Industry 4.0

The Future of Indo-German
Industrial Collaboration

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Executive summary

Industry 4.0 can be described as the fourth industrial revolution, a mega-trend that affects every company around the world. It envisions interconnections and collaboration between people, products and machines within and across enterprises.

Why does Industry 4.0 make for an excellent platform for industrial collaboration between India and Germany? The answers lie in economic as well as social factors. Both countries have strengths and weakness and strategic collaboration using the principles of Industry 4.0 can help both increase their industrial output, GDP and make optimal use of human resources.

As a global heavy weight in manufacturing and machine export, Germany has a leading position in the development and deployment of Industry 4.0 concepts and technology. However, its IT sector, formed by a labor force of 800,000 employees, is not enough. It needs more professionals to reach its full potential. India, on the other hand, is a global leader in IT and business process outsourcing. But its manufacturing industry needs to grow significantly and compete globally.

These realities clearly show the need for Industry 4.0-based collaboration between Germany and India.

So how does Industry 4.0 work? In a first step, we look at the technical perspective – the vertical and horizontal integration of Industry 4.0 principles in enterprises. Vertical integration refers to operations within Smart Factories and horizontal integration to Smart Supply Chains across businesses.

In the second step, we look at manufacturing, chemical industry and the IT sector as potential targets for collaboration between the two countries. We use case studies to illustrate the benefits of the deployment of Industry 4.0. Potential collaboration patterns are discussed along different forms of value chains and along companies' ability to achieve Industry 4.0 status.

We analyse the social impact of Industry 4.0 on India and Germany and find that it works very well in the coming years. Germany with its dwindling labor force might be compensated through the automation. This will ensure continued high productivity levels and rise in GDP.

India, on the other hand has a burgeoning labor market, with 10 million workers annually entering the job market. Given that the manufacturing sector will be at par with Europe in efficiency and costs by 2023, pressure on India's labor force will increase even more. Even its robust IT sector will suffer fewer hires because of increased automation. Rapid development of technologies – for the Internet of Things (IoT) or for connectivity like Low-Power WAN – makes skilling and reskilling of the labor force critical for augmenting smart manufacturing.

India and Germany have been collaborating at three levels relevant to Industry 4.0 – industry, government and academics. How can these be taken forward?

The two countries have a long history of trade. The Indo-German Chamber of Commerce (IGCC) is the largest such chamber in India and the largest German chamber worldwide. VDMA (Verband Deutscher Maschinen- und Anlagenbau, Mechanical Engineering Industry Association), the largest industry association in Europe, maintains offices in India. Indian key players in IT, in turn, have subsidiaries in Germany and cooperate with German companies in the area of Industry 4.0.

Collaboration is also supported on governmental level. As government initiatives go, India has launched the "Make in India" initiative and the "Make in India Mittelstand! (MIIM)" programme as a part of it.
The Indian Government is also supporting "smart manufacturing" initiatives in a major way. Centers of Excellence driven by the industry and academic bodies are being set up.

Germany and India have a long tradition of research collaboration as well. Germany is the second scientific collaborator of India and Indian students form the third largest group of foreign students in Germany. German institutions like the German Academic Exchange Service (DAAD) or the German House for Research and Innovation (DWIH) are working to strengthen ties between the scientific communities of the two countries, and between their academia and industry.

What prevents Industry 4.0 from becoming a more widely used technology? Recent surveys in Germany and India show that awareness about Industry 4.0 is still low, especially among small and medium manufacturing enterprises. IT companies, on the other hand, are better prepared.

There is a broad demand for support, regarding customtailored solutions, information on case studies and the willingness to participate in Industry 4.0 pilot projects and to engage in its platform and networking activities. We also found similar responses at workshops conducted with Industry 4.0 stakeholders in June 2017 in Bangalore and Pune and in an online survey.

What can be done to change this? Both countries should strengthen their efforts to create awareness for Industry 4.0, especially among small and medium enterprises. Germany should also put more emphasis on making their Industry 4.0 technology known to the Indian market. India's IT giants, on the other hand, should make their Industry 4.0 offers more visible to the German market.

The governments should support the establishing of joint Industry 4.0 collaboration platforms, centers of excellence and incubators to ease the dissemination of knowledge and technology.

On academic level, joint research programs and exchange programs should be set up to foster the skilling of labor force in the deployment of Industry 4.0 methods and technologies.

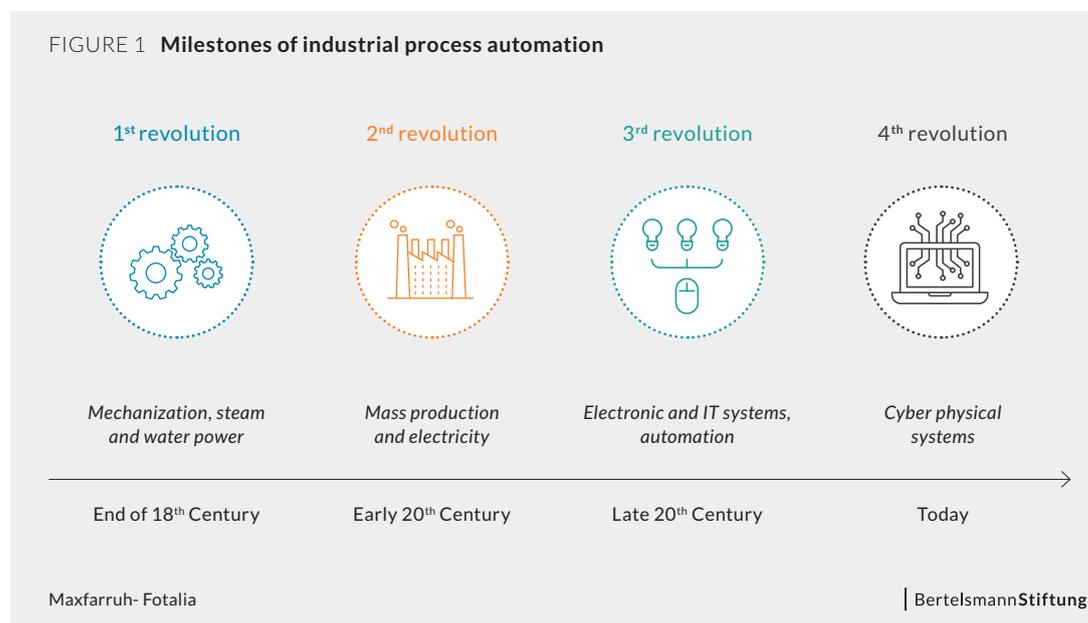# 1 Potential areas for collaboration in Industry 4.0

The world is currently witnessing Industry 4.0, the fourth industrial revolution. The first took place in the 18th century, with the arrival of mechanical weaving looms. The second, between 19th and early 20th century, was characterized by mass production using electric conveyor belts. The third came in the 1970s with automation of production using information technology and computerized control.

The current industrial revolution started at the start of this millennium with production monitoring and automation using cyber-physical systems, the Internet of Things (IoT) and the Internet of Services (IoS). This digitization enables the integration of processes and systems across companies and industrial sectors.

through to outbound logistics." [KaWH13]. Unfortunately, Industry 4.0 is used more as a marketing term than a scientific concept or paradigm.

Digitization, however, is a global trend. Other economies too have coined different terms for similar developments. The US enterprise General Electric initiated the Industrial Internet initiative [EvAn12], which was taken up by the US American government and the Industrial Internet Consortium[1] and tries to establish standards for the horizontal and vertical integration of processes. China calls its Industry 4.0 "Made in China 2025".[2]

Germany, as one of the global industry leaders, is in pole position to grab the best Industry 4.0 solutions.

FIGURE 1 **Milestones of industrial process automation**

1st revolution	2nd revolution	3rd revolution	4th revolution
Mechanization, steam and water power	Mass production and electricity	Electronic and IT systems, automation	Cyber physical systems
End of 18th Century	Early 20th Century	Late 20th Century	Today

Maxfarruh- Fotalia

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In Germany, the term "Industrie 4.0" was brought in in 2011 to strengthen the country's industry. The German government funded the initiative as the backbone of its strategy to digitize industry. Its philosophy is that "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

It is the largest economies in Europe and on the global scale, its GDP ranks fifth behind China, USA, India and Japan.[3] More than half its GDP comes from industrial production and production-related services. Germany also has the lead in many digital innovations in production technology [BMWi16]. However, given that Industry 4.0 is largely IT-driven, a labor force of 800,000 employees in Germany's IT[4] sector is not enough.

India, on the other hand, as the second largest country in the world (population: over 1.2 billion), needs to strengthen its industrial sector to improve its competitiveness, meet growth targets and provide employment to the 10 million youth who join its workforce every year. But India's advantage is that it has more than 1.7 million software developers[5], twice the number Germany has.

Industry 4.0 could offer a prime platform for strategic cooperation that could help them realign their global positions to maximum advantage.

The Department of Electronics & Information Technology of India published the IoT policy estimating that the industry will grow to INR 940 billion by 2020. Focus areas include agriculture, health, water quality, natural disaster, transportation, security, automobile, supply chain management, smart cities, automated metering and monitoring of utilities, waste management, oil and gas.

Cisco estimates that all IoE pillars – Internet of things, Internet of people, Internet of data, and Internet of Process – for India have a value at stake (VAS) of INR 31.880 trillion (about half a trillion U.S. dollars) for the next ten years. Of this, INR 7.263 trillion is in the public sector and INR 24.616 trillion in the private sector.

We now look at Industry 4.0 from a technical perspective to establish the basis for the collaboration opportunities discussed later.

1.1 Industry *4.0* – Technical perspective

Smart Factories are at the core of the vision of Industry 4.0. which addresses both, the vertical and horizontal integration of production processes.

Let us take a close look at the ideas underlying Smart Factories or vertical integration within an enterprise. There is now a greater understanding that data is a valuable asset. This has inspired the vision of the Industrial Data Space as a trusted field for the exchange of information across company boundaries. Such a solution is a prerequisite for the horizontal integration of Smart Factories in smart supply chains.

Vertical Integration – Smart Factories

In Industry 3.0, automation of production processes applied a hierarchical approach, represented by the "automation pyramid". This pyramid works over various levels: physical production processes, supervisory control and data acquisition (SCADA),

production control, and enterprise processes related to production scheduling and resource planning.

In Industry 4.0, this hierarchy is split and the functionality shifted between levels. The Reference Architecture Model for Industry 4.0 (RAMI 4.0) [IEC17] integrates the aspects of
· *product life cycle* – from product development to after-sales services,
· *system architecture* – from business processes to physical production processes on a plant floor, and
· production automation hierarchy, according to international standards for enterprise-control system integration and for describing equipment and procedures in process control.

Smart Factories, according to this model, are regarded as Cyber-Physical Production Systems (CPPS) [KaWH13] in which "intelligent" machines, storage systems, equipment and products communicate directly to exchange information and trigger actions and to control each other autonomously.

A digital Administration Shell was brought in to ease the integration of components into an Industry 4.0 environment. It also visualized a physical entity providing for a standardized communication interface for storing all data and information about the asset.

Horizontal Integration – Industrial Data Space

The Industrial Data Space, as explained before, provides a secure space for the exchange of data between enterprises of different branches and different sizes without losing their sovereignty on their data. This addresses the horizontal integration of processes across enterprises [Otto16]. This space forms an integral part of the German high-tech strategy.

Secure data exchange is a prerequisite for smart services, innovative service offers and business process automation. The Industrial Data Space provides services that comprise, for instance, anonymization of data, integration services or the setting of expiring dates for data usage.

The basis for this is a reference architecture model developed jointly by 12 Fraunhofer institutes and industry partners under Prof Boris Otto, Fraunhofer ISST, and funded by the German Ministry for Education and Research. It is backed also by the Fraunhofer Gesellschaft and by the registered Industrial Data Space Association with more than 80 members. Among these members are key players of the German industry, including associations and organizations from Europe and from Asia.

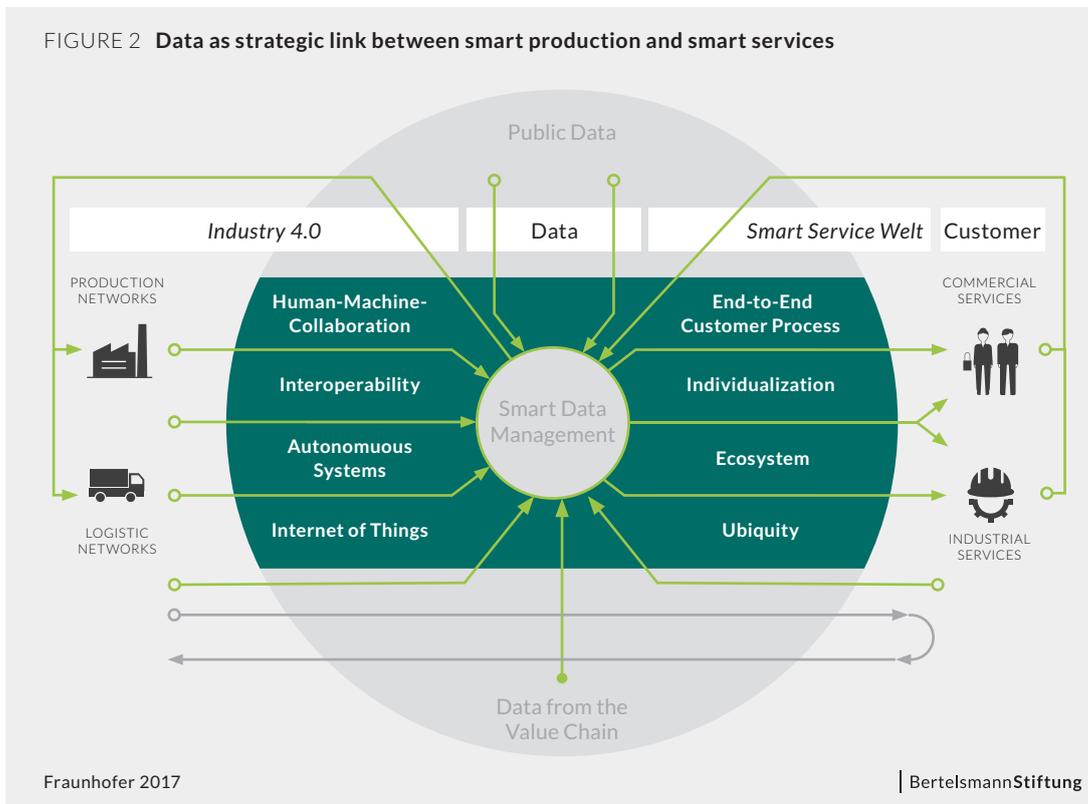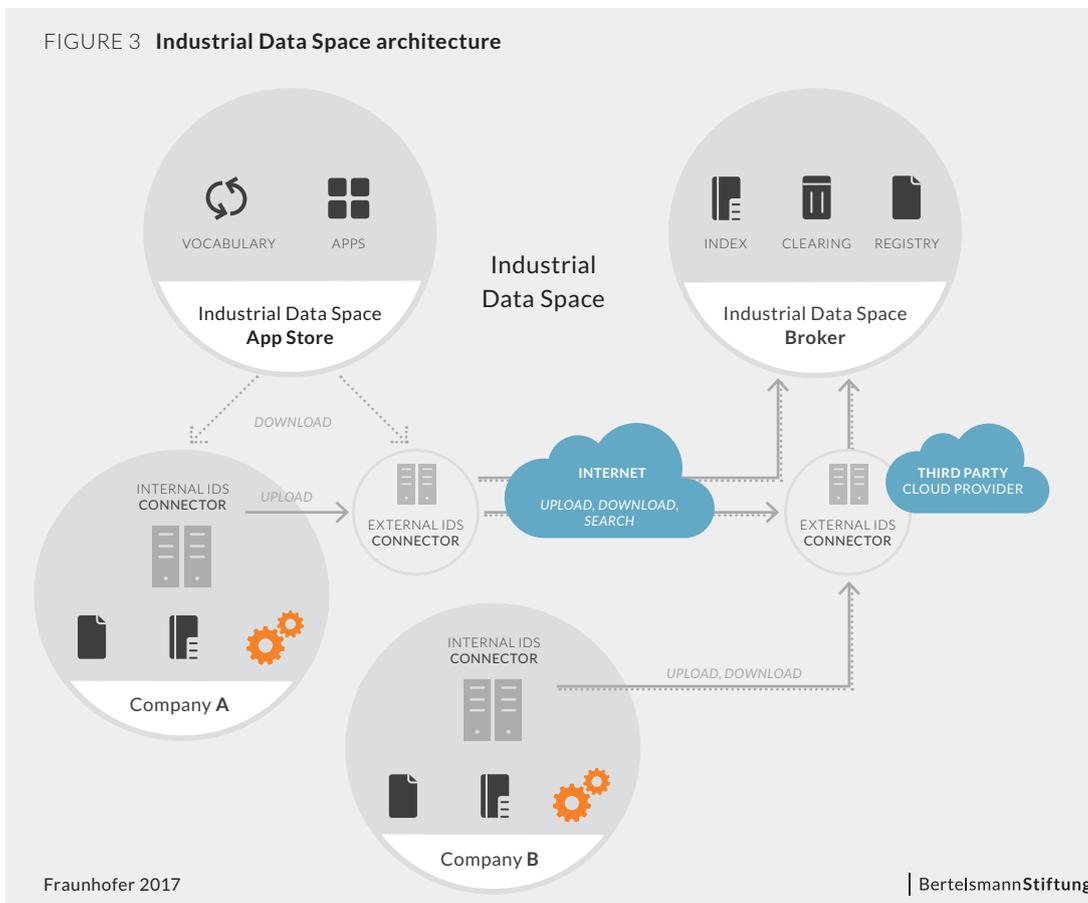FIGURE 2 **Data as strategic link between smart production and smart services**

Public Data

Industry 4.0   Data   *Smart Service Welt*   Customer

PRODUCTION NETWORKS

Human-Machine-Collaboration

Interoperability

Autonomuous Systems

Internet of Things

Smart Data Management

End-to-End Customer Process

Individualization

Ecosystem

Ubiquity

COMMERCIAL SERVICES

LOGISTIC NETWORKS

INDUSTRIAL SERVICES

Data from the Value Chain

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FIGURE 3 **Industrial Data Space architecture**

VOCABULARY   APPS

Industrial Data Space **App Store**

Industrial Data Space

INDEX   CLEARING   REGISTRY

Industrial Data Space **Broker**

DOWNLOAD

INTERNAL IDS **CONNECTOR**

UPLOAD

EXTERNAL IDS **CONNECTOR**

INTERNET
UPLOAD, DOWNLOAD, SEARCH

EXTERNAL IDS **CONNECTOR**

THIRD PARTY CLOUD PROVIDER

Company **A**

INTERNAL IDS **CONNECTOR**

UPLOAD, DOWNLOAD

Company **B**

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The Industrial Data Space consists of a set of all connectors, brokers, a clearinghouse, a registry and an app store. A connector provides a standardized interface for participating companies. It is an access point, enables controlled supply of one's own data as well as authorized access to that of other participants.

This means that it is not a centralized data repository but a data broker that enables secure information exchange between trusted parties without storing it.

1.2 Targets for collaboration

Globalization and digitization are megatrends that affect every company around the globe. Supply chains stretch across continents, requiring increasing transparency and flexibility in dealing with risks and problems. These could have an impact on Indo-German trade and business relations.

In 2015, India was Partner Country of the Hannover Messe. At this occasion, a study "Prospects for Indo-German Collaboration in High-Technology Manufacturing" [GaMu15] was conducted to identify collaboration opportunities. It evaluated 13 potential industry sectors.

In the context of Industry 4.0, we look at Indo-German trade figures with a focus on related technologies and potential application domains.

For a long time, the key areas of collaboration were machinery, electro-technology and chemistry. More recently, information technology has also become a substantial factor.

Imports and exports in these areas have steadily increased in both directions. Hence, they are considered most promising for a closer Indo-German collaboration under Industry 4.0.
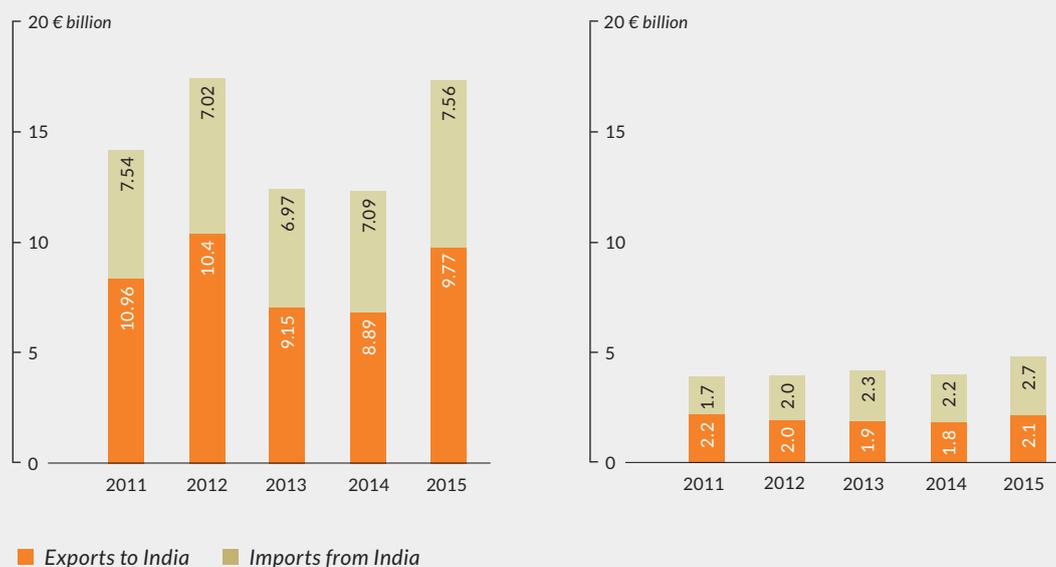
Manufacturing

Manufacturing is the primary target sector for Industry 4.0. It is also one of the most important sectors of the German as well as Indian economy. Machinery and the automotive sector are the major manufacturing activities in both countries.

Germany

Manufacturing is key to the German economy. More than 36,000 enterprises with 5 million employees achieve a turnover of 1.4 billion Euros [VDMA16]. In 2015, the manufacturing share in Germany's GDP was 21 percent. In manufacturing, machinery and equipment take the first place with a share of 19 percent[7]. On a global scale, Germany's manufacturing industry ranks fourth behind China, USA and Japan.[8]

Indo-German collaboration in the domain of manufacturing has a long history. Siemens, for

FIGURE 4 **Indo-German merchandise & service trade[6], 2011–2015**

20 € billion

2011	Imports: 7.54	Exports: 10.96	
2012	Imports: 7.02	Exports: 10.4	
2013	Imports: 6.97	Exports: 9.15	
2014	Imports: 7.09	Exports: 8.89	
2015	Imports: 7.56	Exports: 9.77	

20 € billion

2011	Exports: 2.2	Imports: 1.7	
2012	Exports: 2.0	Imports: 2.0	
2013	Exports: 1.9	Imports: 2.3	
2014	Exports: 1.8	Imports: 2.2	
2015	Exports: 2.1	Imports: 2.7	

■ *Exports to India* ■ *Imports from India*

Destatis (2016)

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instance, has set up the Siemens Engineering & Manufacturing Co. of India Pvt. Ltd. in 1961.[9] Today, Siemens runs 22 manufacturing plants and employs about 16,000 people in India.

Another example is Schaeffler, one of the world's largest technology companies with family ownership. FAG, INA and LuK brands that form the Schaeffler Group are all present in India.[10] FAG Bearings India Limited was already incorporated in 1962. LuK was set up as a joint venture between Rane and LuK (Rane LuK Clutch Ltd.) in 1996 and INA Bearings India Pvt. Ltd. was incorporated in 1998 with the first office in Pune opened in 2001.

Trumpf, one of the world's leading companies for machine tools, laser technology, and electronics for industrial applications, is another family-owned company in the manufacturing domain. It established its India business in Pune more than ten years ago.[11]

Bosch is one of the leading German companies to have focused on creating products for the Indian market. The development of a common railing system for Tata Nano is an excellent example of R&D in the Indian context.

India

India is striving to strengthen its manufacturing industry. The Indian government has defined the National Manufacturing Policy that aims at increasing the share of manufacturing in the country's Gross Domestic Product from 16 percent to 25 percent by 2022.

The government also aims at creating 100 million additional jobs by 2022 in manufacturing sector[12]. Besides Defense, Heavy Equipment and Machine Tools is considered a key sector for India's manufacturing

industry. It is estimated to be worth USD 2 trillion by 2018[13].

Micro, small and medium enterprises (MSME sector) are the backbone of India's economy. They constitute about 80 percent of the total number of industries in India and produce about 8,000 value added products [Das17].

According to the Annual Report 2015–2016 of the Ministry of MSMEs [MSME16] the manufacturing sector's share in India's GDP is 7.04 percent. And MSMEs make up for 37.33 percent of the total manufacturing output.

To achieve the defined goals the "Make in India" initiative has been launched. Its aim is to bring in increased foreign investment in terms of finance and technology into the manufacturing sector. The initiatives include activities to foster the adoption of Industry 4.0 in India's manufacturing industry[15]. The Government has initiated a series of steps to correct some of its past policy and regulatory climate that deterred investment and technology upgradation.

The outreach also includes increased Public-Private Partnership Programmes to motivate the industry and research institutions to collaborate, and catalyze the manufacturing capability.

The productivity of India's manufacturing sector is low for several reasons. The relatively small size of manufacturing firms makes it difficult to exploit economies of scale. Though India has some inherent strengths of human resource capital, its manufacturing is surprisingly capital and skill intensive. Complex labor regulations, difficulty in land acquisition and infrastructural bottlenecks such as frequent power outages and poor transport add to the problem.

However, government impetus has resulted in developing a growth-friendly ecosystem. For example, the Indian Institute of Science (IISc) is building India's first smart factory in Bengaluru. At the Make in India Conference – 'Karnataka Calling' in Bengaluru on 13th and 14th February 2017 – a Memorandum of Understanding (MoU) was signed between the state and central government to set up India's first integrated machine tools park in Tumkur.[16]

Fraunhofer has signed an MoU with the Ministry of Heavy Industries to be the "Technology Resource Partner for Manufacturing in India". The objective is to support the upgradation of Innovation and R&D capability in the field of manufacturing in the Indian industry, both public and private sector. This initiative supports the Make In India Programme, as it aims to develop a strong supply chain in India to scale up operations.

TABLE 1 **Definition of manufacturing MSME in India (Development Commission – MSME, Ministry of MSME)**

	Min *	Max *
Micro Enterprise		2.5 Mio. INR (34,043 EUR[13])
Small Enterprise	2.5 Mio. INR (34,043 EUR)	50 Mio. INR (680.866 EUR)
Medium Enterprise	50 Mio. INR (680.866 EUR)	100 Mio. INR (1,36 Mio. EUR)

* Investment in plant & machinery

Development Commissioner (MSME), Ministry of MSM | Bertelsmann**Stiftung**

As a first step, collaborations have been inked with public sector companies such as Hindustan Machine Tools (HMT) and Bharat Heavy Electricals Ltd (BHEL). Excellence Centers have been set up in clusters in Belgaum and Coimbatore. India today lacks critical technologies in the manufacturing value chain, rendering it extremely dependent on countries like China.

Chemical industry

The chemical industry is an important segment of Germany's and India's manufacturing sector. It is also a part of Indo-German trade relationships for more than a century. It can play an important role in Industry 4.0 in both countries, for example by establishing smart supply chains.

Germany

The chemical industry in Germany, comprising more than 3,800 enterprises with 332.000 employees, achieved a turnover of 142,373.2 million Euros in 2015 [VCI16]. Exports made up 76 percent of this. On a global scale, Germany's chemical industry had a global share of 4.2 percent in 2015 in terms of turnover. This puts it at No. 3, behind China and the USA.

In exports, Germany with a global share of 9.9 percent, ranks second behind the USA.

Export volume to India was 1,485.4 million Euros with a focus on petro-chemicals and special chemicals, representing a share of 1.4 percent of the total export volume. On the other hand, imports from India totaled 968 million Euros. The biggest shares of this are inorganic chemicals and petrochemical products, followed by polymers.

The German chemical-pharmaceutical industry invested 708 million Euros in India (2014). In total 54 enterprises with 25,000 employees generated a turnover of 3.9 billion Euros (2014). Key investors are BASF, Henkel and Wacker Metroark.

BASF started its Indian business with first sales in 1890. In 1967, BASF India Limited was founded,[17] a public limited company with 73.33 percent of shares held by BASF SE. Since then it has begun or expanded production in Tamil Nadu, Gujarat, Maharashtra, Andhra Pradesh and West Bengal, resulting in nine production sites, eight sales offices with more than 2,200 employees, generating a turnover of 1.088 Euro billion (2014). Areawise, the Mangalore site is BASF's largest manufacturing site in South Asia. BASF also maintains two R&D centers in India, in Mumbai and Mangalore, a part of its global technology platform.

Henkel has been in India since end 1996.[18] The headquarter is located in Navi Mumbai, manufacturing sites, offices and SKP Academies are in Mumbai, Chennai, Gurgaon, Himachal Pradesh, Pune, Udham Singh Nagar, New Delhi, Kolkata and Bangalore.

Wacker Chemie AG, headquartered in Munich (Germany), founded Wacker Metroark Chemicals Private Limited in Kolkata in 1998.[19] The company has its registered office and a manufacturing unit near Kolkata and branch offices in Delhi, Mumbai, Chennai and Bangalore.

India

In terms of output, India is the seventh largest producer of chemicals worldwide and third largest producer in Asia. The estimated size of Indian chemicals sector stands at approximately USD 139 billion.[20] India's export of chemicals reached USD 35,945.8 million in 2015, representing a 13.6 percent export share.[21]

Chemicals and chemical products are the most important manufacturing activities (16 percent), followed by coke, refined petroleum products, nuclear fuel (13 percent) and basic metals (11 percent).[22] The volume of chemicals and chemical products account for 2 percent of India's GDP.

Hundred percent Foreign Direct Investment (FDI) is allowed under the automatic route in the chemicals sector, subject to all the applicable regulations and laws.

IT industry

Information technology is a key element of Industry 4.0. Smart sensors and embedded systems are needed for gathering information at the plant floor level and for transferring these data in realtime to control systems and decision support systems on higher levels. This is necessary to implement the Internet of Things and the Internet of Services as constituent parts of Industry 4.0. Companies in Germany and India work at the leading edge on the development of these technologies.

Germany

Although Germany has had a strong history in coal, iron and steel, IT's market volume has significantly increased to 83.7 billion Euros in 2016. The sector is formed by more than 87,000 enterprises with about 1 million employees. About 96 percent of these enterprises make revenues of less than 1 million Euros per year.[23] Only a few have entered the Indian market with offices or subsidiaries there.

SAP, the world's leading provider of business software solutions, headquartered in Walldorf (Germany) has set up its India operation in 1996 with headquarters in Bangalore and offices in Mumbai, New Delhi, Kolkata, and a direct presence in nine cities across India.[24] In 1998 SAP Labs India were founded, representing today SAP's largest Research and Development center outside of Germany. Almost 6,500 employees work in three labs in India (Bangalore, Gurgaon and Pune) on core solutions, product localization and India specific solutions.

India

The IT industry in India has two major components: IT services and business process outsourcing (BPO), with India as No. 1 sourcing location.[25]

The sector is the largest private sector employer, providing 3.7 million jobs in more than 16,000 enterprises. These enterprises generate a turnover of around USD 160 billion, accounting for 9.3 percent of India's GDP. Exports have reached USD 107.8 billion, representing a 45 percent share in India's services export.[26]

Key players in the sector are Tata Consultancy Services, Wipro Technologies, Infosys Technologies, all among TOP 50 largest companies in India. Tata Consultancy Services ranks first as largest Indian company by market capitalization (Rs 475,523.38 cr.).[27] In this category, Infosys ranks 8th and Wipro 21st.

All three companies have been present in Germany for years, with headquarters in Frankfurt/ Main. With more than 360,000 employees, Tata Consultancy Services is active in 45 countries and its operation in Germany started in 1991. A European Solution Center has been established in Düsseldorf. Infosys has also been present in Germany since 1999 with offices in Stuttgart, Munich and Walldorf. Wipro has subsidiaries in Meerbusch, Kiel and Munich.

According to an article by CISCO, countries like India and China are fast-tracking the transition from measured growth and limited connectivity to hyper-growth. Today's innovators, however, are using ICT to completely rethink how they use information, and designing new business models and new capabilities that integrate dispersed partners and co-workers. This has resulted in the creation of disruptive and innovative solutions.

The E-Chaupal is designed to give farmers real time information, services, timely and relevant weather information, transparent price discovery and access to wider markets – all through a mobile device

that feeds off a wider network. This has helped roughly 4 million farmers better at managing risk.

Such models using ICT and attendant technologies can forge the rapid development of solutions and processes. This presupposes capability for not only service but also product development. However, in terms of innovation and product development in IT, India still needs to make huge strides to compete with some of the developed countries. Hence, this area could be a strong contender for joint projects between Germany and India.

1.3 Case studies

The German Platform Industry 4.0 provides a map and list of 154 German examples for Industry 4.0.[28] Here, we take a brief look at two examples, one each for vertical and horizontal integration.

Vertical integration in manufacturing: monitoring of machines

Schaeffler is a German technology company with a focus on automotive and industrial supply. FAG, one of Schaeffler's brands, has developed the condition monitoring system FAG SmartCheck.

PICTURE 1 **Coating machine with condition monitoring at Mitsubishi, Bielefeld**

This is a compact, innovative, modular online measuring system for continuous monitoring of machinery and process parameters on a decentralized basis. FAG SmartCheck is suitable, for example, for early detection of rolling bearing damage, imbalances and

misalignments. The data are recorded and analyzed centrally by the system. The current machine condition can be displayed directly on the device or transferred to any control facility as required. To this end, FAG SmartCheck can be integrated in the existing network structure. Typical fields of application for FAG SmartCheck are motors, pumps, compressors, ventilators, fans and or gearboxes.

Mitsubishi HiTec Paper Europe GmbH is a global supplier of special thermal papers that are manufactured in Bielefeld and Flensburg, Germany. The thermal paper is produced by coating paper in a coating machine. The coating machine transports the paper at a speed of 1,730 m/min and 26 fan units dry the paper without being touched. The machine has now been equipped with 26 FAG SmartCheck systems to monitor these fans to provide an initial warning up to three months in advance of any impending trouble. This is a decisive step towards Industry 4.0 as the solution enables forwarding of information from the field-level to control level, MES to the ERP system.[29]

Horizontal integration in supply chain management: flexible yard management

thyssenkrupp Steel Europe is one of the world's leading suppliers of high-grade flat steel. At its main location in Duisburg, Europe's biggest steelmaking location, about 20,000 trucks are handled every month. Each truck has a window of 30 minutes for

PICTURE 2 **Driver mobile app for estimated time of arrival reporting**

loading/unloading. Any deviation from preplanned schedules causes rescheduling and delays.

To increase the flexibility of the current yard management thyssenkrupp has implemented the first application for the Industrial Data Space (see section 1.1.2). Based on positional and traffic data and the routes the driver is likely to take, an algorithm immediately recognizes any holdups and the computer system then automatically suggests a new loading slot.[30]

1.4 How collaborations can be designed

Potential areas of collaboration could be activities in the area of Smart Factories. Collaboration can be regarded from a value chain as well as technical perspective. We take both views.

Collaboration in value chains

We discuss different value chain scenarios for vertical and horizontal integration on the next page. So far, the described scenarios are mainly fictional. However, there is a broad range of candidates for the implementation of the scenarios, taking the companies mentioned in section 1.2 as examples.

How to judge a company's readiness for Industry 4.0

Here we look at the capabilities required of the stakeholders who intend to collaborate. For the design principles of collaborations, various scenarios have been identified taking into account organizational and technical aspects [HePO16].

Figure 5 shows the four principles. Interconnection of people and objects is a pre-requisite and this means that standards for communication and data exchange are key. As wireless communication gains more momentum in smart factories, security becomes critical.

Cyber-physical, the fusion of the physical and the virtual world, provides the opportunity of gathering more and more data, resulting in a new quality of information transparency. Aggregation, analysis and exploration of data by means of data analytics and machine learning methods are critical elements.

The deployment of cyber-physical systems requires human decisions made using aggregated and visualized information. On the other hand, technical progress in robotics provides physical assistance to human workers.

Indian Original Equipment Manufacturer (OEM) with German supplier (machinery)

The German supplier provides Industry 4.0-compliant production machines from their German manufacturing site. These machines are smart enough to monitor operations and to report status information to the German supplier's cloud. This could, for example, help in predictive maintenance. On the other hand, the machines are able to communicate with Industry 4.0 compliant objects in their new environment. This means that they can automatically adjust processing parameters to the needs of a product to be handled next. These automatic adjustments avoid human errors and reduce machine set-up times.

To implement predictive maintenance the German manufacturing site provides its machines with sensors and interfaces to communication channels like WLAN and Internet access. This enables the transfer of status information from the machines to the predictive maintenance application in the supplier's cloud. On the other hand, the Indian OEM provides an interface to receive maintenance notifications from the German supplier. The Indian OEM uses Industry 4.0 compliant objects that interface with the German machines. For example, it deploys smart products and vehicles that know which products they transport to inform the machine about the processing parameters required.

A practical example for this scenario is TrueConnect, provided by Trumpf.[31] TrueConnect provides connectivity of Trumpf machines, lasers and laser systems to a company network or to the cloud to enhance availability through intelligent maintenance strategies.

German OEM in India with local supplier (IoT)

The German OEM has set up a manufacturing site in India that implements Industry 4.0. Smart machines and autonomous vehicles that transport products in different states of processing between the machines conduct flexible manufacturing processes. Status information on machines and vehicles is continuously collected for data analysis.

Production process control and process monitoring is performed by means of IoT devices from an Indian supplier. Deployed in machines and vehicles, these

devices implement Administration Shells to enable information exchange between these elements and the Big Data application.

German OEM in Germany with Indian supplier (parts)

The German OEM operates an Industry 4.0-compliant plant with flexible manufacturing cells. The resulting products are systemcritical components of machines. Customers hence require a complete documentation of the parts used and their production. The OEM receives Industry 4.0-compliant parts from an Indian supplier.

Each part has a unique identification, is part of an identified charge, knows its history and comes with the required documentation in electronic form (e.g. composition of materials, certificates). These parts are packed in groups according to production orders and Industry 4.0-compliant containers are used that know the OEM's order number and the material data of the parts. To enable this packing, the OEM transfers the necessary order information via a secure communication channel to the Indian supplier.

Upon arrival at the OEM's plant, autonomous vehicles take the containers and transport them into a storage area. In the storage area, documentation is transferred to the OEM's document management. From the storage area, the containers are transported to production. When it arrives at a manufacturing cell a container communicates to it the parts data for automatic adjustment of processing parameters.
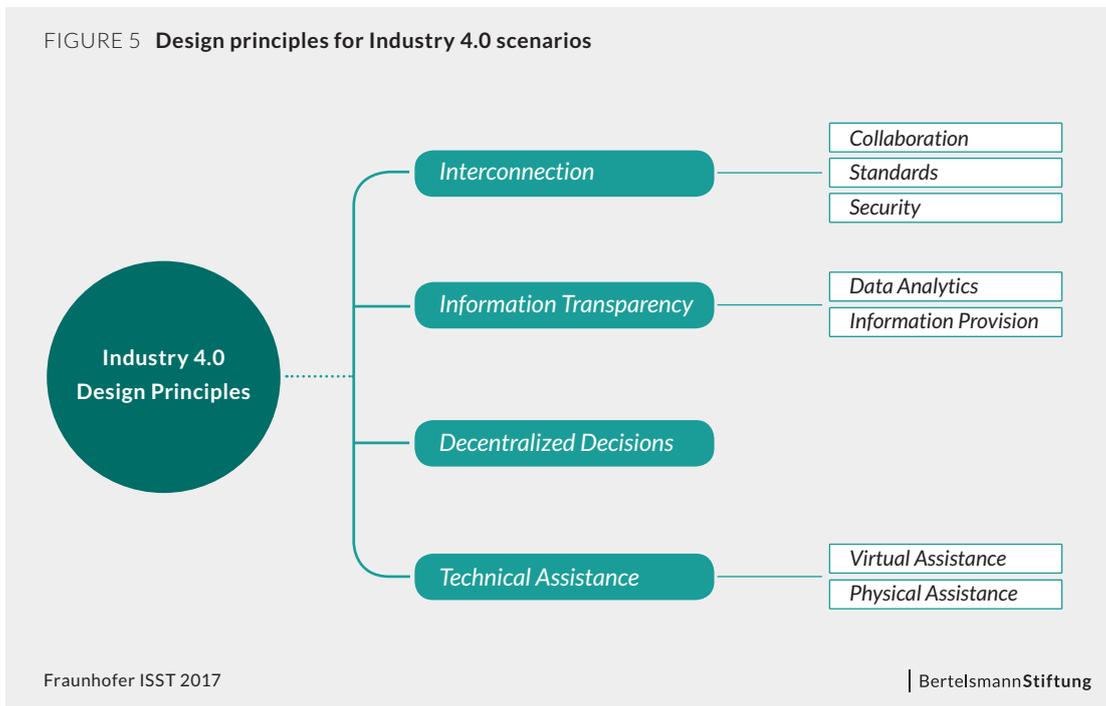
German OEM with global suppliers and Indian service provider

A German OEM operates Industry 4.0-compliant plants in different countries with suppliers of parts and machinery from all over the world. An Indian service provider performs monitoring of production processes.

Status information and events are reported from the plants to the cloud of the Indian service provider. Cloud applications analyze the data and optimize production by scheduling orders between the plants and by directing the parts from the different suppliers to the plants where they are needed.

Industry 4.0
Design Principles

Interconnection

Collaboration
Standards
Security

Information Transparency

Data Analytics
Information Provision

Decentralized Decisions

Technical Assistance

Virtual Assistance
Physical Assistance

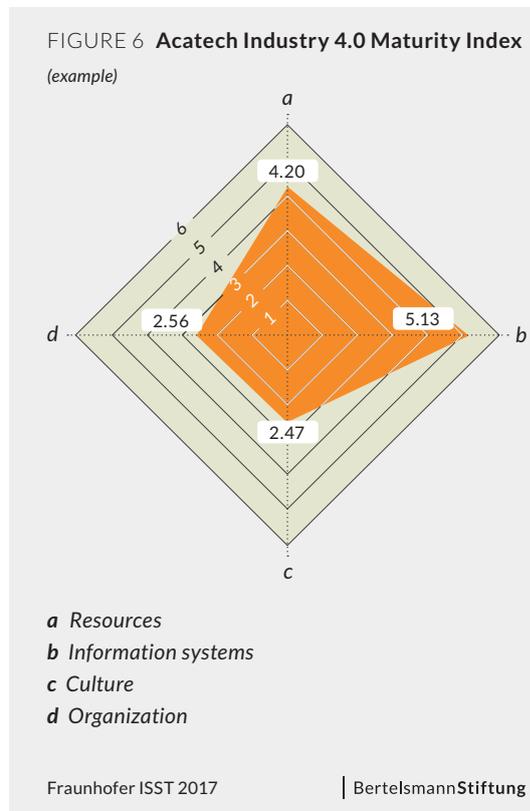Fraunhofer ISST 2017 | BertelsmannStiftung

There is also an effort to develop assessment methods to judge a company's readiness for Industry 4.0. These apply a combination of heuristics and formal methods. The basic idea behind this concept is to determine a company's status, identify gaps to excellence and derive measures to close them.

The most recent approach is the acatech Industry 4.0 Maturity Index presented at the Hannover Messe 2017.[32] It indicates the status quo of a company's Industry 4.0 competencies from a technological, organizational and cultural perspective.

This index provides room for collaboration. Experts from Germany and Infosys (India) involved in its development can apply the method to companies in both countries. The closing of gaps identified then provides more collaboration opportunities. While German companies can provide Industry 4.0 ready machinery, India's large IT companies are predestined to take over the enhancement of IT infrastructure and services from IoT level up to cloud services.

FIGURE 6   **Acatech Industry 4.0 Maturity Index**
(example)

a Resources
b Information systems
c Culture
d Organization

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2 Social impact of Industry 4.0

The social impact of Industry 4.0 including impact on employment figures, work organization and human roles have been studied. We look at these issues from the perspective of both Germany and India.

2.1 Impact on Germany

Germany has a labor force of 43.5 million (2016).[33] Of this, manufacturing has a share of 5.25 million employees [VDMA17], the chemical and pharmaceutical industry almost 450,000 [VCI16] and information and telecommunication industries about 1 million.

According to the Federal Statistical Office of Germany, the GDP for 2016 was 2,821 billion EUR[34]. The figure below shows the shares of industry sectors in it. The German GDP in 2016 ranks 5th place behind China, USA, India and Japan. Its growth rate is 1.7 percent.

FIGURE 7 **Industry sector shares of the German GDP, 2016** *(in percent)*
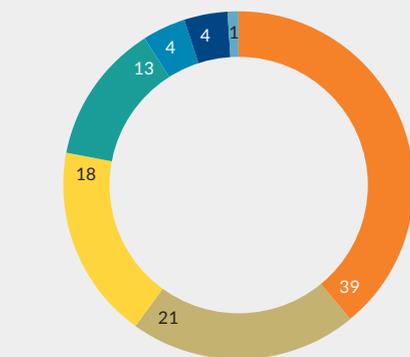
- ■ *Service industries*
- ■ *Industry excluding construction*
- ■ *including: Manufacturing*
- ■ *Trade, transport, accommodation and food services*
- ■ *Construction*
- ■ *Information and communication*
- ■ *Agriculture, forestry and fishing*

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A recent study by Bitkom outlines a business potential of 78.77 billion EUR for Industry 4.0 in Germany until 2025 [Baue14]. The study focuses on the chemical industry, automobiles and parts, mechanical engineering and electrical and optical components as the strongest sectors. These have total share of about 10 percent in the German GDP.

In addition, agriculture, forestry and fishing as well as the information and communication industry sector are considered. The following figure depicts the Industry 4.0-based growth potential for select industry sectors for 2013–2025.

FIGURE 8 **Industry 4.0 based growth potential for 2013 to 2025 for selected German industry sectors** *(in percent)*

Chemical industry — 30
Mechanical engineering — 30
Electrical equipment — 30
Automobiles & parts — 20
Agriculture, forestry and fishing — 15
Information & communication — 15
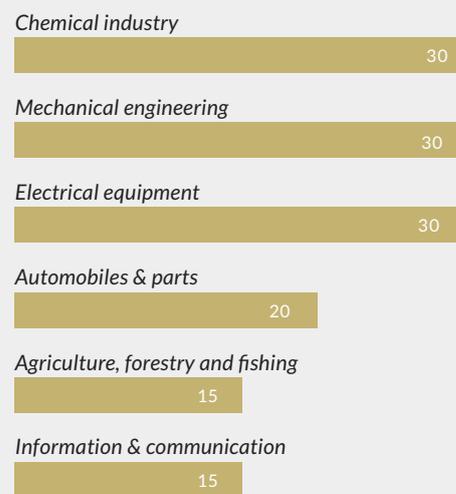
Fraunhofer ISST 2017 | Bertelsmann**Stiftung**

The chemical industry, mechanical engineering and the electrical equipment sector are supposed to be the prime beneficiaries of Industry 4.0. A study of the Boston Consulting Group concludes that Industry 4.0 will lead to an increase of employment of six percent in the manufacturing sector between 2015 and 2025.[35] The biggest growth is expected in the mechanical engineering sector.

The demographic development predicts an increase in the median age from 46.0 years in 2017

to 47.4 years in 2030.[36] The age group of 65+, i.e. people in retirement age, will increase from 17.7 million to 21.8 million while the age group of 20–64, i.e. potential labor force, will decrease from 49.3 million to 43.6 million.

This will lead to a lack of work force in industry. Industry 4.0 provides the chance to keep the current productivity level by replacing manual work with automation.

The consequences of Industry 4.0 on labor and work organization are seen different in different studies [BoSu16]. There is a common agreement that the pressure on human labor will increase due to automation and advanced process analytics. That holds for blue collars as well as for white collars. The majority expect a decrease in low-skilled jobs and a shift towards more complex jobs requiring continuous learning on the job.

2.2 Impact on India

India has a labor force of 513.7 million.[37] Every year about 10 million new workers enter the Indian market. Of them nearly 1.5 million are engineering graduates but only a fraction of them are employable immediately. Most need updated industry experience to ensure productivity. Therefore, skilling and reskilling of the labor force will be a critical factor in the augmentation of smart manufacturing.

The Indian government's "Make in India" initiative is aimed at increasing industry share from 12 percent to 25 percent in 2025. To support this large infrastructure projects have been started for the next couple of years – road construction, extension of the railway network and improvement of ports. The "Digital India" initiative, in addition, is supposed to improve the communication infrastructure.

These improvements are supposed to create new jobs in industry. On the other hand, the global competition also bears risks for the manufacturing sector.

According to a Roland Berger study [AuSi14], India's manufacturing sector will be at par with Europe in efficiency and costs by 2023. This will also increase pressure on its labor force. The World Banks World Development Report 2016 [WDR16, p. 23]

FIGURE 9 **Estimated share of employment in Asia that is susceptible to automation**
(in percent)

Malaysia — 67.8
India — 68.9
Thailand — 72.1
Bangladesh — 76.5
China — 77.1
Nepal — 79.9
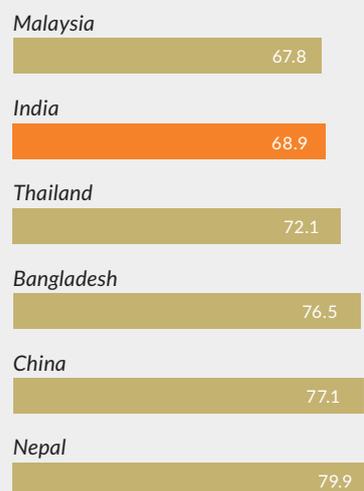
[37] World Banks World Development Report 2016 | Bertelsmann**Stiftung**

indicates that 69 percent of India's jobs are endangered by automation.

Digitization in general and Industry 4.0 in particular also show positive and negative impacts on India's IT sector. According to NASSCOM [NASS17] the Indian IT-BPM industry has become the global number one with a volume of USD 143 billion in FY2016 and an estimated growth rate of 8 percent for FY2017. The workforce is expected to increase by 170,000 new jobs to 3.9 million employees.

However, the pressure on productivity and efficiency hits the IT sector. The number of new jobs has decreased from an annual hiring of 500,000 people to the forecasted 170,000 and a further decrease is expected.[39] Almost 1.4 million mid-level employees, with typically 8–12 years of experience, are feeling the pressure of digitization, automation and newer technologies.[40] Their roles are being increasingly assigned to software tools like IBM Watson. They could lose their jobs to those more familiar with newer technologies.

A growing, Industry 4.0-compliant manufacturing industry could soften the impact of these developments on the IT sector.

3 Existing collaborations and room for improvement

India and Germany have been trade partners for more than 500 years and over the past 50 years, the trade volume between them has steadily increased. German industry has set up subsidiaries in India for many decades and leading Indian IT companies have had regional headquarters in Germany for almost twenty years.

In this section, we take a closer look at these collaborations from the perspective of Industry 4.0 to see what needs to be done to improve them.

3.1 Existing collaborations

Collaborations could be industry-driven, government-driven and academic.

Industry driven activities

The German Chamber of Commerce Network supports German companies with building and extending their business relations to foreign countries. The Indo-German Chamber of Commerce (IGCC), incorporated in 1956 in India, is the largest Chamber of Commerce in India, with more than 6,000 companies.

It is also the largest German chamber worldwide. A committee of 20 elected leading industrialists and CEOs of German and Indo-German companies governs it. The IGCC has set up India Desks in a number of German cities as well as abroad to strengthen Indo-German business relations.

VDMA (Verband Deutscher Maschinen- und Anlagenbau, Mechanical Engineering Industry Association) represents more than 3,200 mostly medium-sized companies in the capital goods industry, making it the largest industry association in Europe. The association represents the shared financial, technical and scientific interests of the mechanical engineering industry. The association reflects the diverse customer-supplier relationships along the whole value chain and promotes sector-specific and overarching cooperation.

In India, the VDMA maintains offices in Kolkata, Delhi, Mumbai and Bangalore, and undertakes several focused activities.

Key players in Germany's Industry 4.0-relevant technologies, also members of IGCC, have subsidiaries in India. Representative examples are Bosch and Sick.

Bosch, a leading supplier of industry technology, has been present in India since 1953. Today it is represented in India through nine companies, including 15 manufacturing sites, and seven development and application centers, with over 30,000 employees, generating consolidated revenue of about Rs 15,250 crores (2014). In 2015, Bosch announced the establishment of a smart manufacturing system across its plants in India until 2018.[41]

The Robert Bosch Centre for Cyber-Physical Systems (RBCCPS)[42] was established as an Indian Institute of Science (IISc) Centre in 2011 in order to promote applied research in the areas of cyber-physical systems. In 2016, the focus was set on research in the more foundational aspects of creation of CPS and Internet of Things (IoT) technologies.

SICK is one of the world's leading producers of sensors and sensor solutions for industrial automation applications. SICK INDIA PRIVATE LIMITED was established in February 2005. Sick has offices in Mumbai, New Delhi, Bangalore, Pune, Jamshedpur, Ahmedabad and Chennai.

Indian key players in IT have subsidiaries in Germany (c.f. section 1.2.3) and cooperate with German companies in the area of Industry 4.0. Examples:

Wipro has recently set up automotive hubs in Wolfsburg, Stuttgart and Munich to support German car manufacturers in their transition towards Industry 4.0 production. Wipro also has an alliance with German key players SAP and Siemens to support smart manufacturing.[43]

In April 2016 Infosys and KUKA, a German specialist in industry automation and pioneer in industry robots, announced a partnership in setting up an Industry 4.0 cloud platform. Infosys also supports the acatech Industry 4.0 Maturity Index.[44]

Tata Consultancy Services and Bosch collaborate in a joint project to integrate standards of the German Platform Industry 4.0 and of the Industrial Internet Consortium in the Bosch factory in Homburg that produces hydraulic valves.[45]

Government-driven activities

To strengthen the position of India's industry and to boost their share of India's GDP the Indian government has launched the "Make in India" initiative. As the Partner Country of the Hannover Messe 2015, the world's largest industry fair, India has successfully promoted the initiative.

As a follow-up measure, the Indian embassy in Berlin has implemented the "Make In India Mittelstand! (MIIM)" programm[46] to attract German Mittelstand companies as investors in India. In the meantime, the MIIM initiative has 71 companies as members that have set up 31 new manufacturing plants in India with a total investment of 634 million Euros.[47]

The Indian Government is also supporting "Smart Manufacturing" initiatives in a major way. Centers of Excellence driven by Industry as well as educational and research institutions are underway. The Kirloskar Institute in association with the Mahratta Chamber of Commerce Industries & Agriculture (MCCIA) is in discussions with Fraunhofer to establish a Centre of Excellence for Industry 4.0 in Pune. The Ministry of Heavy Industries and Public Enterprises, Government of India, is actively supporting this initiative.

The National Productivity Council has received funding support from the Asian Productivity Organization (APO) to institute training and skilling mechanisms in smart manufacturing and IoT driven technologies in a Center of Excellence "IT for Industry 4.0". The Ministry of Electronics and Information Technology (MEITY), along with ERNET, is supporting a Centre of Excellence on IoT at NASSCOM Bangalore to build and drive the IoT ecosystem in India.

Academic activities

Bilateral research collaboration between Germany and India has a long tradition. The German Academic Exchange Service (DAAD) is the key organization with its regional office in New Delhi[48], established in 1960, and its network in Chennai, Pune, Mumbai and Bangalore as well as its close ties with numerous Indian research institutions. The DAAD currently offers 57 funding options for Indian students and researchers in engineering.

In 2012, the German House for Research and Innovation DWIH New Delhi[49] was inaugurated by a consortium of 15 German organizations to strengthen ties between India and German scientific communities and between academia and industry.

In addition to these institutions, several foundations like Humboldt -, Robert Bosch -, Feodor Lynen -

or F.-W. Bessel Foundation give grants and awards to Indian students and scientists.

Because of these efforts, Indian students form the third largest group of foreign students in Germany behind China and Russia. In 2015/2016, about 13,740 funded Indian students studied in Germany.

The "A New Passage to India" programme, launched in 2009 by the German government brought more than 2,400 funded German students to India.

According to the UNESCO Science Report [UNES15], Germany is the second most important scientific collaborator of India – only behind the USA – with 8,540 co-authored scientific papers.

3.2 Recent surveys on Industry 4.0: need for greater awareness

In March 2017, Bitkom Research published the results of a representative survey on the status of Industry 4.0 from the perspective of German ICT companies.[50] More than 300 companies participated in the survey. Only 3 percent of them do not see Industry 4.0 as a business area. For about 40 percent, it is already crucial and another 27 percent expect it to become important in the next one or two years.

So far, Industry 4.0 remains important mostly for the automotive domain, manufacturing makes up for 28 percent of its base. The reason for this reluctance is that almost half the CEOs of medium-size companies do not know the term Industry 4.0; 39 percent of manufacturing companies do not know of its uses and about-two thirds are simply hesitant. Why is this the case? Most problems lie in the field of technical standards, regulatory framework, high investment costs and the lack of skilled personnel.

The study on IT-BPM in India, published by NASSCOM in February 2017 [NASS17], shows the importance of the IT sector in general and of the IT services sector in particular for India. Growth rates of the sector exceed the growth rate of India's economy and almost half of the revenues come from exports. Although not explicitly stated, it is very likely that digital transformation of enterprises and Industry 4.0 plays a notable role in this development.

PwC published a study on Industry 4.0 in India in 2016 [PwC16]. According to this survey, 27 percent of the participating industry companies rated their status as advanced today. Almost two-thirds of participants expected their company to achieve this level within five years.

A survey on advanced manufacturing was conducted with more than 50 leading Indian engineering companies by the Federation of Indian Chambers of Commerce & Industry (FICCI) together with the Tata Strategic Management Group (TSMG) in 2016 [FICC16]. The survey identified weaknesses in the area of product quality, labor productivity, agility of production and logistics processes as well as to the delivery of end-to-end solutions, i.e. product as a service. These problems are solvable if advanced manufacturing technologies are adopted.

3.3 Specific Challenges for the Indian Industry

To understand the ground-level realities faced by Indian and German companies in India, workshops were organized with stakeholders and the Indian government in Pune and Bangalore in June 2017.

The discussions confirmed that manufacturing is a key target area for collaboration (c.f. section 1.2.1). India faces a huge challenge here. Many machines are engineered in Germany, designed in Germany, rendering it difficult for Indian companies to make them Industry 4.0 ready.

Also, Indian companies face the problem of capturing data at machine level. These facts imply a substantial potential for collaboration as outlined in section 1.4.1 (Scenario 1) above.

Another challenge is the level of awareness about Industry 4.0. As pointed out earlier, MSME companies that have a significant share in the output of the manufacturing sector do not have complete information about Industry 4.0 and no incentive to be part of the transformation process. There is a huge need to bring them on board at the earliest.

In order to understand what Industry 4.0 means it would be very useful to set up a model factory and conduct benchmarking studies.

This is not an issue only for India, but also Germany. In this context, it is must be mentioned that participants felt that many concepts are too technology-driven; they do not take into account enough business aspects.

Most stakeholders agree that data is at the core of Industry 4.0, be it data analytics, machine intelligence or deep learning but there is not enough focus in companies on these topics. There is also a need for different transformation paths such as optimization and expansion of core business or launch of new businesses.

PICTURE 3   **Workshop at Fraunhofer Office India, Bangalore**

The Indian government and some private sector players are setting up platforms for Industry 4.0. There is a need to create synergy among these platforms and resulting networks.

In addition to the workshops, an online survey has been prepared for IT and manufacturing companies. Besides general information on the company and participant's role in it, the questionnaire aims at figuring out the status of digitization in the company awareness of and engagement with Industry 4.0, existing collaborations as well as the demand for support in transitioning to it.

The summarized results have to be interpreted with care. Participants are from five different industries and from associations.

Three of four respondents had been connected to Industry 4.0 for only a year; the remaining quarter for two years at the most. None of the respondents had an Industry 4.0 roadmap for their company.

When surveying focal points of digital transformation, it turns out that companies focus on the automation of production processes (50 percent of respondents have partly automated production, using e.g. robots and autonomous vehicles) and on digitizing their supply chain (one out of three respondents is practicing supply-to-order).

Smart products that combine physical products with digital services are still of little interest. One of three respondents had no intention of developing them; 50 percent of respondents are in the planning phase.

When checking the status of collaborations it turns out that all respondents consider smart

production a target; about 40 percent are also interested in smart supply chains. Collaboration in terms of Industry 4.0 is limited to domestic partners; however, even there it has not reached production status yet.

On the other hand, there is a broad interest (80 to 90 percent) in Industry 4.0 case studies, enrolling at a center of excellence and registering with an Industry 4.0 platform. Two-thirds are also interested in participating in Industry 4.0 pilot projects.

4 Recommendations for action

A recent study by Roland Berger India [AuVi16] recommends joint Indo-German activities to improve innovations. The underlying view is of India as a customer, a competitor, a collaborator, a talent hub and an ecosystem. The recommendations discussed leveraging the countries' complementary profiles, the strengthening of joint project consortia and the development of a bilateral start-up portal.

When adopting this view in our observations regarding Industry 4.0 we identified complementary profiles as well. Germany's excellence in manufacturing matches with India's demand for strengthening its manufacturing industry. The increase in German FDIs in India is stimulated by India's economic growth rate and supported by India's government initiatives such as "Make in India" and "Make in India Mittelstand". Germany's lack of IT professionals matches with India's huge and fast-growing IT labor forces.

As we also identified significant gaps, we focus on recommendations for joint collaboration activities in the field of Industry 4.0 based on our summarized findings.

FIGURE 10 **Recommendations for Germany**

Short-term Activities	*Medium-term Activities*	*Long-term Activities*
Industry · Promote Industrie 4.0 and Industrial Data Space as quality labels in India · Increase awareness for Indian business partners	*Industry* · Develop Industry 4.0 related training programs for industry professionals	*Industry* · Establish Indo-German Industry 4.0 ecosystems including industrial and academic partners
Government · Support the creation of awareness for Industry 4.0 in the Mittelstand · Support knowledge transfer of Industry 4.0 and Industrial Data Space, as a part of it, to India	*Government* · Support skill building through the internationalization of Germany's Dual Training Programme	*Government* · Support skill building through the internationalization of Germany's Dual Training Programme
Joint activities · Set up an Indo-German Industry 4.0 Platform · Set up joint Industry 4.0 research projects · Set up incubator activities	*Joint activities* · Establish a Skill Building Expert Group to create pedagogy using German Dual Vocational Training concepts for Indian Students and Industry personnel	*Joint activities* · Establish a long-term Indo-German Industry 4.0 cooperation program on academic and on Industry level

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Short-term Activities	Medium-term Activities	Long-term Activities
Industry · Increase awareness for Industry 4.0, especially in the MSME sector · Set up Industry 4.0 Centers of Excellence as showcase, for knowledge and technology transfer	**Industry** · Conduct Training programmes for industry professionals on reskilling and developing skills towards Industry 4.0	**Industry** · Establish Indo-German Industry 4.0 ecosystems including industrial and academic partners
Government · Support the creation of awareness for Industry 4.0 in India	*Government* · Support the dissemination of Industry 4.0 concepts and technology in key industries through Industry 4.0 Centers of Excellence	*Government* · Set up a joint programme with German Universities and Applied Science Institutes on Dual Education for training and exposure for people on Industry 4.0
Joint activities · Set up an Indo-German Industry 4.0 Platform · Set up joint Industry 4.0 research projects · Set up incubator activities	*Joint activities* · Establish a Skill Building Expert Group to create pedagogy using German Dual Vocational Training concepts for Indian Students and Industry personnel	*Joint activities* · Establish a long-term Indo-German Industry 4.0 cooperation program on academic and on Industry level

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In the following sections these recommendations are discussed in detail.

4.1 Recommendations for industry

The German manufacturing sector is among global leaders and Industry 4.0 is a means to keep this position. A recent Bitkom survey[51] shows that German IT companies are fully aware of Industry 4.0 for their business but manufacturing companies lag behind. Here industry various association should step in and increase for the integration of Industry 4.0 technology into their production processes, products and innovative services related to these products. The German government has already initiated the creation of Industry 4.0 Competence Centers for the Mittelstand.

Platform Industry 4.0 and more recently the Industrial Data Space are German initiatives developed for use in Germany and abroad. Although there is a significant overlap in the stakeholders of both initiatives – and the initiatives address complementary issues – they are often not seen as two sides of the same coin.

So far, concepts and technology have been developed in these initiatives, but clear standards and corresponding labels are still missing. A label like "Industrial Data Space connected", similar to "Intel inside" would most likely provide for better acceptance in Germany as well as in India.

India's industry has a share of 29.8 percent in India's GDP[52] with 16.57 percent coming from manufacturing[53]. The "Make in India" initiative aims at increasing the manufacturing share, however,

adoption of Industry 4.0 is still low. Companies need to increase their awareness to stay competitive and find a place in the international ecosystems.

India and Germany need greater focus on Industry 4.0 programs in SMEs. The definition of SME in Germany is different from that of the Indian SME so matching of companies, as well as planning of joint initiatives needs to take this into perspective.

To achieve these goals Indian companies need to evaluate the benefits of Industry 4.0 for their business and to actively participate in related activities.

As a first step, they should gather information on the vision of Industry 4.0, underlying concepts and already existing success stories to figure out what such a transition means for their company. An easy way is to join an Industry 4.0 platform.

The Industry also needs to introduce Industry 4.0 ready machinery in case of greenfield cases and introduce Industry 4.0 ready machinery when making replacement investments. In the latter case, the approach would be to make existing machinery smart (through add-on sensor technology etc). Industry 4.0 Centers of Excellence could provide knowhow.

4.2 Recommendations for governments

Recent surveys reveal that awareness for Industry 4.0 is still an issue for the German Mittelstand and Indian industry. Greater awareness is needed beyond the IT sector and the government should take measures to address Mittelstand companies. A valuable step would be to match the Mittelstand with Indian software service providers to benefit from their lower cost structures.

The "Make in India" initiative, launched by the Indian government should have a focus on Industry 4.0. A joint Industry 4.0 Center of Excellence should be set up as a showcase for new technology and its successful deployment in companies.

A long-term Indo-German Industry 4.0 cooperation program, including scientific and business collaboration, should be set up. Existing organizations and structures can be used for this. The IGSTC provides the platform for government funded Indo-German joint research projects. These projects are funded in a "2+2 Mode of Partnership", i.e. a research partner and an industrial partner from both sides conduct joint research. So far, the focus of joint research is on medical technology, biotechnology, energy and sustainability. Only few projects are related to manufacturing. This must change.

There is no Industry 4.0 specific academic exchange program. Lack of skill is an issue that affects Germany as well as India. Germany lacks IT experts and the demographic change will most likely lead to a shortage in labor force in general. India, on the other hand, faces the problem of low skills and high training demands for its new labor force.[54] Skillbuilding programmes could provide help.

In a first step, a joint expert group should be set up to develop concepts and strategies for joint programmes with German universities and applied research institutes for training on Industry 4.0 issues. The internationalization of the German Dual Vocational Training concept would be another measure.

For cooperation on business level, it is worth noticing that in the fourth Indo-German Government Consultations between Germany's chancellor Merkel and India's Prime Minister Modi on May 30, 2017, in Berlin, both sides agreed to evaluate collaboration opportunities in the area of Industry 4.0, especially between the industry platforms of both sides.

So far, there is neither an Indo-German Industry 4.0 platform nor an Indo-German Alliance (see the cooperation agreement between China and the German platform Industry 4.0 or Sino-German Industry 4.0 Alliance). Here, the German Platform Industry 4.0[55] and the Industrial Data Space Association[56] could be used. Alternatively, an Indo-German Industry 4.0 Platform could be set up, with stakeholders from across the value chain. The planned or just launched centers of excellence in Pune and New Delhi also represent potential opportunities.

There is no Indo-German Industry 4.0 Incubator Center yet (c.f. Sino-German Intelligent Equipment Manufacturing Industrial Park, Shenyang, China). However, in the field of IoT approximately 850 start-ups exist in Bangalore and there is an active Bangalore–Berlin start-up cooperation. These facts should be kept in mind when taking steps towards more incubation measures.

5 Conclusion

In this paper, we have identified potential areas for Indo-German collaboration founded on Industry 4.0. We started by looking at Smart Factories as representatives for vertical integration of processes within a company and the Industrial Data Space as a means for horizontal integration of processes across companies. In the second step, we looked from an economic perspective and identified manufacturing, the chemical industry and the IT industry as target sectors, using existing trade relationships, market figures and the matching of demand and supply. Then, we provided case studies as examples for horizontal and vertical integrations and outlined potential collaboration patterns, based on value chains and on technical and organizational maturity.

When we consider the social impact of Industry 4.0 on both Germany and India, the need for action becomes obvious. Germany needs to preserve its leading position in manufacturing and in export while facing a declining labor force and a growing lack of IT experts. India, on the other hand, needs to strengthen its manufacturing sector but is a global heavy-weight in IT and business process outsourcing. As the world's second largest population, India's labor force resources are abundant but it needs to boost levels of qualification and training.

A stocktaking of existing Indo-German relationships in Industry 4.0-relevant fields shows that a sound basis has been established over decades, ranging from subsidiaries of German industrial organizations in India over subsidiaries FDIs of Indian companies in Germany and vice versa as well as government initiated programs like "Make in India Mittelstand!" to academic exchange programs. So far, however, these activities are not focused on Industry 4.0.

Recent studies on Industry 4.0 in Germany and in India, workshops recently organized in Bangalore and Pune and an online survey revealed weaknesses on both sides as well as demand for support. From these we derived recommendations for the industry, the governments and finally for joint Indo-German activities towards a broader deployment of Industry 4.0.

It is now up to the addressed stakeholders to take action.

Industry 4.0 – The Future of Indo-German Industrial Collaboration

Endnotes

1   **Industrial Internet Consortium (2017)**, *Website*,
     http://www.iiconsortium.org, retrieved March 27, 2017

2   **The state Council of the People's Republic of China (2017)**, W*ebsite*,
     http://english.gov.cn/policies/latest_releases/2015/05/19/content_281475110703534.htm,
     retrieved March 27, 2017

3   **Central Intelligence Agency (CIA) (2017)**, *The World Factbook*,
     https://www.cia.gov/library/publications/the-world-factbook/rankorder/2001rank.html#gm,
     retrieved March 27, 2017

4   **Bitkom (2017)**, *Thema: ITK-Arbeitsmarkt*,
     https://www.bitkom.org//Marktdaten/ITK-Arbeitsmarkt/index.jsp
     retrieved March 27, 2017

5   InfoQ (2017), https://www.infoq.com/news/2014/01/
     IDC-software-developers, retrieved April 21, 2017

6   **Destatis (2017)**, *Website*, https://www.destatis.de,
     retrieved March 30, 2017

7   **UNIDO Statistics Unit (2017)**, *Basic Information: Germany*,
     http://www.unido.org/Data1/IndStatBrief/Basic_Information.cfm?
     print=no&ttype=C1&Country=GER, retrieved March 27, 2017

8   **UNIDO Statistics Unit (2017)**, *World: Leading manufacturing economies share in world MVA*,
     http://www.unido.org/Data1/IndStatBrief/World_Leading_MVA.cfm?print=no&ttype=
     W6&Country=GER, retrieved March 27, 2017

9   **Siemens (2017)**, *Website: About Siemens India*,
     http://www.siemens.co.in/about-us/overview.htm,
     retrieved March 27, 2017

10   **Schaeffler (2017)**, *Website: Schaeffler India*,
     http://www.schaeffler.co.in/content.schaeffler.co.in/en/company/company.jsp

11   **Trumpf (2017)**, *Trumpf Group: Locations*,
     https://www.trumpf.com/en_IN/company/trumpf-group/locations/
     retrieved March 27, 2017

12   **Make in India (2017)**, *Website: National Manufacturing*,
     http://www.makeinindia.com/policy/national-manufacturing
     retrieved March 27, 2017

13   **Invest in Karnataka (2017)**, *Website: Machine Tools & Heavy Manufacturing*,
     http://investkarnataka.co.in/mii/machine-tools-heavy-engineering.html,
     retrieved March 27, 2017

14   **Indian Units Conversion (2017)**, *Website*,
     http://convert.syzygy.in/what-is-5-crores-in-millions-and-billions,
     retrieved March 27, 2017

15   **Make in India (2017)**: *Towards Smart Manufacturing: Industry 4.0 and India*,
     http://www.makeinindia.com/article/-/v/towards-smart-manufacturing-industry-4-0-and-india,
     retrieved March 27, 2017

16   **Deccan Herald (2017)**, *Karnataka signs MoU with GoI for Machine Tool Park*,
     http://www.deccanherald.com/content/596334/karnataka-signs-mou-goi-machine.html,
     retrieved March 27, 2017

17   **BASF India (2017)**, *Website*,
     https://www.india.basf.com, retrieved March 27, 2017

18   **Henkel India (2017)**, *Website*, http://www.henkel.in, retrieved March 27, 2017

19   **Wacker (2017)**, *Kolkata – India*,
     https://www.wacker.com/cms/en/wacker_group/wacker_facts/sites/kolkata/kolkata.jsp,
     retrieved March 27, 2017

20   **Make in India (2017)**, *Sector: Chemicals*,
     http://www.makeinindia.com/sector/chemicals, retrieved April 3, 2017

21   **UN comtrade (2015)**, *Yearbook 2015*,
     https://comtrade.un.org/pb/CountryPagesNew.aspx?y=2015, retrieved April 3, 2017

22   **UNIDO Statistics Unit (2017)**, *India: Basic Information*,
     http://www.unido.org/Data1/IndStatBrief/Basic_Information.cfm?print=no&ttype=C1&Country=IND,
     retrieved April 3, 2017

23   **Bitkom (2017)**, *Unternehmen & Insolvenzen*,
     https://www.bitkom.org/Marktdaten/ITK-Konjunktur/Unternehmen-Insolvenzen.html
     retrieved April 3, 2017

24   **SAP India (2017)**, *Website*, https://www.sap.com/india/index.html, retrieved April 3, 2017

25   **Nasscom (2017)**, Indian ITBPO-Industry,
     https://www.outsource2india.com/india/bpo-industry-india.asp, retrieved April 3, 2017

26   **Make in India (2017)**, *Website: IT- and BPM*,
     http://www.makeinindia.com/sector/it-and-bpm, retrieved April 3, 2017

27   **Moneycontrol (2017)**, *Market capitalisation*,
     http://www.moneycontrol.com/stocks/marketinfo/marketcap/bse/index.html,
     retrieved April 3, 2017

28   **Plattform Industrie 4.0 (2017)**, *Map of Industrie 4.0 use cases: List*,
     http://www.plattform-i40.de/I40/Navigation/Karte/SiteGlobals/Forms/Formulare/EN/
     map-use-cases-formular.html, accessed on May 12, 2017

29   **Schaeffler (2017)**, *Website: Press releases*,
     http://www.schaeffler.de/content.schaeffler.de/en/press/press-releases/
     press-details.jsp?id=71833665, retrieved May 12, 2017

30   **Thyssenkrupp (2017)**, *Website: Press releases*,
     https://www.thyssenkrupp.com/en/newsroom/press-releases/press-release-118944.html#,
     retrieved May 12, 2017

31   **Trumpf (2017)**, *Website: Smart Factory*,
     https://www.trumpf.com/en_GB/products/smartfactory/truconnect/, retrieved May 12, 2017

32   **Deutsche Akademie der Technikwissenschaften (2017)**,
     Industrie 4.0 Maturity Index – Managing the Digital Transformation of Companies,
     http://www.acatech.de/de/publikationen/publikationssuche/detail/artikel/industrie-40-maturity-
     index-managing-the-digital-transformation-of-companies.html, retrieved May 12, 2017

33   **Destatis (2017)**, *Erwerbstätigenrechnung*,
     https://www.destatis.de/DE/ZahlenFakten/GesamtwirtschaftUmwelt/Arbeitsmarkt/
     Erwerbstaetigkeit/TabellenErwerbstaetigenrechnung/InlaenderInlandskonzept.html,
     retrieved May 12, 2017

34   **Destatis (2017)**, *Inlandsproduktberechnung*,
     https://www.destatis.de/DE/ZahlenFakten/GesamtwirtschaftUmwelt/VGR/Inlandsprodukt/
     Tabellen/BWSBereichen.html, retrieved May 12, 2017

35   **BCG (2017)**, *Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries*,
     https://www.bcg.com/de-de/publications/2015/engineered_products_project_business_industry_4_
     future_productivity_growth_manufacturing_industries.aspx, retrieved May 12, 2017

36   **Federal Statistical Office of Germany (2017)**, *Website*, https://www.destatis.de,
     retrieved May 12, 2017

37   **Central Intelligence Agency (CIA) (2017)**, *The World Factbook*,
     https://www.cia.gov/library/publications/the-world-factbook/geos/in.html, retrieved May 12, 2017

38   **World Bank (2016)**, *World Development Report 2016: Digital Dividends*,
      http://bit.do/WDR2016-FigO_18, retrieved May 12, 2017

39   **Business Standard (2017)**, *Infosys ex-CFO says automation will impact hiring in Indian IT sector*,
      http://www.business-standard.com/article/companies/automation-to-impact-hiring-in-indian-it-
      sector-balakrishnan-117042000970_1.html, retrieved May 12, 2017

40   **The Economic Times (2017)**, *Mid-level employees in Indian IT sector facing an uncertain future*,
      http://economictimes.indiatimes.com/tech/ites/mid-level-employees-in-indian-it-sector-facing-an-
      uncertain-future/articleshow/57503104.cms, retrieved May 12, 2017

41   **Financial Express (2015)**, *Bosch to introduce "smart manufacturing" at India plants by 2018*,
      http://www.financialexpress.com/industry/bosch-to-introduce-smart-manufacturing-at-india-
      plants-by-2018/146922/, retrieved May 12, 2017

42   **Robert Bosch Centre for Cyber-Physical Systems (2017)**, *Website*,
      http://www.rbccps.org, retrieved May 12, 2017

43   **Wipro (2017)**, *Website: Smart-Manufacturing*,
      http://www.wipro.com/industries/manufacturing/services/smart-manufacturing/,
      retrieved May 12, 2017

44   **Kuka (2017)**, *KUKA und Infosys beschließen Industrie 4.0 Partnerschaft*,
      https://www.kuka.com/de-de/presse/news/2016/04/kuka-und-infosys-beschlie%C3%9
      Fen-industrie-4-0-partnerschaft, retrieved May 12, 2017

45   **Markt & Technik (2016**), *Bosch kombiniert Standards von Plattform Industrie 4.0 und IIC*,
      http://www.elektroniknet.de/markt-technik/industrie-40-iot/bosch-kombiniert-standards-von-
      plattform-industrie-4-0-und-iic-128656.html, retrieved May 12, 2017

46   **Make in India Mittelstand (2017)**, *Website*,
      http://www.makeinindiamittelstand.de, retrieved March 27, 2017

47   **Presentation of Vikram Vardhan**,
      Second Secretary of the Embassy of India in Berlin and Deputy Head of the MIIM Programme,
      at the MIIM 3rd Exchange Platform, Embassy of India, retrieved March 27, 2017

48   **German Academic Exchange Service (DAAD) (2017)**, *Website*,
      http://www.daaddelhi.org, retrieved March 27, 2017

49   **German House for Research and Innovation (DWIH) (2017)**, *Website*,
      http://www.dwih.in, retrieved March 27, 2017

50   **Bitkom (2017)**, *IT-Unternehmen bauen Angebote für die Industrie 4.0 aus*,
      https://www.bitkom.org/Presse/Presseinformation/IT-Unternehmen-bauen-Angebote-fuer-die-
      Industrie-40-aus.html, retrieved March 27, 2017

51   **Bitkom (2017)**, *IT-Unternehmen bauen Angebote für die Industrie 4.0 aus*,
      https://www.bitkom.org/Presse/Presseinformation/IT-Unternehmen-bauen-Angebote-fuer-die-
      Industrie-40-aus.html, retrieved May 16, 2017

52   **India Brand Equity Foundation (IBEF) (2017)**, *India: A Snapshot*,
      https://www.ibef.org/economy/indiasnapshot/about-india-at-a-glance, retrieved May 16, 2017

53   **Statistics Time (2017)**, *Sector-wise contribution of GDP of India*,
      http://statisticstimes.com/economy/sectorwise-gdp-contribution-of-india.php,
      retrieved May 16, 2017

54   **The Hindu Business Line (2016)**, *We need Industrial Revolution 4.0*,
      http://www.thehindubusinessline.com/opinion/automation-will-hit-indias-labour-advantage/
      article9262553.ece, retrieved May 16, 2017

55   **Plattform Industrie 4.0**, *Website*,
      www.plattform-i40.de, retrieved May 16, 2017

56   **Industrial Data Space Assocation (2017)**, *Website*,
      www.industrialdataspace.org, retrieved May 16, 2017

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References

[AuSi14] **W. Aulbur and H.V. Singh:** *Next Gen Manufacturing: Industry 4.0. Roland Berger Strategy Consultants*, Theme paper at the Manufacturing Excellence Conclave, New Dehli, 2014.

[AuVi16] **W. Aulbur and N. Viswanathan:** *India Innovation Study*, Bertelsmann Stiftung, September 2016.

[Baue15] **W. Bauer et al.**: *Industry 4.0 – Economic Potential for Germany.* BITKOM, 2014.

[BMWi16] **Federal Ministry for Economic Affairs and Energy (BMWi):** *Digital Strategy 2025*, April 2016. Retrieved from http://www.de.digital/DIGITAL/Redaktion/EN/Publikation/digital-strategy-2025.html, 21.04.2017

[BoSu16] **L. Bonekamp and M. Sure:** *Consequences of Industry 4.0 on Human Labour and Work Organization*, Journal of Business and Media Psychology, vol. 1, 2016.

[Das17] **P. Das:** *Micro, Small and Medium Enterprises (MSME) in India: Opportunities, Issues & Challenges*, Great Lakes Herald, Volume 11 Issue No 1, pp. 77–88, March 2017.

[EvAn12] **Evans, P. C. and M. Annunziata:** *Industrial Internet: Pushing the Boundaries of Minds and Machines*, 2012. Retrieved from https://www.researchgate.net/publication/271524319_Industrial_Internet_Pushing_the_boundaries_of_minds_and_machines, 03.04.2017.

[FICC16] **FICCI:** *FICCI-TSMG Advanced Manufacturing Survey 2016 – Is Indian Manufacturing Ready to Adopt Advanced Manufacturing Trends? Federation of Indian Chambers of Commerce & Industry (FICCI) and Tata Strategic Management Group (TSMG)*, 2016. Retrieved from http://www.ficci.com/spdocument/20893/FICCI-TSMG-report.pdf on 17.05.2017.

[GaMu15] **P.S. Gangadhar, H. Mühleck, eds.:** *Prospects for Indo-German Collaboration in High-Tech Manufacturing*, Embassy of India, Berlin (Germany), 2015.

[HePO16] **Herrmann, M., T. Pentek and B.Otto:** *Design Principles for Industrie 4.0 Scenarios*, Proc. 49th Hawaii International Conference on System Sciences, 2016.

[IEC17] **IEC PAS 63088:** *2017 Smart manufacturing – Reference architecture model industry 4.0* (RAMI4.0).

[KaWH13] **Kagermann, H., W. Wahlster and J. Helbig, eds.:** *Recommendations for implementing the strategic initiative Industrie 4.0: Final report of the Industrie 4.0 Working Group*, acatech, 2013.

[MSME16] **Ministry of Micro, Small & Medium Enterprises:** *Annual Report 2015-16, Government of India*, 2016. Retrieved from http://www.msme.nic.in/mob/ActsRule.aspx on 14.07.2017.

[NASS17] **NASSCOM:** *The IT-BPM Sector in India: Strategic Review 2017 – Executive Summary.* National Association of Software and Service Companies (NASSCOM), February 2017. Retrieved from http://www.nasscom.in/itbpm-sector-india-strategic-review-2017 on 02.05.2017.

[Otto16] **Otto, B. et al.:** *Industrial Data Space, White Paper*, Fraunhofer-Gesellschaft, Munich, 2016.
Retrieved from http://www.industrialdataspace.org/en/industrial-data-space/ on 03.04.2017.

[PwC16] **PwC:** *Industry 4.0: Building the digital enterprise – India highlights. PwC*, 2016. Retrieved from
http://www.pwc.in/press-releases/2016/digitisation-in-industrial-sector-in-india-to-grow-to-65-
percent-in-next-five-years.html on 28.04.2017.

[UNES15] **UNESCO:** *UNESCO Science Report: Towards 2030. UNESCO*, 2015, pp. 599ff.

[VCI16] **VCI:** *Chemical Industry in Figures 2016. Association of the Chemical In-dustry (VCI)*, August 2016.
Retrieved from https://www.vci.de/services/publikationen/broschueren-faltblaetter/chemiew-
irtschaft-in-zahlen.jsp on 28.04.2017.

[VDMA17] **VDMA:** *Mechanical engineering – figures and charts 2017*, March 2017.
Retrieved from http://www.vdma.org/article/-/articleview/12874852 on 28.04.2017.

[WDR16] **World Bank. 2016. World Development Report 2016:** *Digital Dividends*.
Washington, DC: World Bank. doi:10.1596/978-1-4648-0671-1.

Abbreviations

BPO	*Business Process Outsourcing*
CPPS	*Cyber-physical production system*
CPS	*Cyber-physical system*
DAAD	*Deutscher Akademischer Austausch-Dienst,*
	(German Academic Exchange Service)
DWIH	*German House for Innovation and Research*
ERP	*Entreprise resource planning system*
FDI	*Foreign Direct Investment*
GDP	*Gross Domestic Product*
ICT	*Information and communication technology*
IGCC	*Indo-German Chamber of Commerce*
IGSTC	*Indo-German Science & Technology Centre*
IoE	*Internet-of-Everything*
IoS	*Internet-of-Services*
IoT	*Internet-of-Things*
IT	*Information technology*
IT-BPM	*Information technology and business process management*
MES	*Manufacturing execution system*
MIIM	*Make in India Mittelstand!*
	Programme of the Indian government
MSME	*Micro, small and medium enterprises*
OEM	*Original equipment manufacturer*
RAMI 4.0	*Reference Architecture Model for Industry 4.0*
SCADA	*Supervisory control and data acquisition*
VDMA	*Verband Deutscher Maschinen- und Anlagenbau,*
	(Mechanical Engineering Industry Association)
WAN	*Wide-area network*
WLAN	*Wireless local area network*

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