found in the table below.

Example

The threat of new entrants in the airline industry can be considered as low to medium. It takes quite some upfront investments to start an airline company (e.g. purchasing aircrafts). Moreover, new entrants need licenses, insurances, distribution channels and other qualifications that are not easy to obtain when you are new to the industry (e.g. access to flight routes). Furthermore, it can be expected that existing players have built up a large base of experience over the years to cut costs and increase service levels. A new entrant is likely to not have this kind of expertise, therefore creating a competitive disadvantage right from the start. However, due to the liberalization of market access and the availability of leasing options and external finance from banks, investors, and aircraft manufacturers, new doors are opening for potential entrants. Even though it doesn't sound very attractive for companies to enter the airline industry, it is NOT impossible. Many low-cost carriers like Southwest Airlines, RyanAir and EasyJet have successfully entered the industry over the years by introducing innovative cost-cutting business models, thereby shaking up original players like American Airlines, Delta Air Lines and KLM.

4.2 Bargaining power of suppliers

This force analyzes how much power and control a company's supplier (also known as the market of inputs) has over the potential to raise its prices or to reduce the quality of purchased goods or services, which in turn would lower an industry's profitability potential. The concentration of suppliers and the availability of substitute suppliers are important factors in determining supplier power. The fewer there are, the more power they have. Businesses are in a better position when there is a multitude of suppliers. Sources of supplier power also include the switching costs of companies in the industry, the presence of available substitutes, the strength of their distribution channels and the uniqueness or level of differentiation in the product or service the supplier is delivering.

Example
The bargaining power of suppliers in the airline industry can be considered very high. When looking at the major inputs that airline companies need, we see that they are especially dependent on fuel and aircrafts. These inputs, however, are very much affected by the external environment over which the airline companies themselves have little control. The price of aviation fuel is subject to the fluctuations in the global market for oil, which can change wildly because of geopolitical and other factors. In terms of aircrafts for example, only two major suppliers exist, Boeing and Airbus. Boeing and Airbus, therefore, have substantial bargaining power on the prices they charge.

4.3 Bargaining power of buyers

The bargaining power of buyers is also described as the market of outputs. This force analyzes to what extent the customers are able to put the company under pressure, which also affects the customer's sensitivity to price changes. The customers have a lot of power when there aren't many of them and when the customers have many alternatives to buy from. Moreover, it should be easy for them to switch from one company to another. Buying power is low however when customers purchase products in small amounts, act independently and when the seller's product is very different from any of its competitors. The internet has allowed customers to become more informed and therefore more empowered. Customers can easily compare prices online, get information about a wide variety of products and get access to offers from other companies instantly. Companies can take measures to reduce buyer power by for example implementing loyalty programs or by differentiating their products and services.

Example
Bargaining power of buyers in the airline industry is high. Customers are able to check the prices of different airline companies fast through the many online price comparisons websites such as Skyscanner and Expedia. In

addition, there aren't any switching costs involved in the process. Customers nowadays are likely to fly with different carriers to and from their destination if that would lower the costs. Brand loyalty, therefore, doesn't seem to be that high. Some airline companies are trying to change this with frequent flyer programs aimed at rewarding customers that come back to them from time to time.

4.4 Threat of substitute products

The existence of products outside of the realm of the common product boundaries increases the propensity of customers to switch to alternatives. In order to discover these alternatives, one should look beyond similar products that are branded differently by competitors. Instead, every product that serves a similar need for customers should be taken into account. Energy drink like Redbull, for instance, is usually not considered a competitor of coffee brands such as Nespresso or Starbucks. However, since both coffee and energy drink fulfil a similar need (i.e. staying awake/getting energy), customers might be willing to switch from one to another if they feel that prices increase too much in either coffee or energy drinks. This will ultimately affect an industry's profitability and should therefore also be taken into account when evaluating the industry's attractiveness.

Example
In terms of the airline industry, it can be said that the general need of its customers is travelling. It may be clear that there are many alternatives for traveling besides going by airplane. Depending on the urgency and distance, customers could take the train or go by car. Especially in Asia, more and more people make use of highspeed trains such as Bullet Trains and Maglev Trains. Furthermore, the airline industry might get some serious future competition from Elon Musk's Hyperloop concept in which passengers will be travelling in capsules through a vacuum tube reaching speed limits of 1200 km/h. Taken this altogether, the threat of substitutes in the airline industry can be considered at least medium to high.

4.5 Rivalry among existing competitors

This last force of the Porter's Five Forces examines how intense the current competition is in the marketplace, which is determined by the number of existing competitors and what each competitor is capable of doing. Rivalry is high when there are a lot of competitors that are roughly equal in size and power, when the industry is growing slowly and when consumers can easily switch to a competitor offering for little cost. A good indicator of competitive rivalry is the concentration ratio of an industry. The lower this ration, the more intense rivalry will probably be. When rivalry is high, competitors are likely to actively engage in advertising and price wars, which can hurt a business's bottom line. In addition, rivalry will be more intense when barriers to exit are high, forcing companies to remain in the industry even though profit margins are declining. These barriers to exit can, for example, be long-term loan agreements and high fixed costs.

Example
When looking at the airline industry in the United States, we see that the industry is extremely competitive because of a number of reasons which include the entry of low-cost carriers, the tight regulation of the industry wherein safety become paramount leading to high fixed costs and high barriers to exit, and the fact that the industry is very stagnant in terms of growth at the moment. The switching costs for customers are also very low and many players in the industry are similar in size leading to extra fierce competition between those firms. Taken altogether, it can be said that rivalry among existing competitors in the airline industry is high.

By looking at each competitive force individually, you are able to roughly map out the focal industry and its attractiveness. Note that industries might differ in terms of attractiveness depending on the country you are looking at. Government policies are for example likely to be different in each country and also the number of suppliers and buyers might vary from nation to nation.

4.6 Full list of Porter's Five Forces factors

Threat of new entrants	Economies of scale Product differentiation Brand identity/loyalty Access to distribution channels Capital requirements Access to latest technology	Access to necessary inputs Absolute cost advantages Experience and learning effects Government policies Switching costs Expected retaliation from existing players
Bargaining power of suppliers	Number of suppliers Size of suppliers Supplier concentration Availability of substitutes for the supplier's products Uniqueness of supplier's products or services (differentiation) Switching cost for supplier's products Supplier's threat of forward integration	Industry threat of backward integration Supplier's contribution to quality or service of the industry products Importance of volume to supplier Total industry cost contributed by suppliers Importance of the industry to supplier's profit
Bargaining power of buyers	Buyer volume (number of customers) Size of each buyer's order Buyer concentration Buyer's ability to substitute Buyer's switching costs	Buyer's information availability Buyer's threat of backward integration Industry threat of forward integration Price sensitivity
Threat of substitute products or services	Number of substitute products available Buyer's propensity to substitute Relative price performance of substitutes	Perceived level of product differentiation Switching costs Substitute producer's profitability & aggressiveness
Rivalry among existing competitors	Number of competitors Diversity of competitors Industry concentration and balance Industry growth Industry life cycle Quality differences	Product differentiation Brand identity/loyalty Switching costs Intermittent overcapacity Informational complexity Barriers to exit

Sources:

- Porter, M.E. (1979). How Competitive Forces Shape Strategy. Harvard Business Review
- Porter, M.E. (2008). The Five Competitive Forces That Shape Strategy. Harvard Business Review

5 VALUE CHAIN INNOVATION MODEL

The value chain innovation model to be used in the further implementation of the CHAIN REACTIONS project consists in a combination of the previously described drivers for innovation and transformation in existing value chains. In practice, value chain transformations are often the result of the **convergence** of different drivers, and of course also of entrepreneurial activities!

The following picture illustrates the CHAIN REACTIONS value chain innovation model:

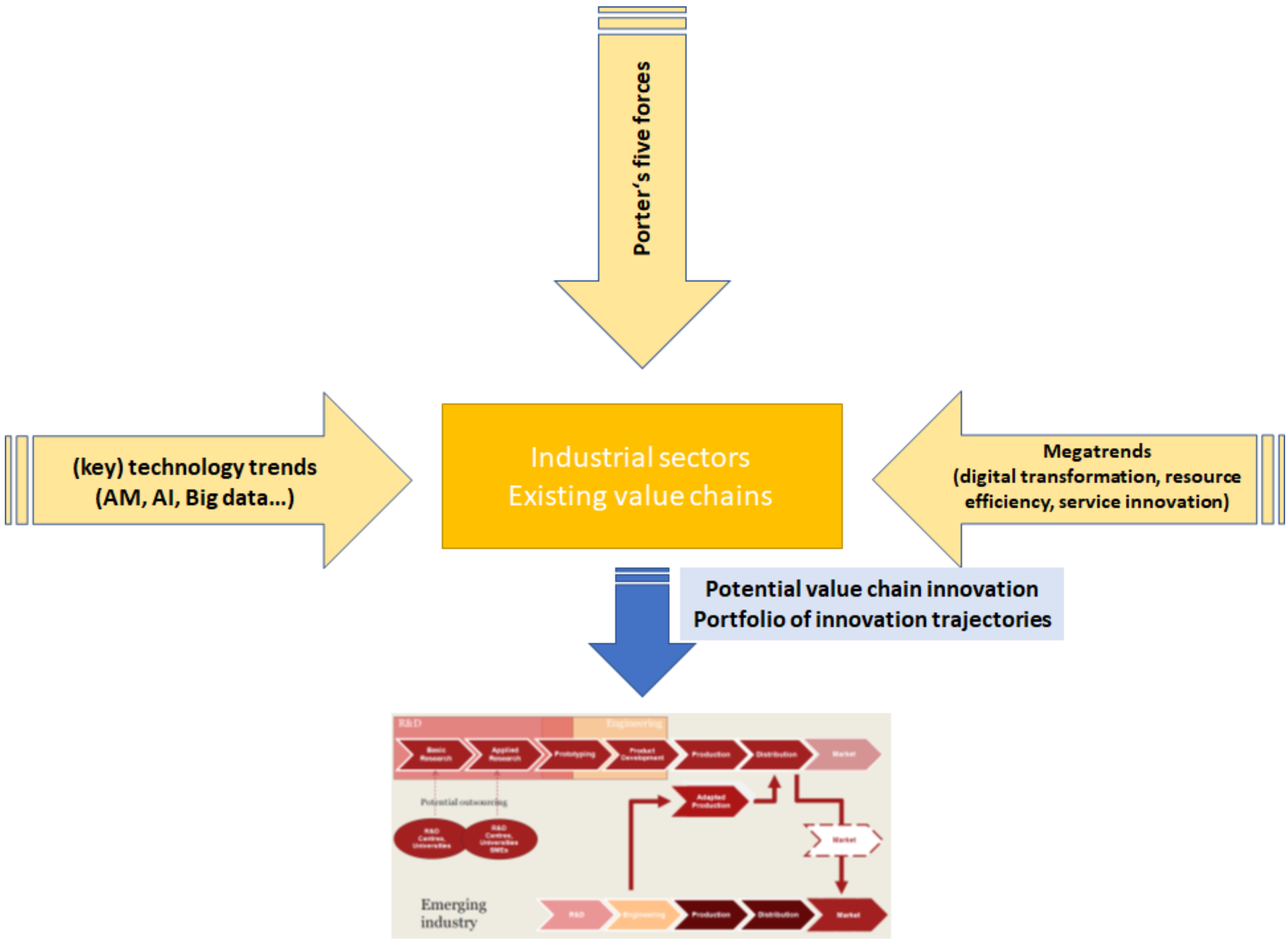

Figure 18: Porter's five forces model
Source: Porter

The expected outcome of the application of this model is a **portfolio of potential innovation trajectories** in the selected industrial areas - in accordance with the S3 priorities of the partners' regions – for the CHAIN REACTIONS project: advanced manufacturing, ICT and electronics, energy and environment, health and bioeconomy.