Industry 4.0 Introduction

Industry 4.0 Market Research

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Industry 4.0 Market Research *(division of* ***HSRC****) is an international market and technology research publisher specializing in premium Industry 4.0 and Quantum Technologies market. With an extensive portfolio of Industry 4.0 and Quantum Computing reports,* ***Industry 4.0 Market Research*** *has been recognized as the global leader in the Forth Industrial Revolution market research.*

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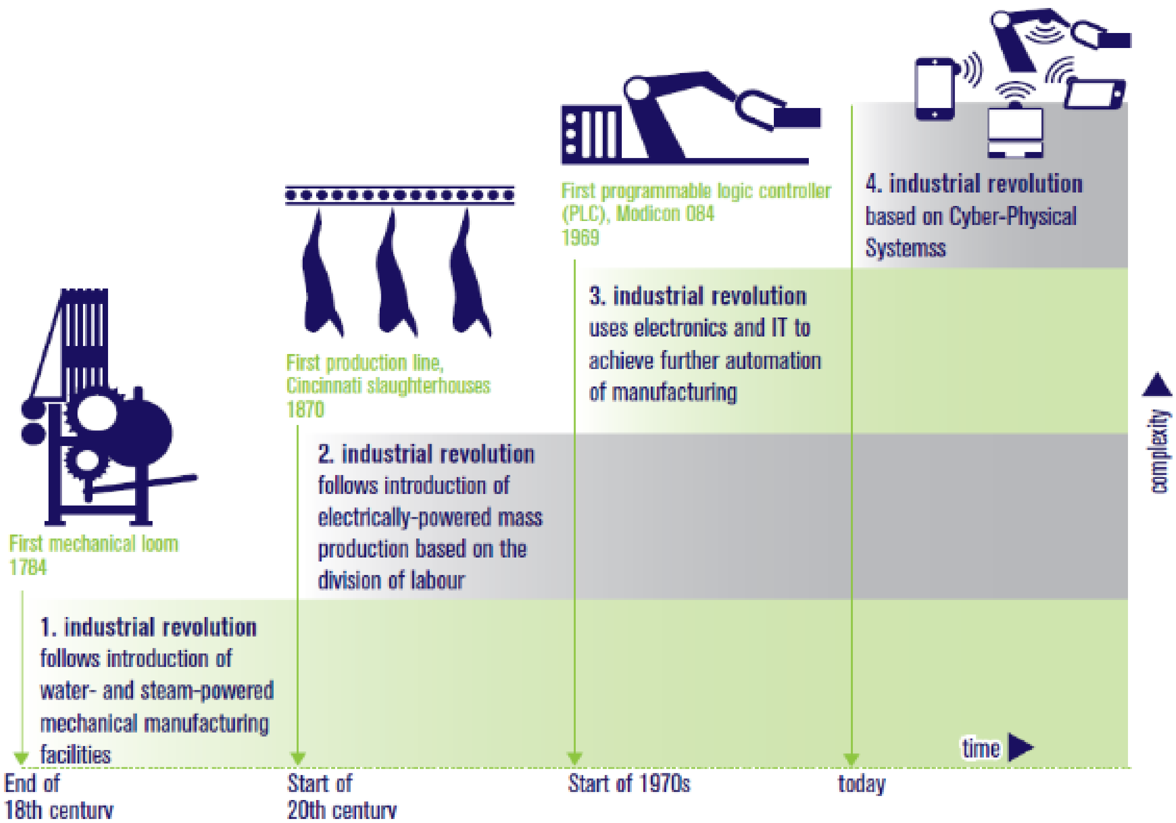
1 Industry 4.0 Definition

We are at the beginning of the fourth industrial revolution. The most commonly used terms to describe this development, which is rapidly changing the industrial landscape are Industry 4.0, smart manufacturing, the Internet of Things, cyber-physical systems and digital transformation. The Industry 4.0 concept encompasses the digitalization of the horizontal and vertical value chain, innovation in products and services and the creation of new business models. The key business drivers of this transformation include improving customer experience, increasing speed to market and reducing costs.

Figure 1 - The 4th Industrial Revolution



Source: DFKI

To reap the benefits of this revolution, directors and CEOs of industrial enterprises must place Industry 4.0 at the top of their agenda. However, implementing an Industry 4.0 production environment will be an incremental journey over several years that will include modernizing legacy systems. Once undertaken, the possibilities of applying Industry 4.0 concepts and technology are unlimited.

Industry 4.0 must be understood as a future concept for society as a whole, "Society 4.0" so to speak, in which people, perhaps more than ever, are at the forefront. The profiles of certain job descriptions are certain to change or be completely reformed. The increasing diversity of products with short delivery cycles and simultaneously decreasing numbers of specialist personnel available can present an additional challenge for many companies. It is also important not to forget that the urban production of the future is moving closer to where people live. This will require different logistics concepts for production supply and disposal.

People are not being disregarded, quite the opposite in fact. Their requirements must be taken into account to a much greater extent in corporate planning in the future. The Industry 4.0 ecosystem consists of not only smart factories but also intelligent products with a memory that controls production. It is a question of allowing people to perform high quality and creative work and giving them the opportunity to achieve a work/life balance – with just as much flexibility as the production systems of the future that will be controlled by people.

Industrial 4.0 technical pillars of the industry include industrial networking, cloud computing, industrial big data, industrial robots, 3D printing, knowledge work automation, industrial network security, virtual reality and artificial intelligence. These nine pillars will generate numerous business opportunities and listing corporation.

Industry 4.0 is enabled by technologies that integrate the digital and real worlds, such as:

- The Internet of Things (IoT): Connecting more and more systems, devices, sensors, assets and people through networks ranging from wireless, low-power wide-area networks to wired high-capacity networks.
- Mobile solutions: Including smartphones, tablets, wearable sensors and smart glasses.
- Cloud computing: Including low-cost processing and data storage solutions.
- Cyber-physical systems (CPS): Monitoring and controlling physical processes using sensors, actuators and processors, based on digital models of the physical world.

"The fourth industrial revolution has the potential both to increase economic growth and defuse some of the biggest global challenges facing humanity."

Klaus Schwab

Chairman of the World Economic Forum

- Big data analytics and business intelligence: Turning data into actionable insights, which include early warning algorithms, predictive models, decision support, workflows and dashboards.
- Advanced manufacturing technologies: Including robotics and 3D printing.

Modern technologies have never been more abundant or affordable. At the same time, the capability to collect, distribute, share and analyze information to make decisions based on real- time data and predictive analytics, and create new business value has improved considerably. This is evident from the significant drop in sensor, bandwidth and processing costs in the last 10 years.

Software has Industrial Internet of Things, industrial network security, industrial big data and cloud computing platform, MES system, virtual reality, artificial intelligence, knowledge work automation, etc. Hardware is the industrial robot, including high-end components, sensors, RFID, 3D printing, machine vision, intelligent logistics (AGV), PLC, data collector, industrial switches and more.

- The first kind is smart factory, which is divided into two kinds; the first is a traditional factory transformation into smart factory, the second is a born smart factory.
- The second type is a solution company, which provides the top design, the transformation path graph and the integration of software and hardware for manufacturing companies.
- The third type is the technology vendors, including industrial Internet of Things, industrial network security, industrial big data and cloud computing platform and MES system.

Besides these three categories, the supplier for virtual reality, artificial intelligence and knowledge work automation technologies will also face great prospects for development.

The Industry 4.0 entails a confluence of technologies ranging from a variety of digital technologies (e.g. 3D printing, Industrial Internet of Things, advanced robotics) to new materials (e.g., bio- or Nano-based) to new processes (e.g., data driven production, artificial intelligence, synthetic biology). These technologies are available. As these technologies have an impact on the production and the distribution of goods and services, they will have far-reaching consequences for productivity, skills, income distribution and well-being.

Industry 4.0 focuses on manufacturing while the Industrial Internet takes a broader view.

> ***"This is an opportunity for social change: Industrie 4.0 can provide entirely new impetus for growth and employment."***
>
> **Max Blanchet,**
> **Senior Partner Roland Berger**

- Industry 4.0, first coined in Germany in 2011, focuses on the manufacturing industry and the optimization of the production process by bringing together intelligent machines, advanced analytics, and people at work. It embodies a network of numerous devices connected by communications technologies that results in systems that can monitor, collect, exchange, analyze, and deliver valuable new insights. These insights help to drive smarter, faster business decisions for industrial companies. Industry 4.0 dominates in the EU due to a strong German manufacturing base, corporate and academic thought leadership and government programs
- The Industrial Internet also known as the Industrial Internet of Things (IIoT), is an American approach that describes similar phenomena to those summarized under Industry 4.0. The main difference between the two systems is that the Industrial Internet goes beyond manufacturing to cover the wider adoption of the web into other forms of economic activity. It applies to several sectors, such as manufacturing, energy, transportation, healthcare, utilities, agriculture and cities. The focus of the Industrial Internet is the optimization of assets and not limited to the production process, as seen in Industry 4.0
- The term "Industrial Internet" was coined by General Electric, and joined by AT&T, Cisco, Intel, and IBM to set up the Industrial Internet Consortium (IIC) in 2014. The IIC is a non-profit, open membership organization with over 250 members that was formed to accelerate the development, adoption and widespread use of interconnected machines and devices, and intelligent analytics. The IIC catalyzes and coordinates the priorities and enabling technologies of industry, academia and the government around the Industrial Internet.
- Industry 4.0 and the Industrial Internet do not compete with one another – they are complementary. Representatives of the platform Industry 4.0 and the IIC have agreed to cooperate to ensure future interoperability of the systems, standardization and the use of common test environments. A common roadmap has been developed for this purpose.

As seen in the table below, Industry is fundamentally influenced by Digital Transformation – Industry 4.0 and the Industrial Internet (IIOT) address distinct aspects.

Table 1 - Industry 4.0 vs. Industrial IOT (IIOT)

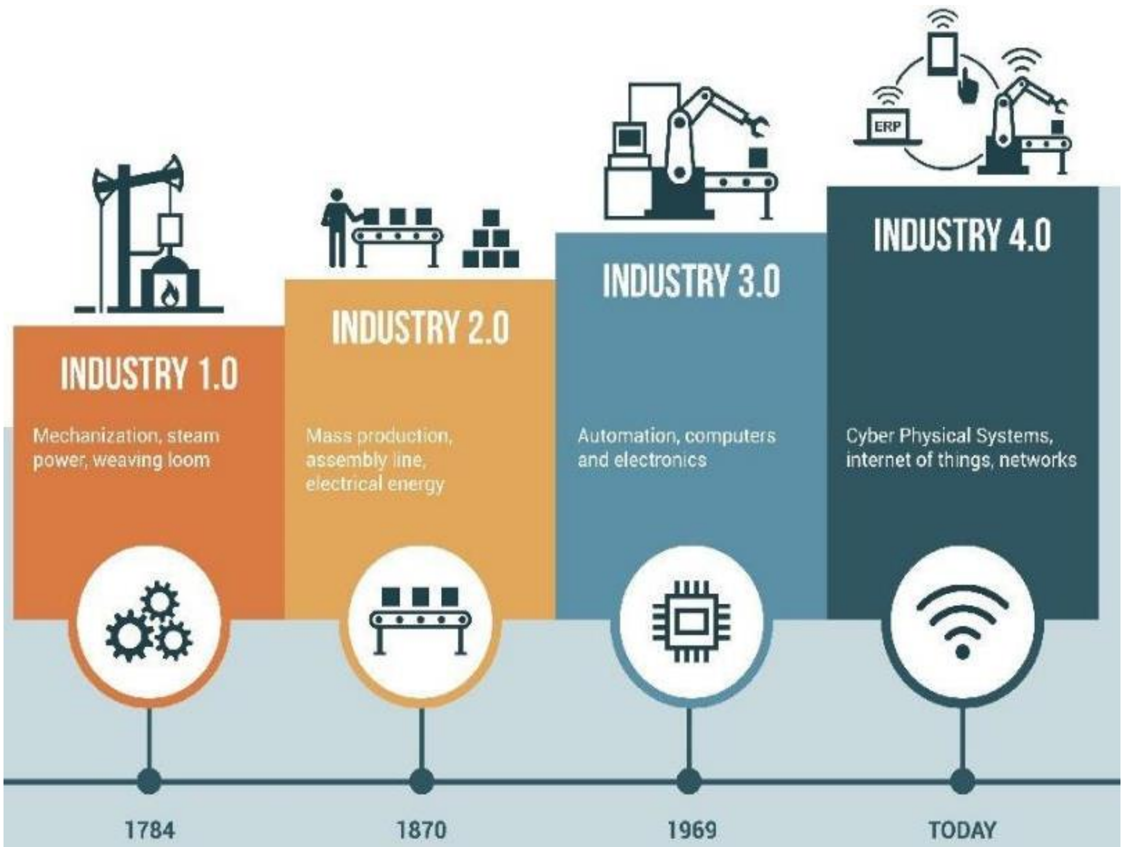
	Industry 4.0	Industrial Internet
Key authors	> German Government, acatech (National Academy of Science and Engineering)	> Large Multinationals such as GE, AT&T Intel, IBM, Cisco
Taxonomy of revolutions	> Four (mechanization, mass production, automation, robotization)	> Three (industrial revolution, internet revolution, industrial internet revolution)
Strategic focus	> Industrial policy: "the German strategic initiative to take up a pioneering role in industrial IT"	> Interoperability: "establishing interoperability in various industrial environments"
Sectoral focus	> Manufacturing	> Manufacturing, energy, transportation, healthcare, utilities, cities, agriculture
Technological focus	> Supply chain coordination, embedded systems, automation, robotics	> Device communication, controls and integration, data flows, predictive analytics, automation
Optimization focus	> Production	> Asset

2 Industry 4.0: Introduction

- The 4.0 Industry revolution is about not only using data during production, or even integrating data from a wide variety of manufacturing systems throughout the supply chain. It is about analyzing and integrating total product and process life cycle, so that the product and customer communicate directly with manufacturing systems and personnel to ensure that each individual customer receives exactly the product that they desire. This enables suppliers to better understand how their products and production operations are performing, and how customers' needs and desires change over time. With such a capability, industry can effectively, efficiently, and rapidly supply customers with a product that suits their needs, and accurately predict and satisfy global customer demand in a rapidly changing world.

> ***Individualized mass production and the return of industrial jobs to high-wage countries in the West: two of the key promises of Industrie 4.0***

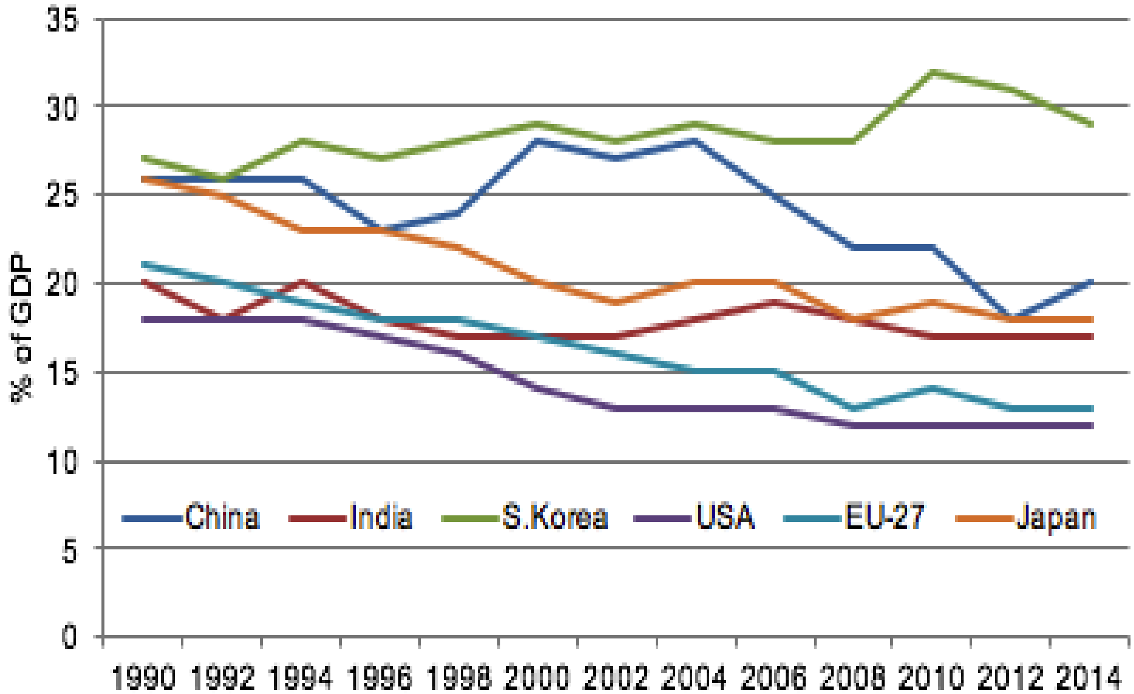
- In a global manufacturing industry that is changing faster than ever, Industry 4.0 trend analysis is critical for all companies to drive sustainable growth. As competition increases and innovative ideas continue to disrupt entire industries, harnessing megatrend analysis allows businesses to remain relevant and succeed in the market place of the future.
- Although the term Industry 4.0 and the reference architecture model behind it originate from Germany (hence "Industrie 4.0", it's clear that the vision – and reality – of the fourth industrial revolution has caught the attention of organizations across the globe. Moreover, Industry 4.0 is not just about manufacturing anymore (even if manufacturing is the main sector involved today).



- So, although Industry 4.0 originally was only used for manufacturing (in contrast with other leading initiatives such as the Industrial Internet and the Industrial Internet Consortium or IIC), it is de facto going further. In the early days of the Industry 4.0 view, we wouldn't have been able to say that it was a manufacturing initiative, period. Today, we clearly see how the several parties, which were involved in Industry 4.0 themselves, move it to smart transportation and logistics, smart buildings, oil and gas, smart healthcare and even smart cities.

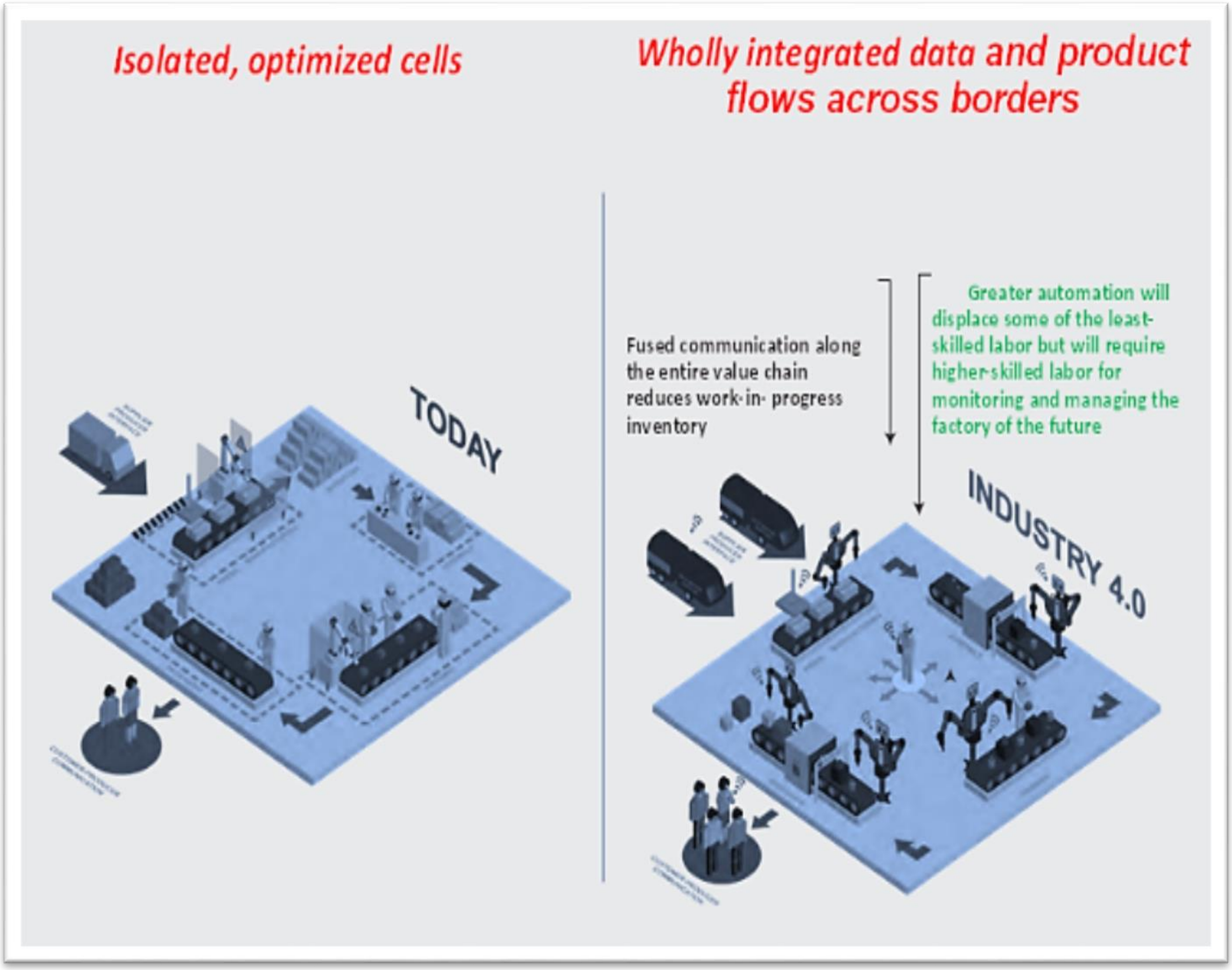
> ***"The possibilities have not yet been explored in full, but already we can see how Industry 4.0 will drive business growth. Very simply, it is a fundamental change in how things are manufactured."***

Figure 2 - Manufacturing Sector Share [%] of GDP by Key Countries



- Following three decades of decline of the manufacturing sector in western economies, Governments and the private sector are adopting 4th industrial revolution technologies to bring manufacturing and jobs back home, close to their markets R&D and managements. The 4th industrial revolution is set to swiftly convert the competitiveness of nearly all industrial sectors across the world as well as change long-held dynamics in commerce and global economic balance of power.
- Developing countries will suffer once the need declines for cheap labor in low-end manufacturing.
- Cybersecurity will be even more important as Industrial IoT becomes more integrated in manufacturing.
- **Economic Industry 4.0 Market Constraints:** Planners worldwide are torn between two seemingly contradictory imperatives: reducing capital investment to help curb spending, and the drive to increase the national industry competitiveness and jobs.

Figure 3 - Inter & Intra Relations:
Present Manufacturing vs. Industry 4.0 Manufacturing



There is more to Industry 4.0 than its technical dimension. Technologies like factory virtualization, smart and intelligent machines, the industrial IoT, the cyber production system, 3D technology, cobots determine the debate. Many are available already or emerging. Companies have launched pilot projects in which they try to embed these technologies in their current manufacturing process. Few, however, have genuinely exploited their potential to the full and implemented new models.

The Industry 4.0 revolution will transform the economic paradigm and the mechanisms for creating value that underpin it. Manufacturing has, in fact switched from a mindset of mass production to one of mass customization. No longer is it based on scale and volume effects but on flexible and localized production situated close to centers of demand. It manufactures "on demand" and no longer creates inventory, instead dynamically adapting itself to demand. It is more predictive and auto corrective and it involves less trial and error. Its logic is now focused not on the product but on usage, and it has switched from a rigid form of labor organization, to a flexible form enhancing the appeal of work as a result. It potentially represents a complete overhaul of the economic rationale behind business.

The industrial model today is still based on the principle of decreasing product costs through the volume of products manufactured: the higher the volume produced, the lower unit costs become. Because of this, industry has been primarily concerned with optimizing the costs and price of products and less so with optimizing the capital required to make them. This in industrial paradigm is now being questioned because there is only so far it can go. Given the climate of uncertainty with regard to volumes a climate generated by the economic crisis and the increasing diversity of customers and their expectations, the investments required to manufacture products at the lowest cost and in large numbers have created an inflationary trend in capital employed caused by a lack of flexibility or the underuse of the manufacturing base.

How large are the Industry 4.0 productivity effects?

Evidence on productivity impacts from new production technologies come mainly from firm and technology-specific studies. A sample of these studies is given here. These studies suggest sizeable potential productivity impacts. However, the studies follow a variety of methodological approaches, and often a report results from a few, early-adopting technology users, making aggregate estimates difficult to derive:

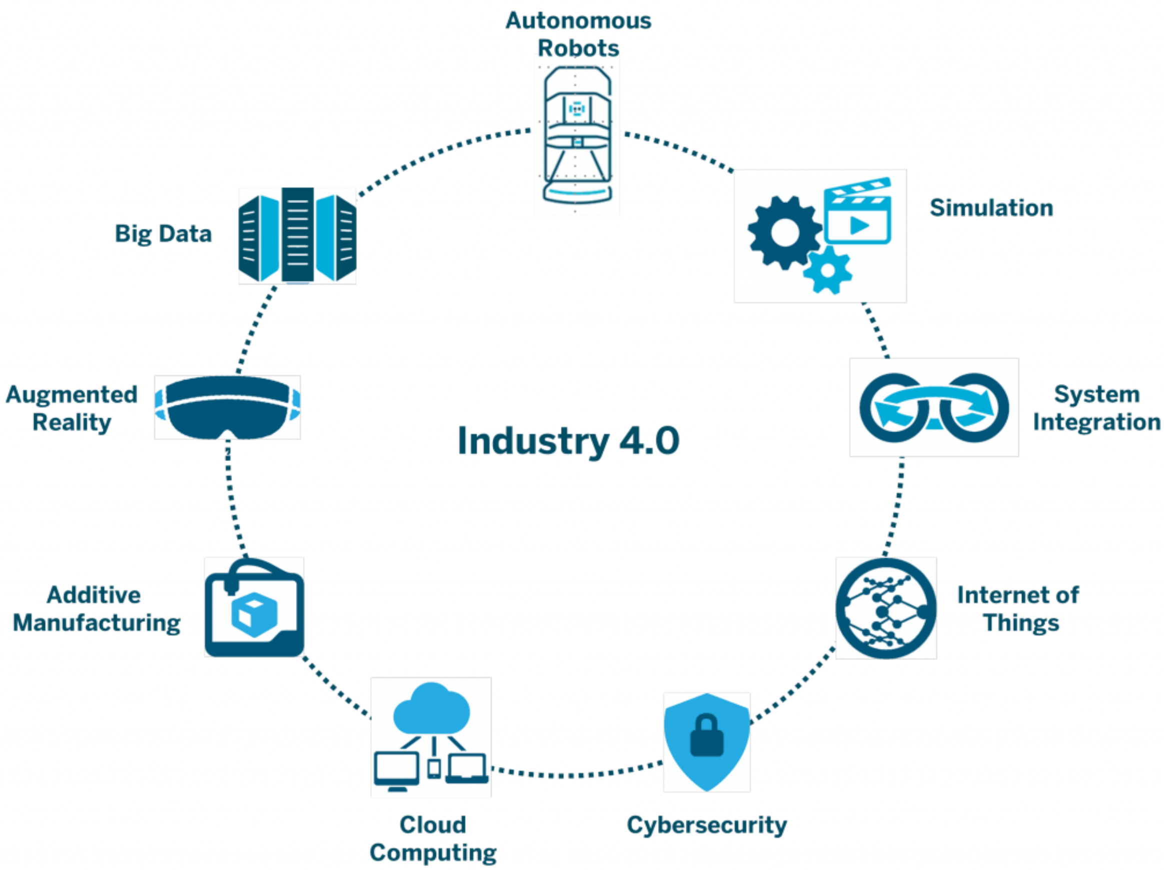
- *In the U.S., output and productivity in firms that adopt data-driven decision making are 5% to 6% higher than expected given those firms' other investments in ICTs (Brynjolfsson, Hitt and Kim, 2011).*
- *Improving data quality and access by 10% - presenting data more concisely and consistently across platforms and allowing them to be more easily manipulated - would increase labor productivity by 14% on average, but with significant cross-industry variations (Barua et al., 2013).*
- *The Industrial Internet of Things (IIoT) reduces costs among industrial adopters by 18% on average (Vodatafone, 2015).*
- *Autonomous mine haulage trucks could in some cases increase output by 15-20%, lower fuel consumption by 10-15% and reduce maintenance costs by 8% (Citigroup-Oxford Martin School, 2015).*
- *Autonomous drill rigs can increase productivity by 30% to 60% (Citigroup-Oxford Martin School, 2015).*
- *Warehouses equipped with robots made by Kiva Systems can handle four times as many orders as un- automated warehouses (Rotman, 2013).*
- *By raising productivity, the new technologies can also improve financial performance among adopters. A case study commissioned for the EU Industry 4.0 project (NPR) shows that, by developing a significant IIoT and data analytics capability, a leading United States automaker has saved around $ 2 billion over the past 5 years (2011- 2014 and most of 2015). A 1% increase in maintenance efficiency in the aviation industry, brought about by the industrial Internet, could save commercial airlines globally around $ 2 billion per year.*

Evans and Anninziata

- **Small Batches:** One important effect of Industry 4.0 is the fact that due to using control automation, many work pieces can be produced cost-effectively not just in large quantities, but also in much smaller lots. A 'batch size of 1' is the buzzword here. One example of this comes in the production of textiles. Another might be in the production of individually designed metal pieces to customer spec, such as post boxes or railings.

Many of the nine technologies that form the foundation for Industry 4.0 are already used in manufacturing but with Industry 4.0, they will transform production: isolated, optimized cells will come together as a fully integrated, automated, and optimized production flow, leading to greater efficiencies and changing traditional production relationships among suppliers, producers, and customers as well as between human and machine.

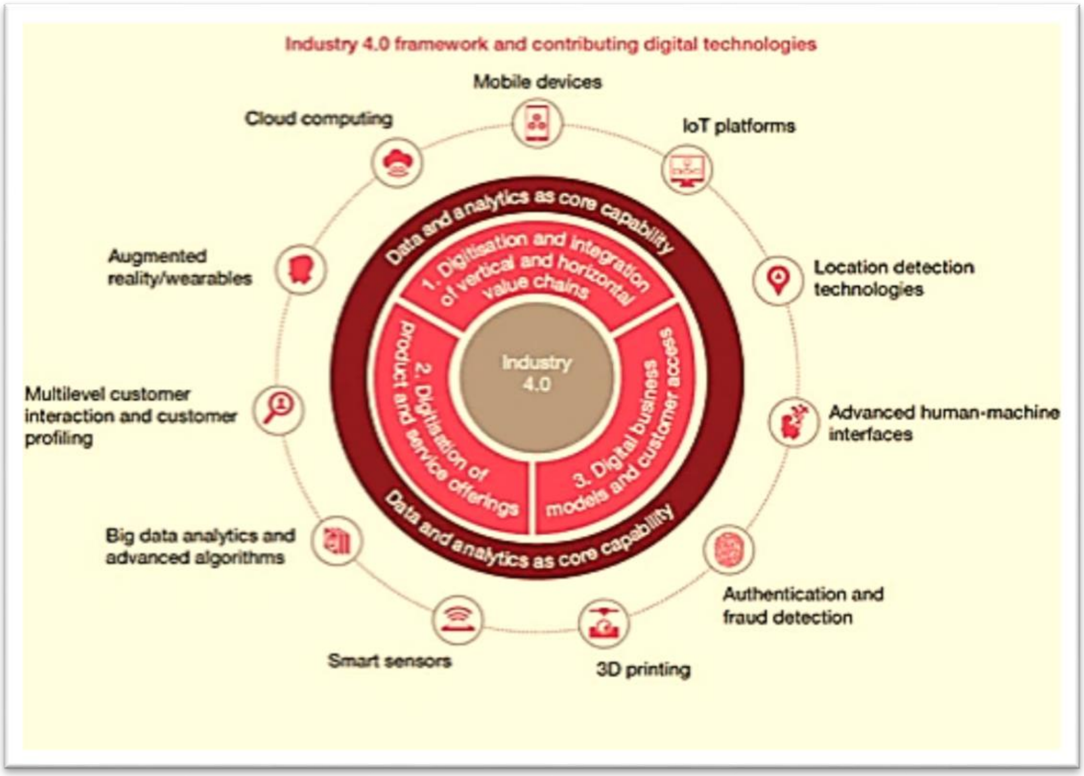
Figure 4 - Industry 4.0 Enabling Technologies



Source: A. Melanson

- Many of the advances in technology that form the foundation for Industry 4.0 are already used in manufacturing, but with Industry 4.0, they will transform production: isolated, optimized cells will come together as a fully integrated, automated, and optimized production flow, leading to greater efficiencies and changing traditional production relationships among suppliers, producers, and customers as well as between human and machine.

Figure 5 - Industry 4.0 Framework & Technologies



Source: Forbes India

1. **Big Data and Analytics:** Analytics based on large data sets has emerged only recently in the manufacturing world, where it optimizes production quality, saves energy, and improves equipment services. In an Industry 4.0 context, the collection and comprehensive evaluation of data from many different sources, production equipment and systems as well as enterprise- and customer-management systems will become standard to support real-time decision-making.
2. **Autonomous Robots:** Manufacturers in many industries have long used robots to tackle complex assignments, but robots are evolving for even greater utility. They are becoming more autonomous, flexible, and cooperative. Eventually, they will interact with one another, work safely side by side with humans, and learn from them. These robots

will cost less and have a greater range of capabilities than those used in manufacturing today.

3. **Simulation:** In the engineering phase, 3-D simulations of products, materials, and production processes are already used, but in the future, simulations will be used more extensively in plant operations as well. These simulations will leverage real-time data to mirror the physical world in a virtual model, which can include machines, products, and humans. This allows operators to test and optimize the machine settings for the next product in line in the virtual world before the physical changeover, thereby driving down machine setup times and increasing quality.
4. **Horizontal and Vertical System Integration:** Most of the present IT systems are not fully integrated. Companies, suppliers, and customers are rarely closely linked. Nor are departments such as engineering, production and their communication protocols identical. Functions from the enterprise to the shop floor level are not fully integrated. Eventually, robots will interact with one another, work safely side by side with humans, and learn from them.
5. **The Industrial Internet of Things (IIoT):** Currently, only some of a manufacturer's sensors and machines are networked and make use of embedded computing. They are typically organized in a vertical automation pyramid in which sensors and field devices with limited intelligence and automation controllers feed into an overarching manufacturing-process control system. However, with the Industrial Internet of Things, more devices—sometimes including even unfinished products will be enriched with embedded computing and connected using standard technologies. This allows field devices to communicate and interact both with one another and with more centralized controllers, as necessary. It also decentralizes analytics and decision-making, enabling real-time responses.
6. **Cybersecurity:** Many companies still rely on management and production systems that are unconnected or closed. With the increased connectivity and use of standard communications protocols that come with Industry 4.0, the need to protect critical industrial systems and manufacturing lines from Cybersecurity threats increases dramatically. As a result, secure, reliable communications as well as sophisticated identity and access management of machines and users are essential.
7. **Cloud computing:** The provision of infinitely scalable computing resources as a service over the Internet—is in the process of transforming virtually every facet of modern manufacturing. Whether it's how manufacturing enterprises operate, how they integrate into supply chains, or how products are designed, fabricated, and used by customers, cloud computing is helping manufacturers innovate, reduce costs, and increase their competitiveness. Critically, cloud computing

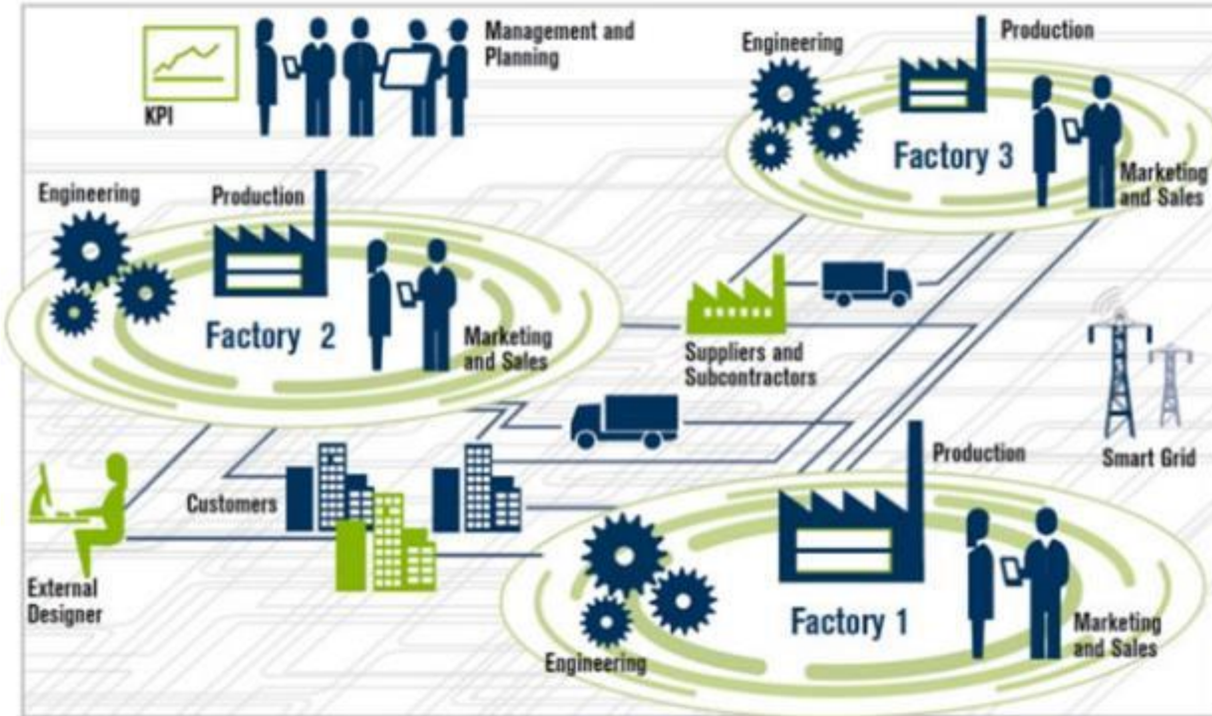
allows manufacturers to use many forms of new production systems, from 3D printing and high-performance computing (HPC) to the Internet of Things (IoT) and industrial robots. Moreover, cloud computing democratizes access to and use of these technologies by small manufacturers. This report describes how cloud computing enables modern manufacturing, provides real-word case studies of this process in action, and recommends actions policymakers can take to ensure cloud computing continues to transform manufacturing and bolster manufacturing competitiveness. Companies are already using cloud-based software for some enterprise and analytics applications, but with Industry 4.0, more production-related undertakings will require increased data sharing across sites and company boundaries. At the same time, the performance of cloud technologies will improve, achieving reaction times of just several milliseconds. As a result, machine data and functionality will increasingly be deployed to the cloud, enabling more data-driven services for production systems. Even systems that monitor and control processes may become cloud based. Vendors of manufacturing-execution systems are among the companies that have started to offer cloud-based solutions.

> ***The cloud is changing the rules of industrial automation. New entrants don't have much time left to rethink. Top management must get involved.***
>
> **Senior Partner Roland Berger**

8. **Additive Manufacturing:** Companies have just begun to adopt additive manufacturing, such as 3-D printing, which they use mostly to prototype and produce individual components. With Industry 4.0, these additive-manufacturing methods will be widely used to produce small batches of customized products that offer construction advantages, such as complex, lightweight designs. High-performance, decentralized additive manufacturing systems will reduce transport distances and stock on hand.

9. **Augmented Reality:** Augmented-reality-based systems support a variety of services, such as selecting parts in a warehouse and sending repair instructions over mobile devices. These systems are currently in their infancy, but in the future, companies will make much broader use of augmented reality to provide workers with real-time information to improve decision making and work procedures.

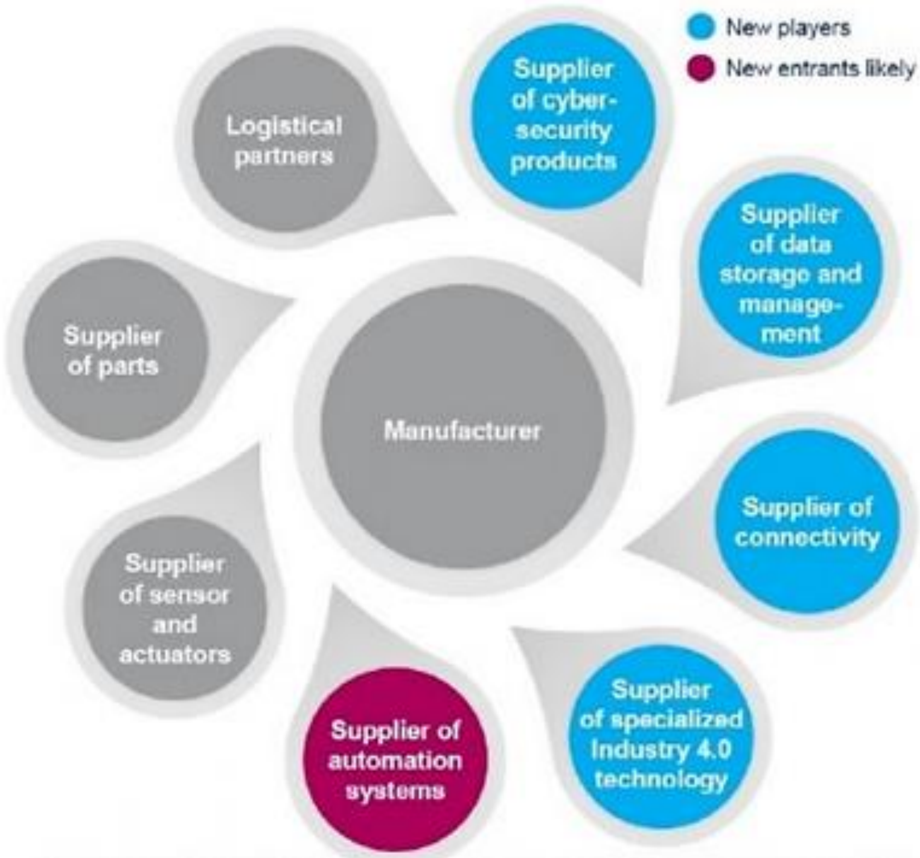
Figure 6 - Industry 4.0 Horizontal Value Chain



Source: Fraunhofer, HP

- ❑ Manufacturing will be transformed from single automated cells to fully integrated, automated facilities that communicate with one another and boost flexibility, speed, productivity, and quality. For example, in Germany's "Industrie 4.0" manufacturing landscape, Industry 4.0 can drive productivity gains of 5-8% on total manufacturing costs over ten years.
- ❑ It is easier to make money today with fewer workers than it was a quarter of a century ago. In a book on the Fourth Industrial Revolution handed to each of the delegates at the 2016 World Economic Forum, Schwab compares Detroit in 1990 with Silicon Valley in 2014. In 1990, the three biggest companies in Detroit had a market capitalization of $36 billion, revenues of $250 billion and 1.2 million employees. In 2014, the three biggest companies in Silicon Valley had a considerably higher market capitalization ($1.09 trillion) and generated roughly the same revenues ($247 billion) but with about 10 times fewer employees (137,000).

Figure 7 - Industry 4.0 Value Chain Suppliers & Participants



Source: McKinsey

3 Industry 4.0: Conclusions

- The Industry 4.0 transformation will change long-held dynamics in commerce and global economic balance of power.
- In the next decades, businesses will establish global networks that incorporate their machinery, warehousing systems and production facilities in the shape of cyber-physical systems. In the manufacturing environment, these cyber-physical systems comprise smart machines, storage systems and production facilities capable of autonomously exchanging information, triggering actions and controlling each other independently. On the one hand, these changes add to the traditional business pressure on manufacturers, but on the other hand, they offer unprecedented opportunities to optimize production and manufacturing processes.
- Industry 4.0 facilitates fundamental improvements in the industrial processes involved in manufacturing, engineering, material purchasing and usage, supply chain and life cycle management, predictive maintenance and real-time management overview. The smart factories that have already appeared across most industries employ a completely novel approach to production. Smart products are uniquely identifiable, they can be located at all times, know their own history, current status, and alternative routes to achieving their target state.
- The embedded manufacturing systems are vertically networked with business processes within factories and enterprises and horizontally connected to dispersed value networks that can be managed in real time from the moment an order is placed right through to outbound logistics. In addition, they both enable and require end-to-end engineering across the entire value chain.
- Industry 4.0 holds immense potential. Smart factories allow individual customer requirements to be met, meaning that even one-off items can be manufactured profitably. In Industry 4.0, dynamic business and engineering processes enable last-minute changes to production and deliver the ability to respond flexibly to disruptions and failures on behalf of suppliers.

> ***"Industry 4.0 offers a huge payout […] the value of Industry 4.0 is estimated at $15 trillion of global GDP by 2020."***
>
> **David Floyer**
> "***Defining and Sizing the Industrial Internet***"

- End-to-end transparency is provided over the manufacturing process, facilitating optimized decision-making. Industry 4.0 will also result in new ways of creating value and novel business models. It will provide start-ups and SMEs with the opportunity to develop and provide downstream services.

- The Industry 4.0 competition is about not only technology or offering the best products; it is also, and in particular, about the companies that gather the appropriate data, combine them to provide the best digital services, and in addition, utilize the data for their own benefit. Those who know what the customer wants, and can forecast consumer demand, will provide the information to develop an "unfair" competitive advantage.
- The major winners might be those that control "Industry 4.0 Platforms", software layers that syndicate various devices, information and services, on top of which other firms can build their own offerings.
- The Industry 4.0 "market race" is led by the global tech giants (see figure below) that invest billions of dollars in Industry 4.0 products R&D, M&A, commercialization and internal use.

Figure 8 - Tech Giants Participating in the Industry 4.0 Market Race

- The transformation of the economy being brought about by Industry 4.0 means that business processes such as supply, manufacturing, maintenance, delivery and customer service will all be connected via the Industrial IoT systems. These extremely flexible value networks will require new forms of collaboration between companies, both nationally and globally.
- To maintain their industrial base and create new jobs, governments across the globe invest billions of dollars in Industry 4.0 projects and R&D, and provide subsidies and tax incentives for Industry 4.0 investors.
- On the one hand, governments and private sectors of countries with high labor costs (e.g., EU countries and the U.S.) invest in Industry 4.0 to increase their industrial sector, which has been taken over by low labor cost countries, and on the other hand, low labor costs industries and their governments (e.g., China, India and Cambodia) react to this trend by investing in Industry 4.0 as well.
- The 2016-2023 Asia-Pacific Industry 4.0 market is the fastest growing regional market that will increase at a CAGR of 23.7%. China invests hundreds of billions to retain its #1 position as the world's leading manufacturing economy.
- During four decades, APAC led by China, has proved to be the "global factory", driven by low labor costs and globalization. With the Industry 4.0 revolution, which depends more on employees' skills rather than cheap labor and western economies Industry 4.0 investments the tide is reversing. In order to mitigate this threat, APAC emerging economies, South Korea, Japan and China invest heavily in the 4th industrial revolution to compete with western economies Industry 4.0 ramifications. They provide government funding for Industry 4.0 projects, R&D, subsidies and tax incentives to Industry 4.0 investors.
- China is unique in terms of the breadth and size of its Industry 4.0 strategy and funding; the PRC government commenced in 2015 the "Made in China 2025" scheme, specifying ten industries including semiconductors, aerospace, agricultural equipment, quantum computing and other sectors, which are the core of government planning.
- The PRC "Made in China" plan, an industrial-policy program is derived in part from Germany's "Industrie 4.0" model, which focuses on creating a helpful environment through training and policy support but leaves business decisions to companies. China's version is much more hands-on. The plan includes 1,013 "state-guided funds", endowed with $807B, much of it for "Made in China" industries.
- The program includes a manufacturing-subsidy program, spread across 62 distinct initiatives. According to the report, China will dominate 42% of the APAC Industry 4.0 market by 2023.

- In India, the world's fastest growing economy, it is estimated that the industrial sector will embrace Industry 4.0 and transform the Indian manufacturing economy.
- Japan is a highly robotized country and the world´s predominant industrial robot manufacturer with a market share of 52%. To address its 21st century challenges economic, social and industrial Japan launched its "Society 5.0" program. The "Society 5.0" includes (but is not limited to) Japan's Industry 4.0 program.
- The Asia Pacific Industry 4.0 transformation will change long-held dynamics in the balance of economic power between the far east, the U.S. and Europe
- The fourth industrial revolution is a deeper change, which will fundamentally alter the way we live, work, and relate to one another
- Revolution is by its nature disruptive, and Industry 4.0 is no different from its predecessors. The work that people do will change. Sophisticated "aware" robots could replace people doing manual, labor intensive work, repetitive activities or work in hazardous environments. New roles will emerge requiring new skills. The availability of those resources may be too low in the early days, slowing companies moving to Industry 4.0 models.
- Where there is data there is risk. Leading on from risk there are hackers who will hack. As a result, maintaining secure networks and keeping data safe will be paramount. This is particularly important when considering all the devices we are using and the connected "things" we are interacting with. Technology will continue to evolve rapidly.
- While the extent of change the fourth industrial revolution will bring is an unknown quantity, we do know that we are facing an eminent point of transformation. Capitalizing on this and embracing it in a timely fashion would be akin to the technological difference between a ship running on steam and one running on diesel.
- Industry 4.0 will revolutionize manufacturing around the globe, as did the first three industrial revolutions. With global supply chains and highly interactive markets, this revolution will be vastly different from the previous ones: being much faster and generating results that were heretofore unexpected. It will highlight the fact that minor changes in one area of the manufacturing ecosystem will create significant ripples throughout the ecosystem, due to connectivity throughout the supply chain and the speed at which information propagates.
- Industry 4.0 will transform the design, manufacture, operation, and service of products and production systems. According to a study, done by BCG, connectivity and interaction among parts, machines, and humans will make production systems as much as 30 %faster and 25 %more efficient and elevate mass customization to new levels.

- Although the full shift toward Industry 4.0 might take 20 years to reach fruition, in the next 5 to 10 years key advances will be established and winners and losers will emerge.
- Industry 4.0 will enable information to flow not only from manufacturer to product, but between producers, products and most importantly, customers.
- The ability to embrace Industry 4.0 and use the opportunities that will rapidly (and, in many instances, unexpectedly) present themselves will be a key to success in the new global market. Enabling that innovation to proceed from a concept to a mass-produced product will be critical for success; and ensuring a talent pool in the manufacturing workforce that can move those innovations rapidly forward will be equally important.
- What makes it all the more fascinating (and at first sight complex) is the convergence of two worlds which have been disconnected thus far: Information Technology (IT) and Operational Technology (OT)with the hyper-connected digital industry, the bridging of digital and physical, cyber-physical production systems and the Industrial Internet of Things as parts (and names) that describe this fourth industrial revolution.
- The integration of IT and OT is far from a fact yet, although there are differences, depending on the Industry 4.0 projects. As it is still early days in the maturity journey and vision of Industry 4.0, there mainly is a focus on projects (while Industry 4.0 at a more mature level is a holistic given) and such projects can vary a lot. Projects around energy efficiency, factory energy management and HVAC (Heating, ventilation and air conditioning), for instance, bring us to an entirely different world (with different solutions, skills and standards) than, for instance, additive manufacturing, robotics or augmented reality to name a few. In the end, integration and convergence is what it will be about, as specialists will continue to be needed.

"Industry 4.0 creates a value that immensely exceeds the cost savings that most manufacturers pursue today."

- Despite the vastness, terminology and many concepts, in the end Industry 4.0 is about the digital transformation in and of industrial markets, in the beginning only manufacturing, and with a big role for the Industrial IoT, as we'll see. In addition, just like digital transformation it requires a strategic view and staged approach.
- The technologies considered in this report, from ICTs and robots to new materials, have more to contribute to productivity than they currently do. Often, their use is predominantly in larger firms. In addition, even in larger firms, many potential applications are underused. Unexploited opportunities exist throughout manufacturing. This may be particularly the case with the cluster of technologies that make up the Industry 4.0 digital,

material and process that are combinatorial and as such interact in ways that are hard to assess.

Table 2 - Industry 4.0: Trends, Challenges and Technology Enablers

The Trends	The Challenges	The Enablers
Low volume high mix	Automation complexity and unpredictability	Collaborative automation for greater flexibility
Shorter cycles, faster launches	Shop floor disruptions and high engineering costs	Better software for engineering efficiency
Increased need for automation and scalability in SMEs	Lack of robot integration and programming expertise	Easier to use robots with more intuitive programming
Rising cost of downtime	Higher lifetime TCO due to increase in planned downtime	Advanced analytics and services for greater reliability
Increased and sporadic human intervention	Lost productivity to maintain safety	Collaborative automation to maintain safety and productivity

- ❑ While new technologies will create jobs through many direct and indirect channels, and productivity-raising technologies will benefit firms and the economy overall, the associated adjustments could be significant. Hardship could affect many if rapid labor displacement were to occur in a major sector, or in many sectors simultaneously. Policymakers need to monitor and actively manage the labor market adjustments.

"In 1990, the three biggest companies in Detroit had a market capitalization of $36 billion, revenues of $250 billion and 1.2 million employees. In 2014, the three biggest companies in Silicon Valley had a considerably higher market capitalization ($1.09 trillion) and generated roughly the same revenues ($247 billion) but with about 10 times fewer employees (137,000).

Schwab Founder World Economic Forum

- ❑ Diffusion of the technologies must include not only the hardware, but also the complementary investments and know-how needed to fully exploit the technologies, ranging from skills to new forms of business organization, especially for SMEs. Here, the efficient deployment and reallocation of human and financial resources will be essential, as is the creation of an environment that fosters business dynamism. Aligning framework policies that promote product market competition, reduce rigidities in labor markets, remove disincentives for firm exit and barriers to growth for successful firms is critical. New firms will introduce many of the new production technologies.

- Effective institutions dedicated to technology diffusion will also be necessary. Some of these institutions, such as technical extension services (which provide information and outreach, especially for SMEs), tend to receive low priority in the overall set of innovation support measures. However, there is evidence that they can be effective, if well designed (for instance, manufacturing extension services, which provide outreach, often to small firms, have been carefully evaluated).
- Data is at the center of many of the Industry 4.0 technologies and need to be treated as a new infrastructure for 21st century production. Policy mixes are needed that encourage investments in data that have positive spillovers across industries, obstacles to the reuse and sharing of data should be examined carefully, and coherent data governance frameworks should be developed/
- Rapid technological change could challenge the adequacy of skills and training systems. Some new production technologies raise the importance of inter-disciplinary education and research. Greater interaction between education and training institutions is often needed, and this need may grow as the knowledge content of production rises. Ensuring good digital and generic skills such as literacy, numeracy and problem solving throughout the population will be important.
- Public understanding and acceptance of new production technologies is crucial. Policymakers and institutions need to be realistic about what can be expected from technology. Hyperbole is too frequent. Science advice should be demonstrated to be unbiased and trustworthy. In addition, public deliberation is essential for building mutual understanding between scientific communities and the public.

Industry 4.0 uses digital technologies to react more rapidly to market changes, offer more personalized products and increase operational efficiency.

- Better anticipating trends through technology foresight could assist policy and the allocation of research funds. Foresight processes can bring benefits in themselves, such as strengthened stakeholder networks. They can also encourage policy co-ordination and organizational innovation and help direct sound policies for science and R&D. Many of the technologies covered in this report have arisen because of advances in scientific knowledge and instrumentation emanating from both the public and private sectors.
- Sound science and R&D policies are also essential. For instance, synthetic biology, new materials and nanotechnology have all arisen

because of advances in scientific knowledge and instrumentation, while basic knowledge of artificial intelligence has been elaborated over decades in academic research before surfacing recently in a business context. Among other things, policies must support basic science, inter-disciplinary research, research interaction with industry and the efficient commercialization of research.

- Long-term thinking is essential. Leaders in business, education, unions and government must be ready to examine policy implications and prepare for developments beyond typical election cycles. A long-term perspective on policy also requires reflection on how policy priorities might need to evolve, for instance as a consequence of technological change itself. For example, major challenges to the intellectual property system could come from the emerging ability of machines to create (at least one machine-derived invention has already been patented).

> ***"Work is not disappearing, it is being redefined. As production becomes networked, the demand for specialists in mathematics, computer science, natural science and technology will grow."***
>
> **H. Kagermann**
> **President ,German Academy of Science and Engineering SAP**

- While Industry 4.0 will present a challenge to developed countries, it could be especially challenging for emerging and developing countries. New production technologies could erode the low wage advantage of some developing economies, leading to shifts in global value chains. Development models predicated on successive stages of industrialization may be challenged and the gap between the technologically advanced countries and the rest could grow. However, this scenario might be mitigated by several factors including rapidly declining costs of many of these technologies, more efficient channels of knowledge diffusion, and improved regulations, laws and standards across countries. More work is needed to better analyze this issue, but the Industry 4.0 project will provide relevant insights from recent developments in China.
- The more governments understand how production could develop in the near future, the better placed they will be to prepare for the risks and reap the benefits. The Industry 4.0 raises multiple complex policy challenges and will require adjustment to a wide range of public policies to reap its full benefits. However, through judicious policy, the opportunity exists to influence the introduction of Industry 4.0 now.

Table 3 - The Ingredients of Industry 4.0

Instrumented	Interconnected	Inclusive	Intelligent
Data Devices contain sensors, actuators and software that generate data	**Connectivity** An information network connects devices together; gathers and processes the data either at the edge of the network or centrally – selectively	**Context** Industry knowledge, data external to the network (weather etc.) adds context to the data	**Decision-Making** Machine learning, predictive analytics and cognitive computing makes sense of the data; decentralized decision-making, move towards autonomy

What Industry 4.0 Enables		
Design	**Make**	**Use**
Integrate – Use of existing products by equipping them with sensors to bring them into the connected environment	**Optimize** – predictive maintenance of production lines optimizes uptime and maximizes throughput	**Satisfy** – predictive maintenance of products assures optimal usability and availability, optimized supply chains assure availability
Predict – design new products based on utilization of existing products and market reaction to concepts	**Fulfil** – meet market demands by providing what is most utilized	**Safety** – hazardous tasks and environments are delivered by robots
Innovate – insight from sensor data can guide equipment usage and new product or service design based on customer use and use across a network	**Extend** – machines will come with intelligence pre-built. The applications for those product-service hybrids will become revenue streams	**Sensory** – new ways for humans to interact digitally with machines through voice, sight, tough and movement
	Employ – new roles for product and experience designers, application developers, data scientists equipment/network production, implementation and support	

- **Industry 4.0 Presents Tremendous Opportunities**, and this fact highlights the need for a highly trained and flexible workforce and production capacity that can answer the needs of tomorrow as well as those of today.

- **Industrial IoT Proliferation:** By 2025, Industrial IoT (IIoT) will touch over 40% of the global economy and will be worth more than twice the consumer internet. According to a report from Accenture, the IIoT could add $14.2 trillion to the GDP of 20 major economies, by 2030.

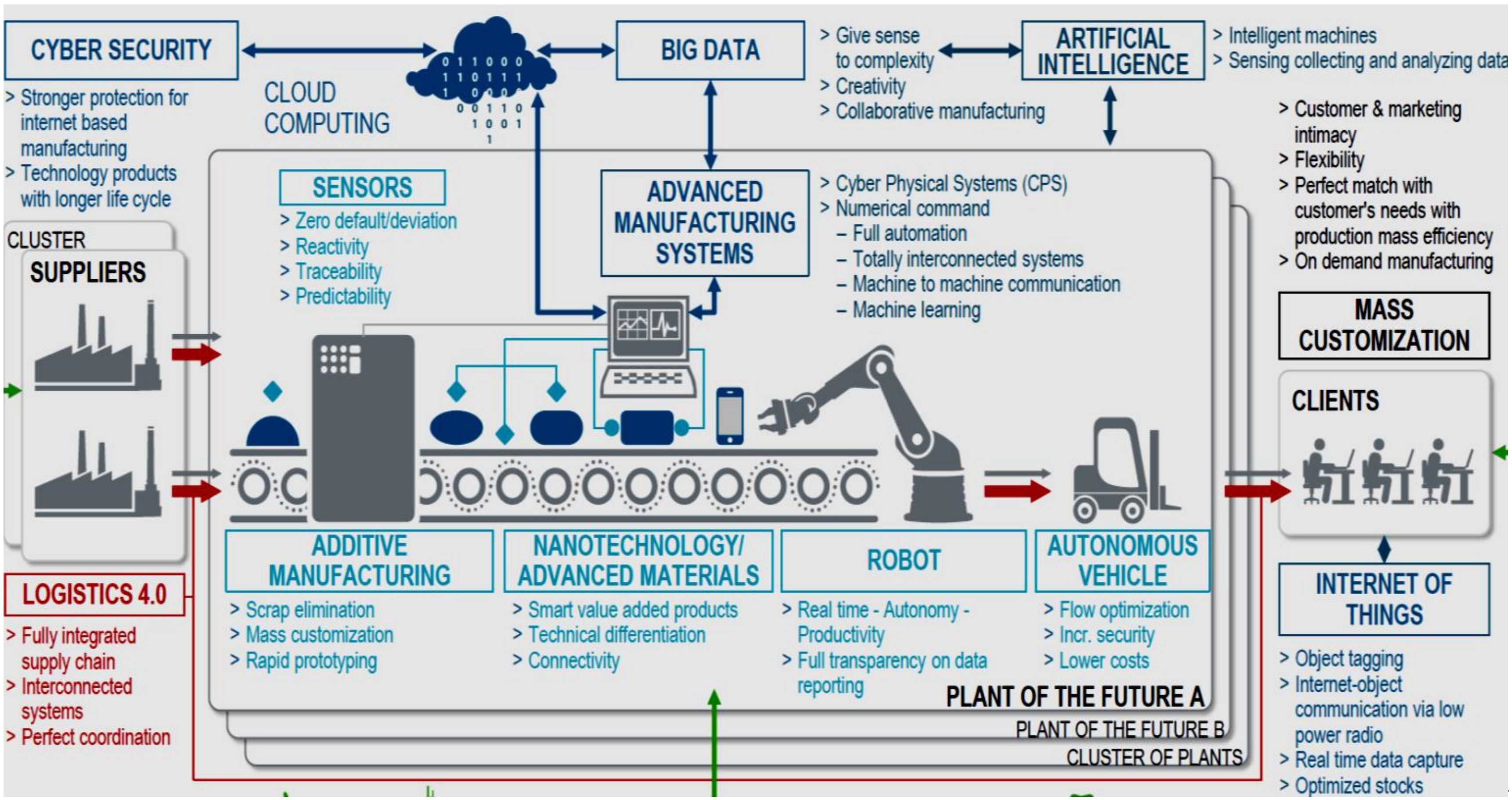
- **Barriers** to the rollout of the technology remain however, including Cybersecurity concerns as more internet connected devices add additional attack vectors; a lack of ubiquitous communications standards;

as well as normative concerns related to the effects of further automation on working people – robots may come to displace humans from low-skilled employment in the manufacturing industry, with potential, negative, social consequences.

- **Industry 4.0 Market Trends:** The Industry 4.0 markets now dominated by the U.S., China and Europe are moving to other countries.
- **Industry 4.0 RDT&E:** The demand for development and deployment of improved capabilities in Industry 4.0 systems is driving a dynamic and multi-faceted RDT&E sector. Despite years of development in technologies Industry 4.0, there is no game changing modality in the market that challenges the cost performance of 2017 Industry 4.0 technologies
- **Industry 4.0 Technologies Proliferation:** Industry 4.0 technologies have the potential to overcome these limitations, but due to their high lifetime cost, Industry 4.0 technologies captured a fraction of the potential market.
- **Technological Evolution:** The Industry 4.0 market is driven by the growing dependence of Industry 4.0 on ICT technologies.
- **The Emergence of New Technologies** such as Additive Manufacturing-3D Printing, Industrial IoT, Big Data & Analytics, Autonomous Robots, Cybersecurity & the Cloud, Augmented Reality, and Simulation will drive more cost-effective Industry 4.0 products.

4 Industry 4.0 Eco-System

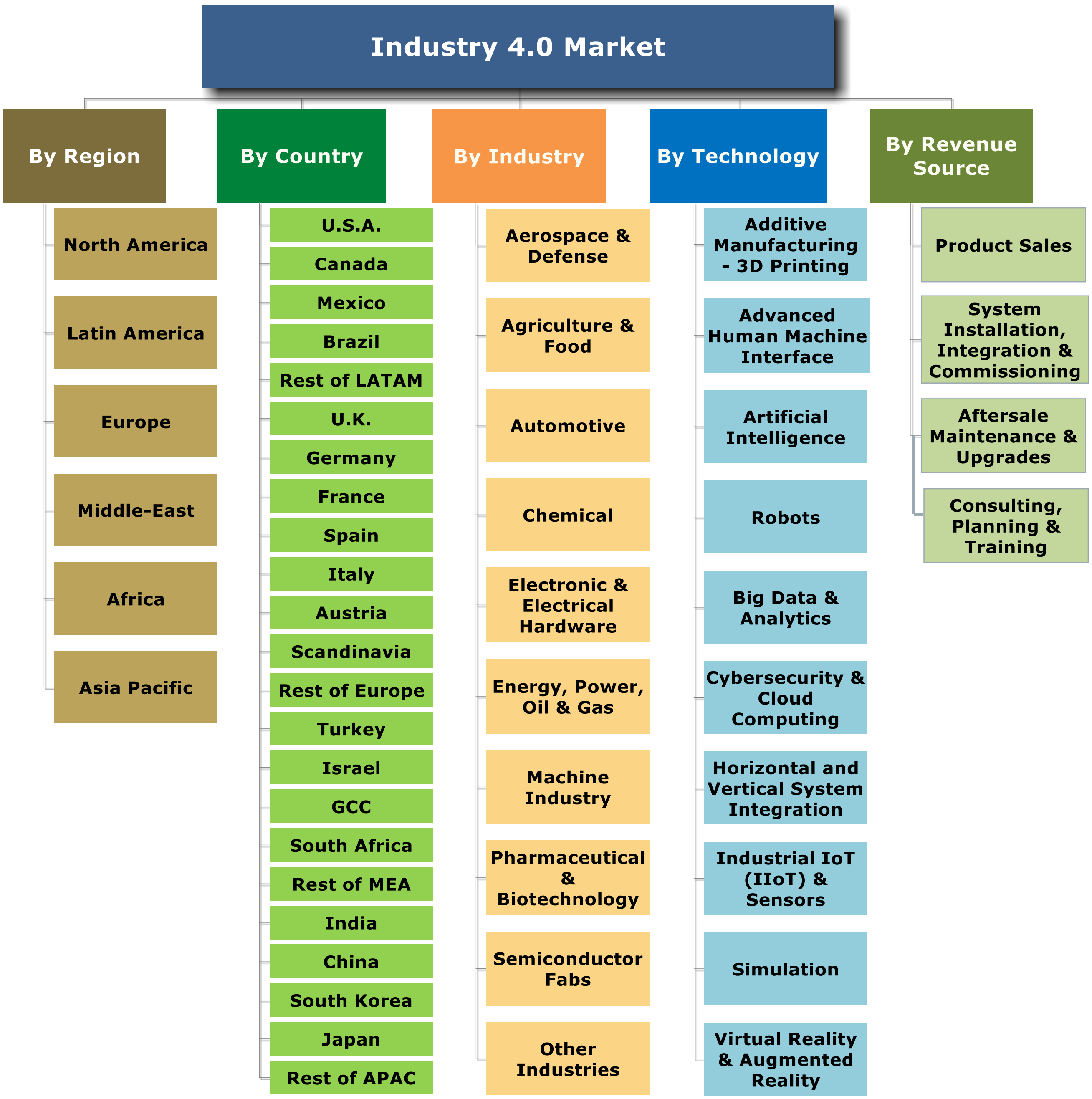
Figure 9 - Industry 4.0 Eco-System



Source: HPE

5 Industry 4.0 Research Vectors

Figure 10 - Global Industry 4.0 Market Vectors



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