WHITEPAPER

Skill Development for Industry 4.0

BRICS Skill Development Working Group

INTRODUCTION

The manufacturing industry is currently witnessing the fourth industrial revolution, better known as Industry 4.0 where the 'real' and the 'virtual' world are to be seamlessly connected giving rise to what are known as cyber-physical production systems. As a result, the traditional manufacturing processes are undergoing an enormous transformation which will change the way companies approach manufacturing.

Industry 4.0, which started off as a brainchild of Germany, is being adopted by countries around the world. Developed nations like USA, France and Japan have already taken the first step in this direction by launching nation-wide programs. The adoption of Industry 4.0 by developed nations presents a significant threat to the BRICS nations as it will result in job migration from the BRICS to the developed nations due to loss of competitiveness. In order to maintain global manufacturing competitiveness, each of the BRICS nations needs to actively participate in this fourth industrial revolution.

In their journey to adopt Industry 4.0, each country is expected to encounter a number of challenges related to the skill level of their work force. The skills which are important today will cease to be so in the future and the work force will be expected to possess new skills in the domain of information technology, data analytics, etc. A higher percentage of the jobs will give importance to cognitive abilities and system skills over physical abilities while defining core work-related skill sets.

In most BRICS nations, there exists a mismatch between the skill sets job applicants have and the skill sets they are expected to possess. In the scenario where Industry 4.0 technologies have been widely adopted, this demand-supply gap will widen even further if necessary actions are not taken by each country. Though the governments of the BRICS nations have undertaken independent initiatives to promote vocational education and skill development in their countries, there are still significant efforts required for focusing on skill development for Industry 4.0. There exists an opportunity for the BRICS nations to collaborate for skill development and to work together to prepare their work force for Industry 4.0. This report aims to address this issue and recommend numerous ways of collaboration.

The report has been divided into 4 sections. The first section gives a brief overview on Industry 4.0. The second section assesses the current level of Industry 4.0 adoption in BRICS and compares it with the adoption levels in other developed nations – specifically Korea, Japan, Germany and USA. The third section evaluates the current skill levels in BRICS, skill sets required for Industry 4.0, challenges faced in skill development, various skill development initiatives undertaken and existing bilateral collaborations. The fourth section presents a set of recommendations to enable collaboration among the BRICS nations to address the issue of skill development for Industry 4.0. The recommendations cover a wide range of initiatives like collaborating for curricula development and training the trainers, hosting skill competitions, jointly developing skill training methodologies, building a cloud IT platform for sharing methodologies and standardizing qualification frameworks to name a few.

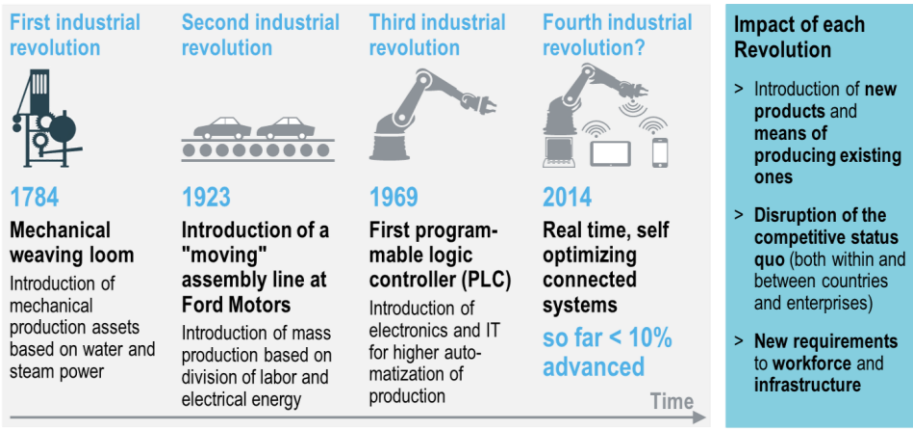
TABLE OF CONTENTS

Industry 4.0 – An overview

1. The birth of a new era of industrialization

Industry 4.0, christened so based on its promise as the fourth industrial revolution, encompasses a wide spectrum of technological advances across the value-chain. Industry 4.0 technologies – Automation / Robotics, Internet of Things, Artificial Intelligence, Additive Manufacturing, etc. – are revolutionizing traditional manufacturing processes. As a result of increased use of digital technologies, the boundary between the real and the virtual world is increasingly blurring, giving birth to what are known as cyber-physical production systems.

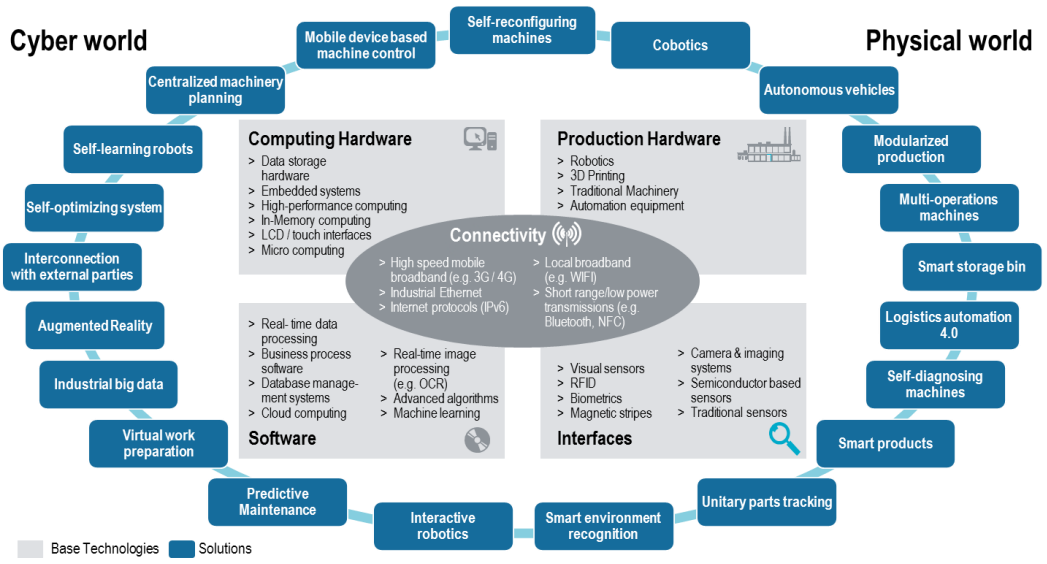
Figure 1: Development stages of industrial manufacturing



Source: Roland Berger

A movement that started off as Germany's brainchild has become an imperative undertaking for companies and countries to bolster their manufacturing prowess. Public and private sector bodies are starting to dedicate more time and resources towards the research and prototyping of innovation-driven manufacturing. Several technologies in the umbrella of Industry 4.0 have already gained or are gaining prominence.

Figure 2: Potential Industry 4.0 solutions



Source: Roland Berger

However, a 'Smart Factory' or Factory 4.0 that leverages all key tenets – internet of things, additive manufacturing, big data, etc. – is not yet very common. Though there are few companies besides large global players that have devised concerted, company-wide or market specific Industry 4.0 strategy, the full potential of Industry 4.0 is yet to be leveraged, particularly in emerging markets.

2. A new economic edge for companies

Industry 4.0's primary appeal lies in its ability to act as an economic game-changer, which would open up a myriad of opportunities for companies to revamp or create entirely new offerings and business models.

Industry 4.0 enables mass customization which offers greater flexibility for companies to meet varied demand from their customers, who are increasingly favoring more flexible and customizable outputs over standard product offerings. For example, Adidas, the leading global sports brand, has been running its mass customization program 'miAdidas' for several years. The program allows customers to personalize and customize their sports footwear to meet their performance and styling needs. In their effort to bring manufacturing closer to their customers in the respective countries, Adidas has also planned to open its first fully automated factory in Germany. Advanced technologies that reduce the need for workers are the key drivers behind this strategy. As part of this initiative, Adidas had also unveiled a running shoe sole manufactured using 3D printing technology.[1]

Such technologies have also helped companies in reducing lead time for prototype development. As a result, companies are able to speed-up their time to market. For example, Dash CAE, a leading supplier of automotive products, has reduced lead times by 83% for the production of parts and tools.[2]

Figure 3: Industry 4.0: What is changing for companies?

	Traditional Manufacturing	Industry 4.0 Manufacturing
PROCESS	Rigid and manual	Agile and automated
PRODUCT	Standardized	Personalized and customized
SCALE OF FACTORIES	Large factories at centralized locations	Small factories at decentralized locations
SUPPLY CHAIN	Stock based planning	Dynamic and predictive
SUCCESS METRIC	Low cost, high efficiency	High return on capital employed (ROCE)
CLIENT RELATIONSHIP	Low and indirect	High and direct

Source: Roland Berger

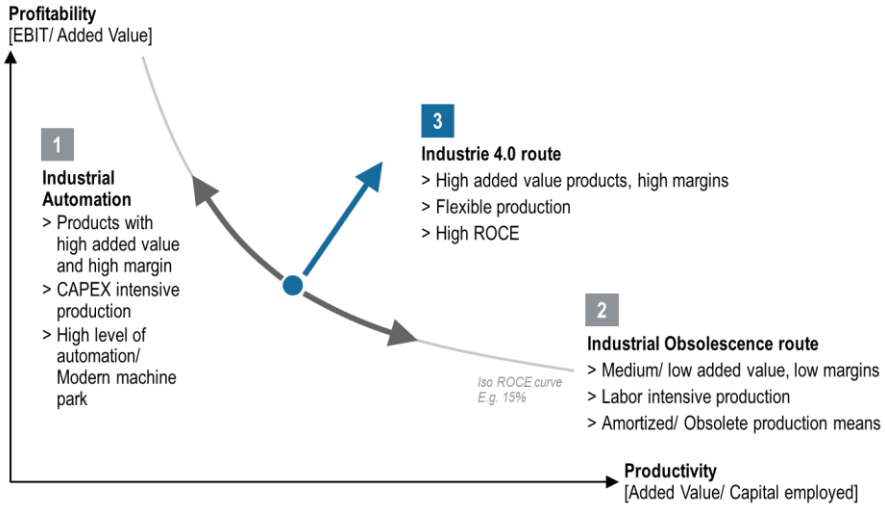
Figure 3 lists down transitions expected across the business models with the implementation of Industry 4.0. Industry 4.0 represents a paradigm shift from the previous era of rigid, efficiency-focused and manual manufacturing to a more dynamic, agile, and automated manufacturing. It marks a shift of focus from mass production to mass customization, enabled by flexible production and shorter lead times. Similarly, there will be a transition from large-scale factories specialized for a product to smart factories with high-technological equipment that can produce multiple products at competitive cost. Flexibility will also manifest in the ability to work remotely using technologies such as augmented reality.

The success metrics for businesses will also alter from achieving low cost efficiency to extracting higher return on capital employed. Industry 4.0 increases profitability by facilitating greater customization, reducing labor costs and decreasing the cost of complexity. In parallel, it helps in decreasing the capital employed by enabling greater flexibility and utilization of assets.

Figure 4 indicates the effect on profitability and productivity as a result of adopting three different routes – (1) continue using obsolete technology, (2) implement automation, and (3) adopt industry 4.0. Profitability is

improved within Industry 4.0 route due to reduction in labor cost and enhanced asset utilization rate, which compensates for increase in automation-related depreciation. Margins are also improved due to the increased value of products as a result of improvement in quality and flexibility of customization. Industry 4.0 also allows for better asset use by reducing changeover time, machine downtime, inventory and maintenance times, etc.

Figure 4: Three options for development



Source: Brokers, Roland Berger analysis

Given the advantages Industry 4.0 provides, traction in Industry 4.0-related technologies across industries seems inevitable. Figure 5 lists down a few benefits that Industry 4.0 offers. Internet players were the first to tackle digitization and, hence, are well-equipped for the transition to the digital elements of Industry 4.0. Companies in the manufacturing and production sectors, such as automotive companies need to navigate a more extensive, and challenging transformation to reap benefits from this revolution.

Figure 5: Benefits of Industry 4.0

Cost Optimization	> Reduce manpower cost > Boost labor productivity
New Opportunities	> Adapt to changing demographics & customer demands > Adopt mass customization > Identify new value-generating services
Greater Operational Efficiency	> Improve process visibility and quality of products > Reduce variability in operations > Allow remote monitoring and maintenance through networked systems
External Factors	> Develop competitive pressure on other companies > Derive benefits from government mandates and incentives

Source: Roland Berger

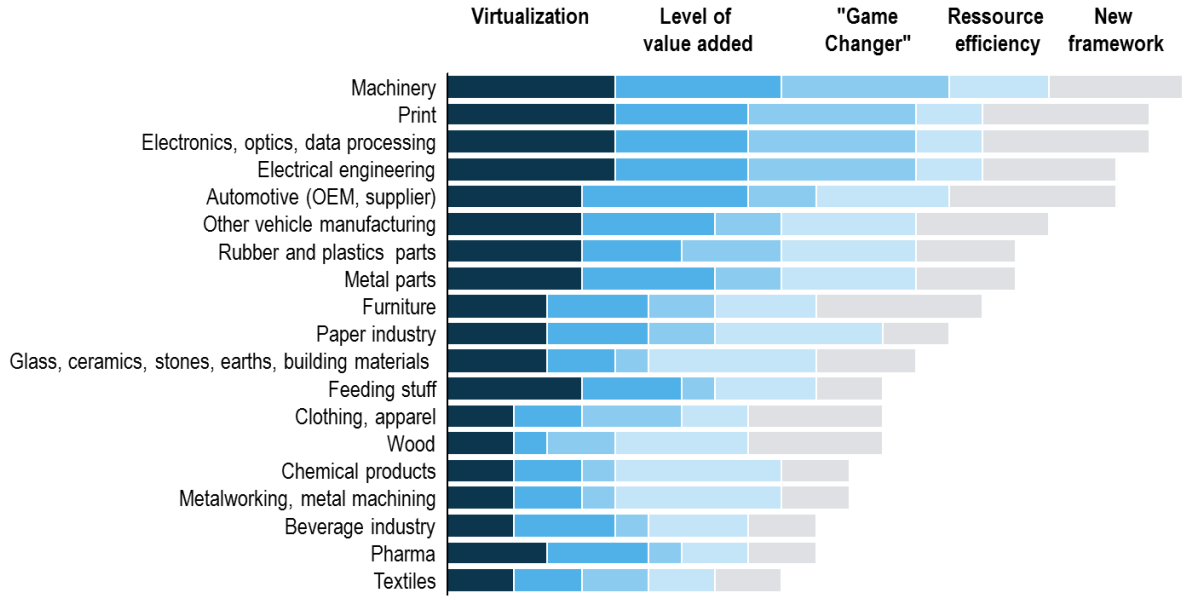
Moreover, with the rapid rate of obsolescence of technologies and offerings, companies will likely want to enjoy an early-mover advantage in Industry 4.0 to place themselves ahead of their competitors in the global manufacturing race. Now with governments in various countries investing resources into the Industry 4.0 mandate, it is a further incentive for companies to formulate their Industry 4.0 strategies.

3. Industries that will drive this change

The degree of adoption of Industry 4.0 has been varied, ranging from tepid acknowledgement of the Industry 4.0 technologies to fully-operational, extensively-automated smart-factories as seen most predominantly in the innovation-driven industries such as automotive. The potential for future implementation have been evaluated across five key indicators that determine the relevance and level of impact of Industry 4.0 in a specific industry:

1. **Virtualization of work processes:** Extent of usage of technologies such as augmented reality, virtual plants, etc. for automated information exchange and monitoring, controlling and simulation purpose.
2. **Level of value added and value-chain complexity:** Additional value created and quantum of processes simplified as a result of using Intelligent digitization technologies.
3. **Disruption technologies (Game changer):** Extent of change in business models and processes with adoption of new technologies like internet of things, 3D printing, smart grids, etc.
4. **Resource efficiency of core processes:** Improvement in efficiency of the resources and optimization of operations of the machines employed in the processes by adopting industry 4.0 technologies.
5. **Foreseeing of new framework or regulation:** Development of policies or launch of initiatives to promote adoption of new technologies.

Figure 6: Ranking of key industries affected by Industry 4.0



Source: Roland Berger

Currently, the highest adoption, maturity levels and potential for future implementation are observed in industries like machinery, electrical, electronics and automotive, each of which are classified as either medium-high tech or high-tech intensity industry. This can be attributed to the high-levels of virtualization already employed in these industries resulting in disruption in their business.

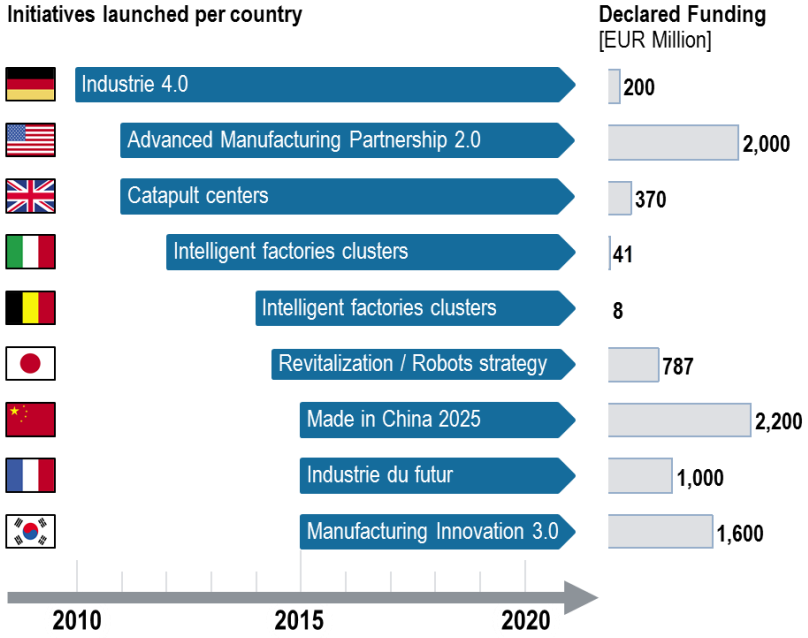
The next best promise for adoption is demonstrated by auto-components, aviation and aerospace, construction, logistics, food processing, chemicals, rubbers, plastics, industrials, metals, engineering, etc. In such industries, there appear fewer prospects of disruptions that might result in significant changes in business models and processes. However, these industries are expected to undergo improvement in resource efficiency with implementation of industry 4.0. In industries such as textiles, pharmacy, beverage and agriculture – predominantly the low-tech industries (not withstanding pharma), there has been limited adoption at this stage.

As it stands today, Industry 4.0 is still at a nascent stage in all but a few developed industries. Companies are still in the phase of evaluating the advantages and disadvantages of Industry 4.0. And an industry-wide implementation is not expected before 2025 or 2030.

4. Garnering geopolitical focus

Industry 4.0 or Industrial Internet (as it is called in some countries) has now also come into geopolitical focus garnering attention from national government bodies. Countries across the world have taken initiatives to be a part of this fourth industrial revolution.

Figure 7: Worldwide initiatives and related investment announced



Source: Roland Berger analysis

More technologically developed countries have pioneered full-fledged national missions focused on advanced manufacturing technologies, such as the Industrie 4.0 in Germany, Advanced Manufacturing Partnership 2.0 in USA, Revitalization and Robots Strategy in Japan, Industry du Futur in France and Intelligent Factories Clusters in Italy, to name a few. Emerging markets, on the other hand, have not been far behind in terms of launching national strategies – most notably, China launched 'Made in China 2025' in early 2015, not long after Germany and USA. India also initiated the 'Make in India' mission to promote manufacturing by bringing in policy changes to attract global manufacturing houses for setting-up operations in India. Russia has launched 'Technet' initiative, focusing mainly on advanced manufacturing technologies & smart manufacturing

Additionally, with key missions of national focus launched by three out of five BRICS countries, it is now a lever and a substantial opportunity for other BRICS countries to drive symbiotic geopolitical partnerships and collaborations.

5. Effect on Jobs

One of the contentious points of discussion with regards to Industry 4.0 is its expected effect on the employment. Two school of thoughts have emanated in expert discussion regarding the impact of Industry 4.0 on jobs.

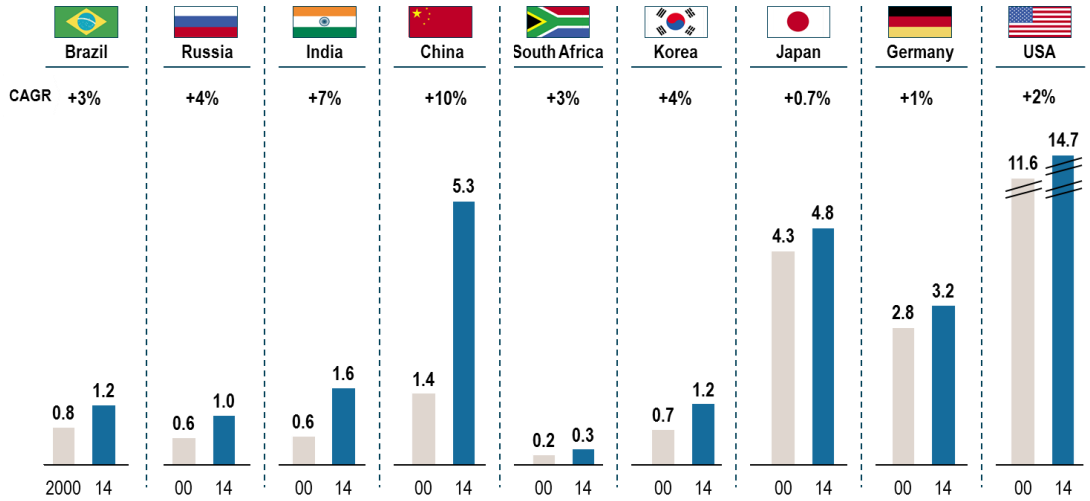
A number of experts believe that adoption of Industry 4.0 will result in increased use of automation and robots in the shop floor. Given that these robots will be capable of performing tasks multiple times with high levels of accuracy and within shorter time duration than humans, robots will act as an efficient replacement for labor. For example, an employee whose job is to fix a specific part while assembling an engine will be replaced by a robot who will carry out the same job accurately and in lesser time. The quantum of job loss, however, is expected to vary with country, industry and employed levels of automation.

The experts on the other end of the spectrum believe that the use of industry 4.0 technologies will not result in job loss, if not an increase in employment. The basis behind such a statement is the fact that Industry 4.0 will result in an increase in labor productivity and in the quality of the products manufactured. As a result, the demand for quality products manufactured will increase, rendering companies with no option but to increase capacity to meet the demand. There is no doubt that certain low-skilled jobs will be eliminated. However, it is expected that an increase in capacity will have a positive effect on the creation of jobs, requiring higher levels of skills. Employees who were rendered jobless due to elimination of low-skilled jobs need to be re-skilled or up-skilled to make them ready for the new requirements. All in all, the creation of new high skilled jobs will compensate, to a large extent, for the elimination of low skilled jobs.

Are BRICS Nations ready to take the leap?

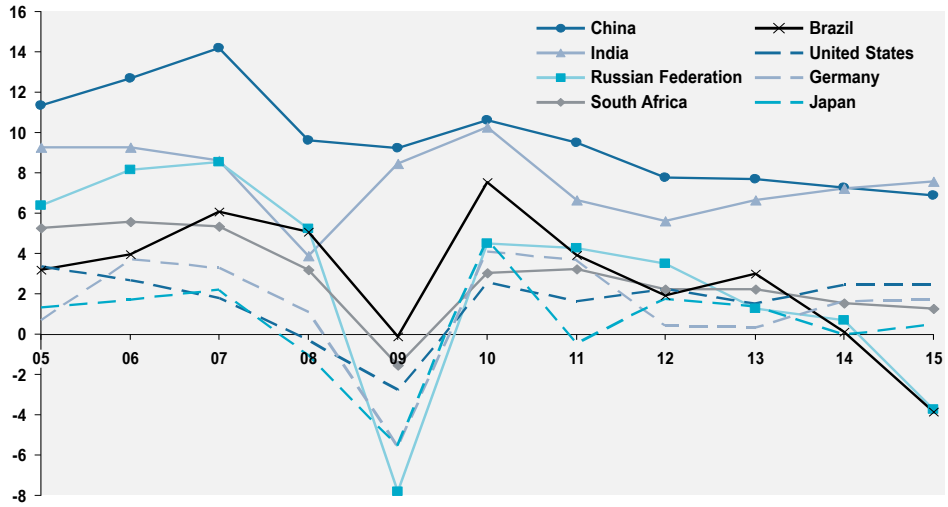
In the last decade and a half, BRICS nations have gained significant traction in the world economy as key producers of goods and services, investment destinations and potential consumer markets. They have been recognized as some of the fastest growing economies in the world. They have also been considered as engines of the global recovery as they still continue to grow strongly in contrast to other developed nations.

Figure 8: Gross Domestic Product at constant 2005 prices [USD trillion; 2000 and 2014]



Source: United Nations Statistics – National Accounts

Figure 9: GDP growth of BRICS and developed nations [%; 1990 to 2015]



Source: World Bank Data

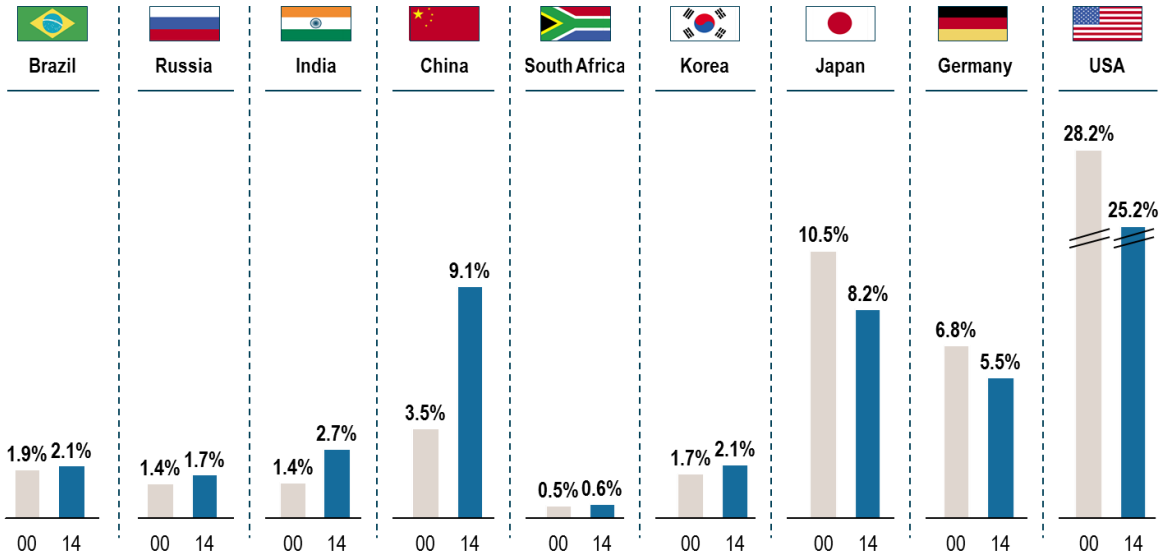
Note: The above rates are annual percentage growth rate of GDP at market prices based on constant local currency.

Each BRICS nation has its own set of advantages. While a few BRICS nations have been recognized as strong domestic demand-based economies with significant outward linkages, others have benefited from their large resource base and their proximity to untapped markets. As a result, BRICS nations have come to play a major role in the global market.

The contribution of BRICS nations in the global GDP (Figure 10) has increased significantly over the years. Currently, these countries account for approximately 16% of the global GDP, much higher than their 8.7%

contribution in 2000. A major part of this increase has been achieved due to the phenomenal growth of China – its share in global GDP has grown from 3.5% in 2000 to 9.1% in 2014. Other BRICS nations – Brazil, Russia and India – have also registered a moderate increase in their share of global GDP to 1.7-2.7%.

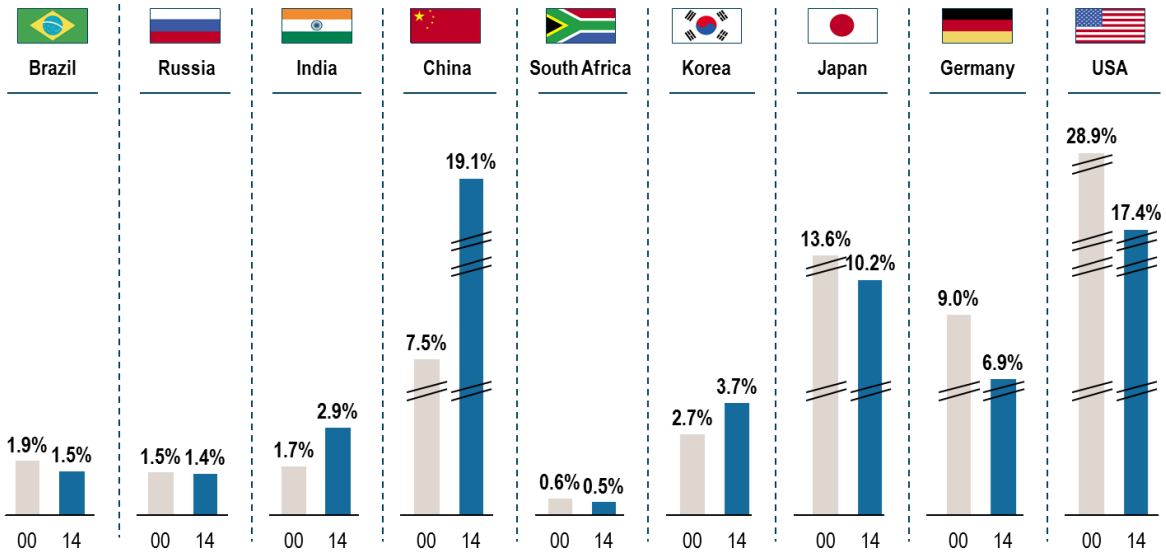
Figure 10: Share of global GDP [%; 2000 and 2014]



Source: United Nations Statistics – National Accounts

In terms of global manufacturing value add, the BRICS nations together accounted for close to 25.5% of manufacturing value added around the world in 2014 (Figure 11). China, which has been recognized as a global manufacturing hub, accounted for 19.1% of the global manufacturing value add. The remaining 6.4% is contributed by the other BRICS nations. The current contribution of BRICS nations marks a steep improvement from their contribution of 13.2% in 2000. This makes the prospect of Industry 4.0 implementation in BRICS countries a matter of critical interest.

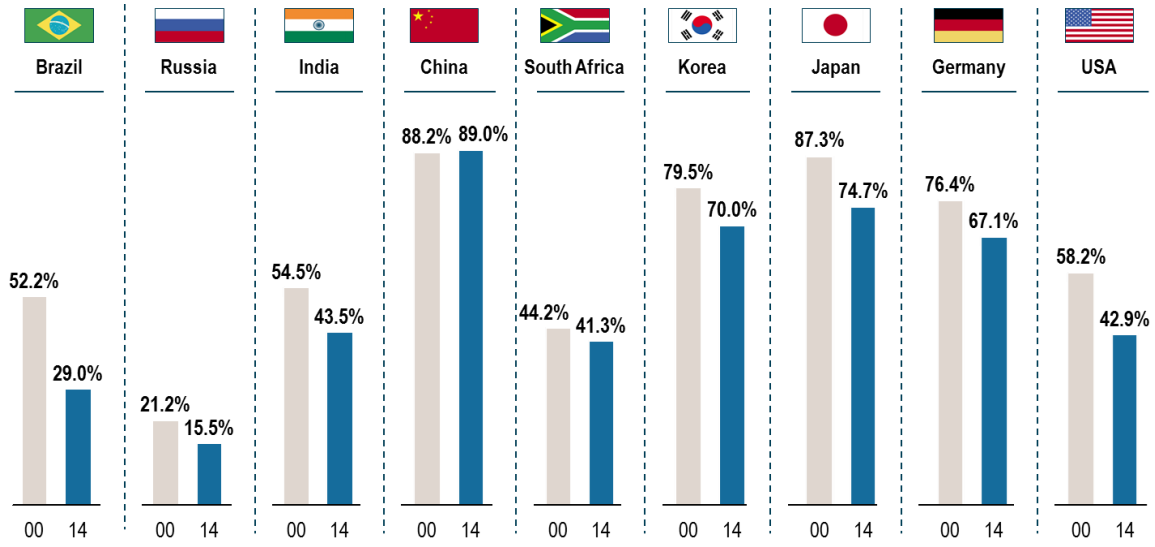
Figure 11: Share of global manufacturing value added [%; 2000 and 2014]



Source: United Nations Statistics – National Accounts

At a global level, the share of manufactured exports of BRICS nations has increased in the last few years from 7.2% in 2000 to 21.3% in 2014, with China contributing 17.9% of the total global exports. All countries barring China have seen a decline in the share of manufactured exports in their total exports.

Figure 12: Share of manufactured exports in total exports [%; 2000 and 2014]

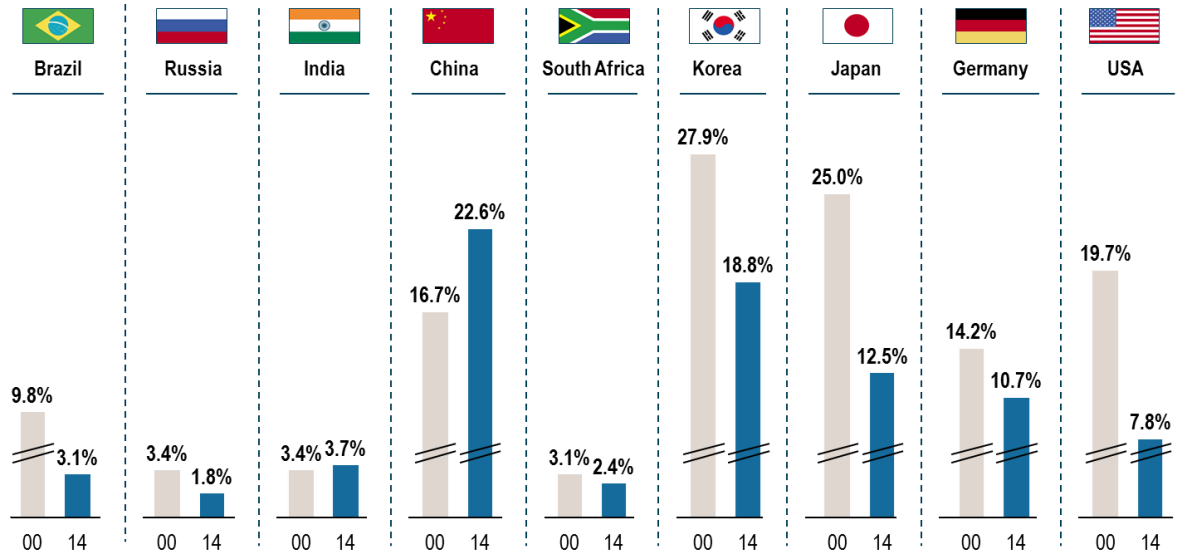


Source: World Bank

Note: The share has been calculated using the exports value at current prices in USD.

China has also emerged as a key supplier of high tech products in the global market – 22.6% of China's total exports are high-tech exports. Though the share of other BRICS nations has not changed much, developed nations have seen a decline in the contribution of high-tech exports in total exports (Figure 13).

Figure 13: Share of high-tech exports in total exports [%; 2000 and 2014]



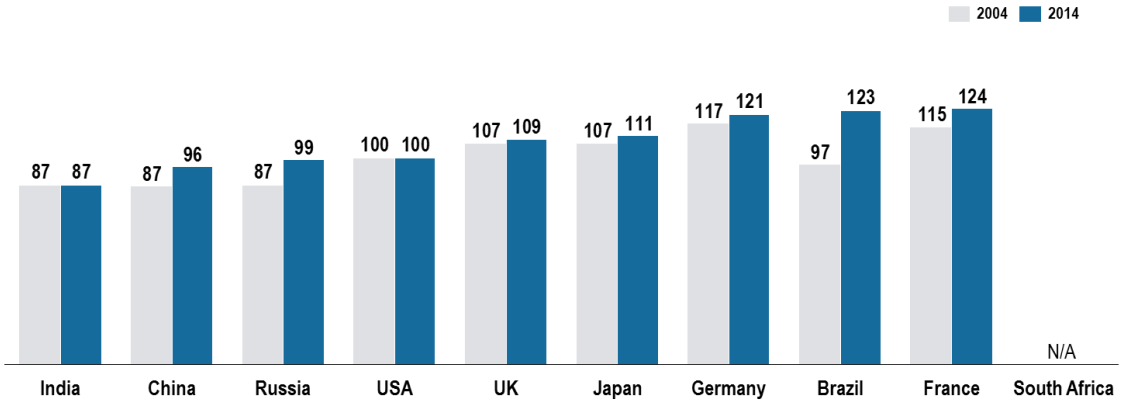
Source: World Bank

Note: The share has been calculated using the exports value at current prices in USD.

Industry 4.0 will require countries to reassess, recalibrate and create entirely new value propositions to continue as manufacturing havens. Particularly for emerging markets such as the BRICS nations, which have served as low-cost manufacturing hubs and gateways to larger consumer markets for companies, Industry 4.0 poses both a threat and an opportunity.

Not long ago, the positive GDP forecasts and easy availability of cheap labor forces incentivized firms from the developed nations to set up local manufacturing plants in BRICS nations. China and India further emerged as important destinations due to their huge population and large unpenetrated domestic market.

Figure 14: Manufacturing Cost Index, 2004 & 2014

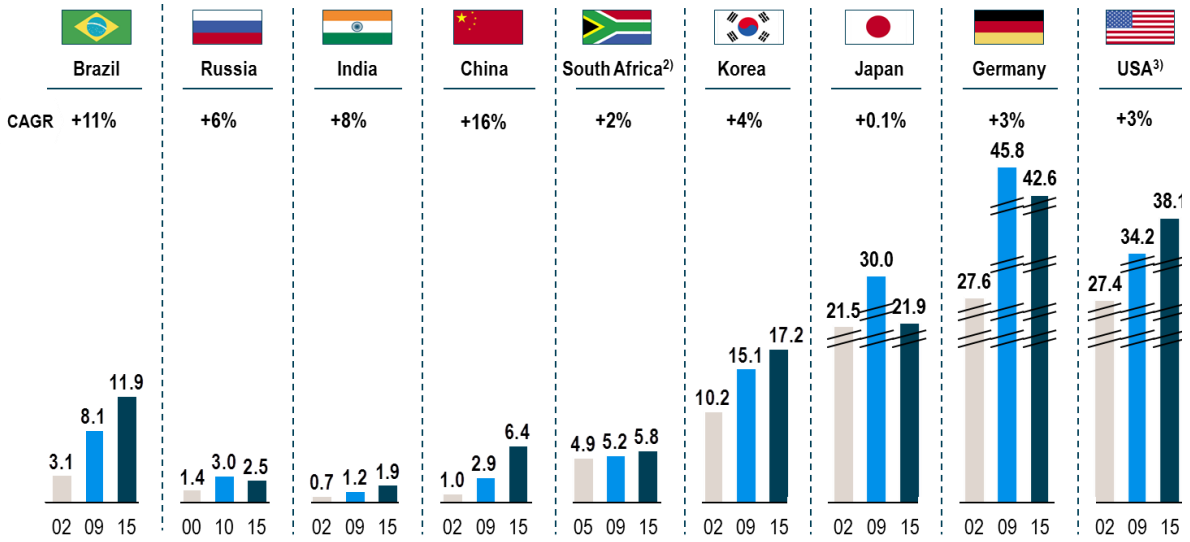


Source: Industry reports

Note: USA is taken as base for both the years. Manufacturing cost index is based on manufacturing wages, productivity, energy costs & currency exchange rates

A major part of the cost advantage offered by BRICS nations was derived from cheap large labor force. However, this cost differential is narrowing fast with most of the BRICS nations witnessing a significant increase in manufacturing costs. This increase is primarily because of the rise in wages across these countries. China, for instance, has seen a rise in the labor wages from USD 1 per hour in 2002 to USD 6.4 per hour in 2015. Brazil, on the other hand, has seen an increase from USD 3.1 per hour in 2002 to USD 11.9 per hour in 2015.

Figure 15: Hourly compensation cost in manufacturing [USD; 2002 and 2015]

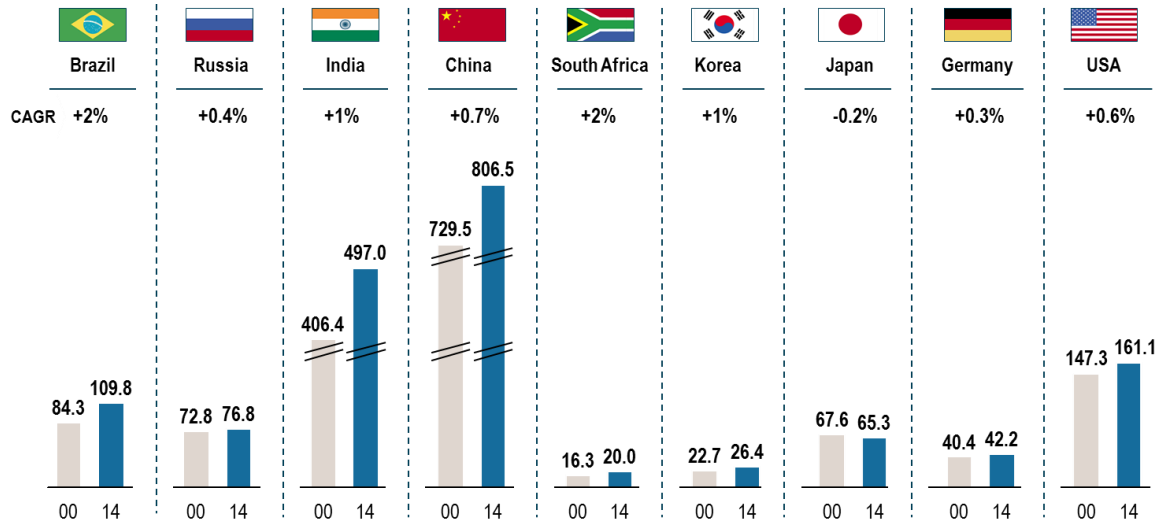


Note: For Russia and South Africa, data is for 2000 and 2005 respectively and not for 2002. 1) Data for 2015 is forecasted. 2) For Russia, 2000 & 2015 data and for Korea, 2015 data has been calculated assuming 26 days a month & 8 hours a day working.

Source: ILO; Oxford Economics; Russia Federal State Statistics; Korea Labor Statistics; South Africa Statistics

BRICS nations, excluding South Africa, were able to offer such low labor wages due to availability of a large labor force in the past. They have had a high labor force participation rate, comparable, and exceeding in the case of India and China, with other major developed manufacturing based countries.

Figure 16: Total Labor Force [Million; 2000 and 2014]

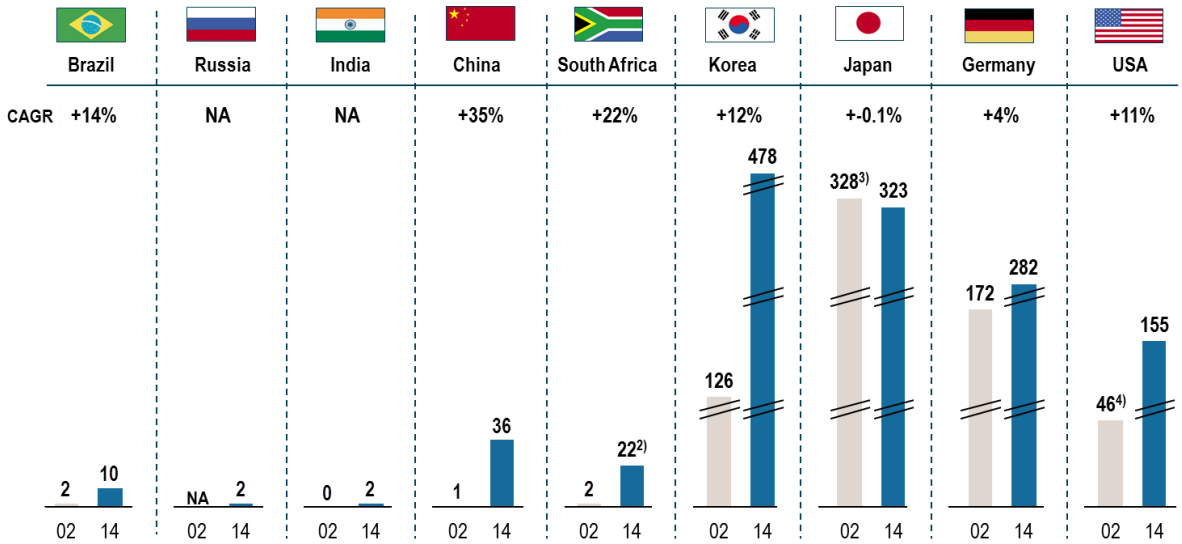


Source: World Bank Data

As far as the relevance of Industry 4.0 in BRICS nations is concerned, there exists skepticism in the industry about its immediate relevance in emerging markets, with several experts questioning both the demand and preparedness. This is evidenced by the markedly low levels of industrial automation that exists in the BRICS countries compared to their more developed counterparts.

In developed countries like Germany, USA and Japan, which have been at the forefront of implementing advanced manufacturing, the number of robots per 10,000 employees in manufacturing is significantly higher than that in the BRICS nations. The global average robot density in 2014 stood at 66 robots.[3] BRICS nations, on the other hand, have a robot density less than half of the global average. Figure 17 gives an overview of how robot density in the manufacturing sector has changed in BRICS and developed nations in the last 12 years.

Figure 17: Robot density in manufacturing [2002 and 2014]



Source: International Federation for Robotics (IFR); Ministry of Economy, Trade and Industry, Japan

Note: 1) Robot density is defined as number of robots deployed per 10,000 employees

When it comes to taking initiatives to develop Industry 4.0-related technologies, amongst the BRICS nations, China emerges as a major player in applying for patents and supporting research in such technologies. It has also emerged as a global leader in Machine-to-Machine (M2M) connections.

Figure 18A: Number of Industry 4.0-related patents[1] [2014]

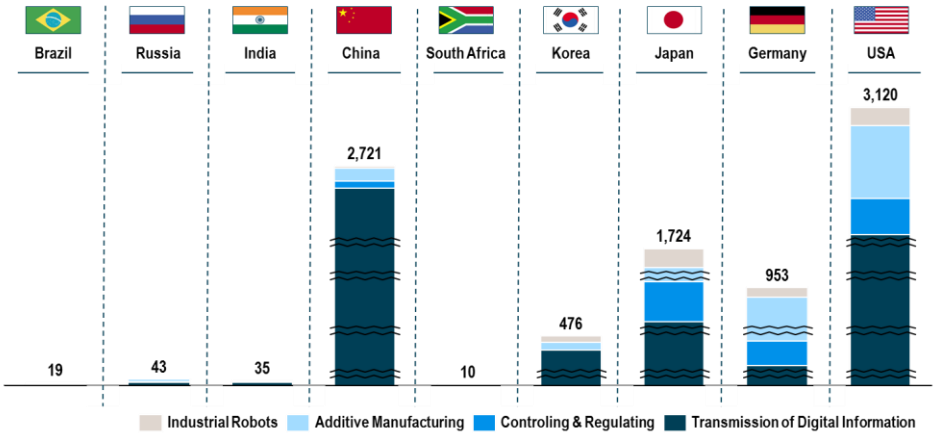


Figure 18B: Regional distribution of Industry 4.0-related technology companies

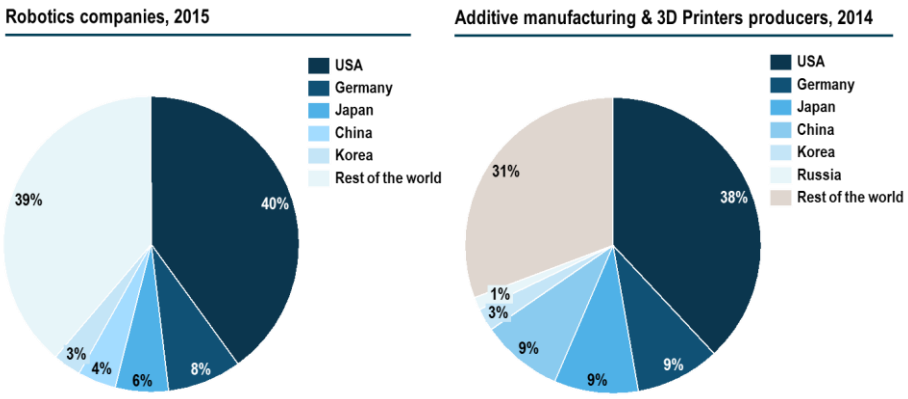
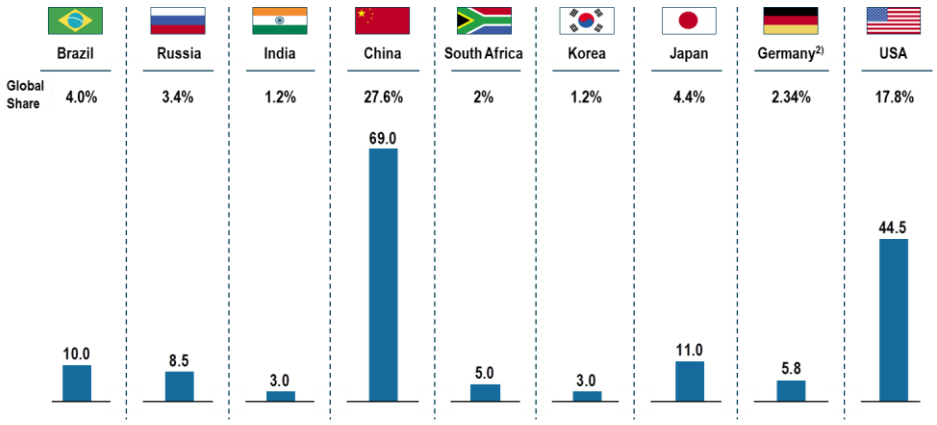


Figure 18C: Number of M2M Connections[2] [# Million; 2014]

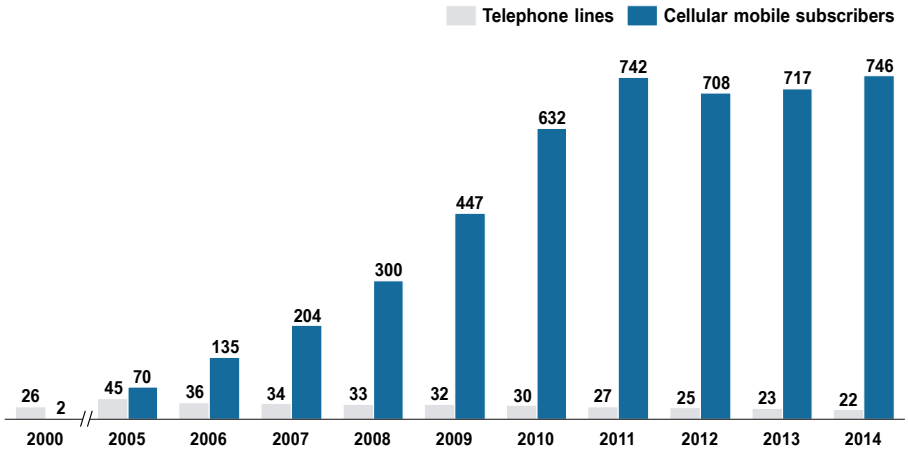


1) Industry 4.0-related patents have been assumed to be registered in 4 major categories – H04L (Transmission of Digital Information), B25J (Industrial Robotics), B29C (Shaping or joining of plastics) & G05B (Control & Monitoring Systems) 2) M2M connections are defined as SIM connections that enable mobile data transmission between machines. It does not include SIMs used computing devices in consumer electronics such as smartphones, dongles, tablets, e-readers, routers or hotspots.

Source: WIPO; GSMA Intelligence; Director General of Internal Policies, European Government

Though the above charts indicate that the BRICS nations have still not fully adopted Industry 3.0, there is an opportunity for the BRICS nations to simultaneously adopt Industry 4.0 while implementing Industry 3.0 technologies. This is possible as Industry 4.0, which deals with technologies like connectivity of machines is an extension of Industry 3.0, which primarily involves automation. A good example of how a new technology can gain significant traction is the quick growth of the mobile cellular phone subscribers in India over the years. For example, in 2000, the number of fixed telephone lines per 1000 inhabitants in India stood at 26, significantly more than the number of cellular mobile phone subscribers which stood at 2 per 1000 inhabitants. Over the years, the number of cellular mobile phone subscribers per 1000 inhabitants grew at a CAGR of 52% between 2000 and 2014. This happened even after a delayed arrival of cellular phones as compared to fixed telephone lines (Figure 19).

Figure 19: Number of telephone lines and cellular mobile subscribers per 1000 inhabitants in India



Source: BRICS Joint Statistical Publication, 2015

However, several challenges exist for BRICS nations. The massive upfront capital requirements and sizeable investments into R&D and implementation deter corporations, particularly those in the emerging markets, from foraying into Industry 4.0. Furthermore, the education and skill level of the labor force has been often below the expectations of the companies looking to expand their businesses in these markets (a topic that will be explored in greater detail later in this paper).

Which BRICS nations will emerge?

Each of the BRICS nations has a unique mix of opportunities and challenges with regard to the adoption of Industry 4.0. In the following section, we provide a detailed, country-specific view on the state of manufacturing, level of industrialization, initiatives undertaken by various stakeholders, challenges and opportunities for Industry 4.0.

1. Brazil

Services focused GDP growth

Brazil's GDP grew at a moderate CAGR of 3.2% from USD 778 billion in 2000 to USD 1,206 billion in 2014. This growth happened through a growing services sector and helped the country gain new international recognition and influence. Currently, it accounts for 2.1% of the global GDP, a marginal increase in its share of 2% in 1994.

The contribution of manufacturing as a percentage of GDP declined from 14.5% in 2000 to 12.1% in 2014. At a global level, the contribution of Brazil's manufacturing has gone down. In 2014, it accounted for 1.5% of global manufacturing value add, while in 2000 its share stood at 1.9%. Loss of competitiveness due to rising labor costs, bureaucracy, etc., resulted in slow growth of Brazil.

Brazil has a labor force comparable to other manufacturing-based nations with around 70% of its working age population participating in the labor force. A very high percentage, around 62%, of this labor force has been employed in the services sector. Due to shortage of the labor force in manufacturing, the hourly compensation cost has risen steeply. In 2002, hourly compensation cost in manufacturing was USD 3.1, which had gone up to USD 8.1 in 2009 and USD 11.9 in 2015, twice of that in China and six times of that in India. This impacts Brazil's competitiveness in the global manufacturing space.

Adoption of Industry 4.0 is low – an opportunity to benefit from

The use of digital technologies in the Brazilian industry is not widespread. According to a 2016 report by National Confederation of Industry (CNI), only 58% of companies are aware of the importance of technologies for industrial competitiveness and less than half of them are actually using these technologies.

According to a report by the International Federation for Robotics, in 2014, Brazil had a robot density of 10 robots per 10,000 employees in industry vis-à-vis a global average of 66 robots.[3]

Given the high cost of labor and increasing competition from other South American countries like Mexico, adopting Industry 4.0 and moving towards high value added production presents an opportunity for Brazil to strengthen its competitiveness in the global market.

Figure 20: Factsheet: Brazil

Key Facts

Parameter	Value
Gross Domestic Product (GDP)	$1,206 Bn
Share of Global GDP	2.07%
Share of Manufacturing in GDP	12.06%
Share of Global Manufacturing GDP	1.48%
Share of Manufacturing in Exports	28.97%
Labor Force	109.84 Mn
Labor Force Participation Rate	75%
Hourly compensation (2015)	$11.91
Robots per 10,000 employees	10
Number of M2M connections	10 Mn

Key Findings

Overall status: Low Adoption

- Significant growth in GDP in last few years due to growing Services sector
- Share of global GDP has increased marginally. However, share of global manufacturing GDP has declined
- High labor force participation
- Significantly higher monthly wages vis-à-vis other manufacturing focused economies
- Low awareness about Industry 4.0
- No major initiatives yet taken. However, Government is in the process to develop policies

Source: UN National Accounts; World Bank Data; CNI; IFR; ILO; Roland Berger analysis

Note: GDP and manufacturing value added are at constant 2005 prices. Unless mentioned all the data is for the year 2014.

The Brazilian Government and private sector have taken initial steps

Though Brazil has had low adoption of Industry 4.0 technologies so far, government, industry associations and individual companies have taken initial steps to change that. Given below are few of the initiatives undertaken by various stakeholders.

- **Industry-wide survey conducted**: The National Confederation of Industry (CNI) recently conducted a survey across industries to assess the current state of Industry 4.0, to understand internal and external barriers hindering adoption of digital technologies and to understand the measures that companies want government to take to accelerate adoption. The survey indicated that less than half of all participating companies use at least one of the 10 digital technologies (like CAD/CAM, etc.) considered in survey. It also found that 27% of the companies use digital automation with sensors for process control and only 8% of the companies use digital automation with sensors to identify products and operating conditions. Not more than 5% of the companies were using simulations and analysis with virtual models, additive manufacturing and rapid prototyping (3D printing).[4]

- **Establishment of Networked Society Lab**: In April 2016, the Brazilian government has also joined hands with Ericsson to develop a Networked Society Lab to drive Internet of Things (IoT) innovation in the country. The lab will test new technologies and assess the positive impact of Industrial IoT projects. Through the collaboration, the Brazilian government will try to understand and be at the forefront of how they can leverage technology to develop smart cities and to improve agricultural output and energy and industrial production.[5]
- **Collaboration to develop policies**: The Brazilian government has joined hands with industry bodies to conduct multiple workshops across the country to gather opinions from more than 500 specialists, primarily from private sector in the field of advanced manufacturing. Based on the recommendations of the specialists, the group plans to develop a National Advanced Manufacturing Policy.[6]
- **Industry 4.0-related courses introduced**: Pollux, an industrial automation company, has launched a four-month course in association with local universities to educate 20 students about robotics and Industry 4.0. Once the course is completed, a few of these students will be employed by Pollux. The initiative has been undertaken to help foster a new generation of engineers with the know-how to put Industry 4.0 concepts to practice.[7]
- **Virtual training for shop floor operatives**: Embraer has started training shop floor operators, a year before production starts, virtually in 3D. The project had undergone 12,000 hours of testing before the aircraft took off. As a result, a number of faults that would have been determined during the testing phase were identified in the preparation stage. As part of the project, the operators use computers and tablets with augmented reality technology and the videos of standard operating procedures to clarify any doubts that arise. Such an initiative has resulted in a 25% reduction in assembly line time.[8]

Lack of awareness hindering the adoption

Low level of awareness among the companies is a big obstacle to adoption of Industry 4.0 technologies in Brazil. As per the survey conducted by CNI, 43% of the companies could not identify which digital technologies in a list of 10 options will give them competitive advantage in the future and 52% of the companies in low technology industries could not identify any of the 10 digital technologies.[4] Lack of awareness also results in lack of usage, impacting competitiveness of Brazil in the global market.

Companies considered Industry 4.0 adoption to be an expensive exercise due to high implementation cost. Also, lack of clarity in defining return on investment, difficulties in integrating new hardware and software, inappropriate IT infrastructure and information security risks are some other internal barriers that restrict companies from adopting digital technologies.

In terms of external barriers, lack of skilled workers, insufficient telecommunication infrastructure, difficulty in identifying useful technology and solutions, lack of sufficient credit and low development of the market (customers and suppliers) are some of the challenges quoted by companies in Brazil.

2. Russia

Manufacturing – An important opportunity

Between 1990 and 1998, Russia went through an economic crisis and observed a major decline (of more than 42%) in its GDP. Post 1998, Russia's GDP increased at CAGR of 4.63% from USD 485 billion in 1998 to USD 1,000 billion in 2014. Currently, manufacturing contributes around 14% in Russia's GDP. Russia's share in global manufacturing value add has almost remained constant at around 1.5% over the last fifteen years.

Except for areas like St. Petersburg, Moscow, etc., Russia has a small population density because of its relatively small population inhabiting its large geographical area. The number of people active in the labor force is also low as compared to other developing nations like China and India. In 2014, Russia had around 77 million people in its labor force. In terms of labor force participation, around 74% of the population between 15 and 64 years of age actively participate in the labor force. About 13.5% of the labor force was employed in manufacturing. Historically, the hourly labor compensation cost in manufacturing in Russia has been more than that in China and India – in 2000, the hourly compensation cost in Russia was USD 1.4 as compared to

USD 0.7 in India and USD 1 in China. In terms of labor productivity, each labor employed in manufacturing contributed approximately USD 23,200 of value add in 2014.

Figure 21: Factsheet: Russia

Key Facts

Parameter	Value
Gross Domestic Product (GDP)	$999.7 Bn
Share of Global GDP	1.72%
Share of Manufacturing in GDP	14.03%
Share of Global Manufacturing GDP	1.43%
Share of Manufacturing in Exports	15.46%
Labor Force	76.75 Mn
Labor Force Participation Rate	73.6%
Hourly compensation (2015)	$2.51
Robots per 10,000 employees	2
Number of M2M connections	8.5 Mn

Key Findings

Overall status: Medium Adoption

- Share of global GDP and global manufacturing value add has increased marginally in 2 decades
- Low population density results in low labor force & high labor wages
- Ageing population is an issue
- Government requirements are driving the adoption of Industry 4.0
- However, in Robotics, there is less focus on industrial robots and more on service robots & autonomous driving vehicles
- Technet initiative has been launched with focus on advanced manufacturing technologies

Source: World Bank Data; IFR; ILO; Roland Berger analysis

Note: GDP and manufacturing value added are at constant 2005 prices. Unless mentioned all the data is for the year 2014.

Increasing manufacturing costs (including labor wages) and low labor availability have been diminishing Russia's status of a manufacturing destination. Industry 4.0 might turn tables in Russia's favor as it will help in overcoming the challenges faced with low productivity and insufficient skills. It may help Russia to re-engage with the global supply chain.

Low productivity and ageing population are driving advanced technology adoption

Russia has been a natural-minerals driven economy and, hence, manufactured exports have contributed a very small percentage in total exports – in 2014, around 5.5% of the total exports were manufactured exports. The share of high tech exports in the total exports is also low at around 1.8%.

With regards to adoption of advanced manufacturing technologies, the adoption has been sporadic and segment-focused with few examples of full-fledged smart factory implementations. In 2014, on an average only 2 industrial robots were employed in manufacturing shop floor per 10,000 employees. And those few ones were mainly used in the automobile industry. Development of robots in Russia is mainly spearheaded by a number of start-ups, big established companies have not taken significant steps. Given that Russia has a very small population density, it has been focusing on developing drones to carry out surveillance across its vast geographic area. Ideas like developing highways for driverless trucks have also emanated to improve the supply chain of products.[9]

Though the adoption of Industry 4.0 is low, it presents itself as a significant opportunity for Russia to tackle the challenges it faces with low productivity, ageing population and low population density. Use of advanced digital technologies should not only be restricted to industry as it can play an important role in overcoming the challenges faced with having a large geographic area also.

Government is fueling the move towards Industry 4.0

The predominant trigger for initiating research and development projects mainly stems from governmental requirements.

- **Program to develop the manufacturing industry**: The Government of the Russian Federation issued a program called the *'Development of the manufacturing industry and boosting its competitiveness in the horizon of 2020'*.[10] According to this program, the efficiency of the labor force will be improved with

modernization of the manufacturing process using IT. Industry 4.0 technologies like robotics and 3D modelling and printing will play a significant role.[11] The program focuses on adopting individual Industry 4.0 components in 5 years and promoting wide-spread adoption of advanced manufacturing in 10 years.[10] It has set the goal to produce all materials required for robotics and nano-electronics locally, which is a significant shift from the current import of 90% of these materials.[12]

- **Factories of Future under National Technology Initiative**: The National Technology Initiative (NTI) is a long term technology development program designed for the time period till 2035. It aims to create conditions for the emergence of companies that would be competitive in fundamentally new markets of the future. Under NTI's TechNet initiative, the project Factories of the Future has been launched to facilitate development of markets of the future and hi-tech companies through adoption of cutting-edge production technologies. The main purpose of the project is to form a network of international level competencies based on the integration of advanced manufacturing technologies and business models for the "factories of the future".
- **Robotics included in school curriculum**: Russia was among the front leaders in modernizing the education system as a response to the advent of advanced manufacturing. Robotics is now a part of the curriculum of schools and universities as an integral part of IT education, a move that other nations can emulate. As per a report by the Head of the Skolkovo Robotics Center, there are 30 universities that offer robotics and mechatronics engineering majors to undergraduate students in Russia.[13]
- **Agencies established to promote R&D**: Agencies such as the Russian State Scientific Center for Robotics and Technical Cybernetics (RTC) have been established with a mission to implement governmental R&D policy by creating cross-industry educational complexes for research, development and technology innovation. These educational complexes will be responsible for the development of cybernetic and intelligent robotics systems, unified components for management, processing and information exchange systems.[14]
- **Apex bodies set-up to develop technology-focused projects**: The Moscow Innovation Development Centre was established in June 2012 with a goal to support new technology start-ups in Moscow. The Navigator Campus was set up with a goal to provide space and equipment for new projects in 3D printing and prototyping, robotics and IT.

Private sector is catching up

One of the most successful Russian case studies driving the development of industry 4.0 technologies is St. Petersburg Polytechnic University's Computer-Aided Engineering Centre of Excellence. It is Russia's unrivaled leader in carrying out unique R&D (contracted also by the world's largest high-technology companies) and in educating the next generation of industry 4.0-ready engineers. Although the major push towards Industry 4.0 innovation has come from the government, some private players are preparing themselves for Industry 4.0 in Russia.

- **Establishment of a Robotics Centre**: The global electrical equipment manufacturer, ABB Electrical Group, plans to invest about USD 750,000 (RUB 50 million) into the creation of a robotics center in Technopolis Moscow. The center will develop technological solutions for robotized systems of arc and spot welding and high-precision material processing adapted for the Russian market. The company plans to set-up a training center with a capacity of 15 trainees and a show room for displaying the latest advanced manufacturing equipment.[15]
- **Partnership to promote Industrial Internet**: Rostelecom and Russian Space Systems (RSS) have signed a memorandum for the establishment of the *'National Industrial Internet Consortium'.* The association aims to assist the application of Industrial Internet technologies for Russia's economic growth and to facilitate cross-sector integration of solutions by uniting efforts of major industry players, manufacturing enterprises, software and hardware suppliers, integrators, operators, research entities and other interested parties.[16]
- **Innovative offerings by medium-sized firms**: Medium-sized firms in Russia have launched innovative offerings in the Industry 4.0 domain. Belfingroup Holdings has started offering engineering solutions for industrial robotics, production management, consulting services, agile quick manufacturing software and distributed production solutions. Hi-Tech Engineering company provides production control systems, which include analytics, project management and operation control. Competitive Technology

Manufacturing has launched a networked plant project, uniting distributed production facilities into a single ecosystem operated by artificial intelligence.[10]

- **Global companies open labs and centers in Russia:** In response to the growing IoT sector, Intel has opened an Ignition Lab to provide solutions to Russian companies using intel processors for transport and energy. Mitsubishi Electric has started operations in Russia in October 2014 to strengthen Mitsubishi's Factory Automation business. SAP has announced its intention to open a Russian Center for IoT in 2016 to provide customers and partners an opportunity to learn about the company's IoT technologies.[17]

Challenges in adoption of Industry 4.0 in Russia

Russian innovation happens primarily in the domestic market and international customers have low access to such innovations. Another challenge mentioned by experts is the lack of proper documentation of the manufacturing processes followed at plants, hindering the efforts of automating processes.[9] Even when the manufacturing processes have been documented, they vary from what is being actually followed at the shop floor.[9]

Adoption of Industry 4.0 is also hindered by lack of modern infrastructure, limited demand for innovation among large economic players, lack of trust towards foreign partners and limited adaptability of foreign software. Stagnating investments, expensive credit and constrained access to global capital markets are some other financial obstacles apart from exchange rate volatility.

3. India

Manufacturing contributes 18.4% in GDP

India has been considered as a global hub for the services sector, with manufacturing contributing only 18.4% in the GDP. Though manufacturing plays a small role in the Indian GDP as well as in employment of the labor force, its contribution at global level has improved in the last few years.

Since 2000, India's GDP has grown to USD 1,573 billion in 2014 at a CAGR of 7%. Its share in the global GDP has almost doubled from 1.4% in 2000 to 2.7% in 2014. During the same time period, its share in global manufacturing value add also increased from 1.7% to 2.9%. The share of manufacturing in India's GDP, on the other hand, increased marginally from 17.2% in 2000 to 18.4% in 2014.

Figure 22: Factsheet: India

Key Facts

Parameter	Value
Gross Domestic Product (GDP)	$1,573 Bn
Share of Global GDP	2.7%
Share of Manufacturing in GDP	18.44%
Share of Global Manufacturing GDP	2.95%
Share of Manufacturing in Exports	43.46%
Labor Force	496.96 Mn
Labor Force Participation Rate	56.5%
Hourly compensation (2015)	$1.93
Robots per 10,000 employees	1
Number of M2M connections	3 Mn

Key Findings

Overall status: Medium Adoption

> Share of global GDP has doubled in 2 decades, with services contributing most in this growth

> Share of manufacturing in India's GDP has declined

> Availability of large and cheap labor force

> Digital technologies are growing. However, there is still some time for market to develop

> Manufacturing has become an important agenda for Government (Make in India)

> However, Industry 4.0 initiatives are yet to be launched

Source: World Bank Data; IFR; ILO; Roland Berger analysis

Note: GDP and manufacturing value added are at constant 2005 prices. Unless mentioned all the data is for the year 2014.

The Index of Industrial Production (IIP), which is an indicator of how the Indian industries are performing, grew by 2.8% in FY15 and 2.4% in FY14. Manufacturing, which accounts for 75.5% in the IIP, grew by 2.3% in FY15 and 2.0% in FY14.[18] Prior to 2011, manufacturing grew at a CAGR of more than 10% between 2005 and 2011. The slow growth in the last few years is due to a slowdown in the economy and internal challenges.

Like China, India is home to a large labor force. In 2014, India had close to 496 Mn people in the labor force, 13% of which were employed in the manufacturing industry.[19] On a per capita basis, each employee in manufacturing contributed USD 6,300 of value add. Due to a fair labor participation rate of 56.5% and low minimum wages set by the government, India has been considered as a low-cost manufacturing destination.

Though India has maintained its manufacturing cost competitiveness vis-à-vis other manufacturing economies, it has not always been a first choice for many companies. Companies have been wary of setting up manufacturing plants in India due to bureaucratic hurdles, infrastructure issues, high cost of capital, agonizing land acquisition process, labor issues and unreliable supply of resources like power and water.

Geared to adopt changes

India has been slow in adopting Industry 4.0 technologies and currently faces a serious threat from other countries which are leapfrogging to implement advanced manufacturing solutions. The level of automation in India is low. As per a report by the International Federation of Robotics, in 2014, India had only 1 robot per 10,000 employees in the manufacturing sector. And in 2014, only 2,126 industrial robots were sold in India, accounting for 0.9% of global industrial robot sales.[20]

With a strong background in IT, India has seen a number of start-ups in the digital technology space. Companies like Imaginarium which provide 3D printing services have come up. Though the current market for 3D printing is small[21], big companies like Hero, L&T, Pidilite and ISRO have used such technologies to develop prototypes. Implementation of such technologies in industry on a large scale is bound to take some more time.

In terms of sectors driving Industry 4.0 adoption, the Automotive sector is at the forefront. Some other areas that have seen some traction in adoption of such technologies include packaging in the FMCG sector, service management at hospitals and monitoring in the energy / power sector.[22]

India faces a significant threat due to shrinking labor cost arbitrage compared to countries like Vietnam, Indonesia, etc. Manufacturers have been looking at other attractive destinations which offer the cost advantage which countries like India have offered historically. With adoption of Industry 4.0, India has an opportunity to turn the tide in its favor as Industry 4.0 will help India in evolving as a hub for manufacturing quality products at low cost when compared to other countries.

Government is determined to increase share of manufacturing in GDP

Manufacturing is on top of the agenda for the current government. Several initiatives have been taken to revive the growth in manufacturing and to adopt new technologies.

- **Launch of National Manufacturing Policy**: For years, the manufacturing sector has contributed between 15% and 18% in India's GDP. Recognizing that the manufacturing sector has a multiplier effect on the creation of jobs, the Government of India launched India's first ever National Manufacturing Policy (NMP) in 2012 with an aim to enhance the share of manufacturing in GDP to 25% and to create 100 million jobs. In order to make the rural youth employable, it also aims at taking necessary actions to impart necessary skill sets for various jobs.[23]

- **Make in India**: In September 2014, Prime Minister Modi launched the 'Make in India' initiative. The program has been devised to transform India into a global design and manufacturing hub. It aims at raising the contribution of the manufacturing sector to 25% of the GDP by 2020, in line with the objective of the NMP. Some of the strategic goals are enhancing job opportunities, minimizing imports, expanding exports and creating a conducive environment for technological evolution.[24]

  Though the initiative is primarily focused on bringing in more companies to set up manufacturing plants in India, it does not promote implementation of Industry 4.0 solutions which has become an inevitable necessity for India to realize its plans of elevating manufacturing to global levels of excellence.

- **MoU for developing research roadmap:** Some other initiatives include the Ministry of Heavy Industries and Public Enterprises (Government of India) signing an MoU with the Fraunhofer-Gesellschaft to support and augment the 'Make in India' program through increasing the innovation and technology prowess of the Indian industry. As part of the collaboration, Fraunhofer will support the Indian government as a Technology Resource Partner and will create a roadmap for technological development of the Indian industry. Fraunhofer will identify and plug technology gaps and implement corresponding projects in manufacturing.

Private companies are catching up

Though the Government of India and Prime Minister Modi have shown significant interest in promoting manufacturing and Industry 4.0 through various other policies like Digital India and Skill India, response from the private sector has been low. However, a few initiatives have been taken in the right direction – primarily in increasing the level of automation and implementation of Industry 3.0 solutions.

- **Auto OEMs spearheading automation:** For example, one auto manufacturer in India has started using a remote server controlled assembly system that guides workers to select the correct parts depending on the car model. This technology enables them to use a single assembly line for engines of different models of cars while eliminating human-error. The system also keeps track of inventory in real-time.
- **Plans to implement industry 4.0 in plants:** Hardware and software providers have taken a few initiatives to educate Indian manufacturing companies about Industry 4.0 technologies. They have also taken the first steps to adopt Industry 4.0 by implementing advanced manufacturing technologies in their own plants and by developing new technologies in the Indian context.

  Bosch, a leading global industry solutions provider, organized the Smart Manufacturing Conclave in November 2015, attended by more than 250 business leaders and key policy makers. The purpose of this conclave was to provide a platform to all the major stakeholders to share insights about Industry 4.0 and discuss about the possibilities and opportunities of connected manufacturing technology in India. Bosch announced that the company aims to implement connected production in all of its 15 Bosch plants in India by 2018. This is part of Bosch's three-ponged strategy – (1) learn and transfer know-how from European counterparts, (2) develop customized solutions for the Indian market, (3) lead Industry 4.0 development globally.[25]
- **Start-ups in the smart manufacturing space**: Start-ups such as Altizon have been established with focus primarily on smart manufacturing. Altizon, a technology company headquartered in Pune, is focused on making enterprises Internet of Things ready.[26] They have developed technology to bring the existing machines on a network to continuously track the data. Its flagship product – Datonis – helps build IoT products by providing device connectivity kits, a device management layer, a real-time big data engine and an alerting and monitoring service. It is also involved in providing the service of performing analysis on data collected from machines and providing recommendations for efficient operations.[27] Companies are using Altizon's product for condition monitoring, predictive analytics, operations and for driving consumer insights.
- **Seed funding for first smart factory**: Boeing is providing seed funding to the Centre for Product Design and Manufacturing in the Indian Institute of Science (IISc), Bangalore, to set-up India's first smart factory. The facility will be a scaled down version and will manufacture parts, though not in high numbers.[28]
- **Collaboration with educational institutes**: Companies have also shown interest in associating with educational institutes for Industry 4.0 technologies. AlfaTKG, a Japanese technology firm, signed a MoU with the Indian Institute of Technology Madras to undertake research for developing smart manufacturing technologies for India.[29] General Electric (GE) launched the GE Edison Challenge 2016, an open innovation challenge for the university student community. The competition is primarily focusing on digital-physical industrial internet solutions, promoting technology and product innovation, and encouraging young minds to come up with out-of-the box products related to Industry 4.0.[30] GE has also signed a MoU with IIT Madras to set-up an Industrial Internet Centre of Excellence to develop Industry 4.0 applications that will help companies save cost. [31] Festo Didactic, a leading provider of equipment and solutions for

technical education, has joined hands with BITS Pilani, a private technical institute in India, to develop a learning factory that allows practical application of modern manufacturing technologies.

Lack of overarching policy hinders adoption of Industry 4.0

Currently there is no central policy or government body to drive Industry 4.0. Companies are taking individual initiatives like conducting seminars, etc. Moreover, a comprehensive study evaluating pros and cons of Industry 4.0 has not yet been conducted – whether it will make sense to implement Industry 4.0 in India and if it does, what should be the roadmap for a successful transition.[32]

Though India has significant experience in developing IT-related infrastructure, it currently lacks a strong hardware capability network. As of now, a number of Indian IT firms are capable of handling the software part. However, not many companies exist which can understand the technicalities of developing Industry 4.0 hardware and building the same at cheap cost.

4. China

Global manufacturing leader

China has historically been considered as a world leader of low-cost exports and a hub for the manufacturing industry. It is today the world's largest manufacturing economy as indicated by its high share of 19.2% in global manufacturing value add in 2014 – a significant rise as compared to its contribution of 7.5% in 2000. Moreover, manufacturing has played a major role in the Chinese GDP. It contributed approximately 35.4% in Chinese GDP in 2014. China's GDP has also grown significantly at a CAGR of 10% from USD 1,439 billion in 2000 to USD 5,302 billion in 2014.

China's manufacturing advantage arises from the availability of a large labor force of 806 million, which is twice that of India and numerous times larger than that of other nations. Historically, China has had a high labor force participation rate. For the last few years, it has been around 77%. In 2014, 18.7% of the labor force was employed in manufacturing. In terms of productivity, on a per capita basis, each employee in manufacturing contributed approximately USD 19,400 of value add. Cheap labor, good infrastructure, favorable government policies, a large consumer base and an established supplier network have helped China in being competitive in the manufacturing sector.

Figure 23: Factsheet: China

Key Facts

Parameter	Value
Gross Domestic Product (GDP)	$5,302 Bn
Share of Global GDP	9.13%
Share of Manufacturing in GDP	35.37%
Share of Global Manufacturing GDP	19.12%
Share of Manufacturing in Exports	88.96%
Labor Force	806.5 Mn
Labor Force Participation Rate	77.6%
Hourly compensation (2015)	$6.44
Robots per 10,000 employees	36
Number of M2M connections	69 Mn

Key Findings

Overall status: Medium Adoption

- Share of global GDP and global manufacturing value add has grown significantly in 2 decades
- Share of manufacturing in GDP has increased by multifold
- Availability of large and cheap labor force
- Made in China 2025 launched to move from low cost to high-tech and high quality manufacturing
- Research on Industry 4.0-related technology & use of industrial robots has significantly increased
- Private players are actively taking part in adopting Industry 4.0

Source: World Bank Data; IFR; ILO; Roland Berger analysis

Note: GDP and manufacturing value added are at constant 2005 prices. Unless mentioned all the data is for the year 2014.

However, China is facing radical demographic changes, and availability of cheap and hardworking young workers is slowly declining. The demand for skilled employees has increased. The competitiveness that the Chinese labor force provided in the past has been eroded due to a steady rise in wages. Hence, to draw level with leading industrialized nations, government and companies are working to use new information and communication technologies to enhance efficiency and quality in industry.

Considered as low cost hub, but slowly catching up with technology

With China being a low cost country, Chinese manufacturers are still operating in the age of Industry 2.0, i.e. labor intensive, phase and are in the process of implementing Industry 3.0 technologies.

In terms of adopting advanced technology, China has been slow as compared to other nations but has made progress in the right direction in the last few years. As per a study done by Fraunhofer IOA, China registered more than 2,500 patents for Industry 4.0-enabling technology. In the USA and Germany, this number was 1065 and 441, respectively.[33] According to the International Federation for Robotics, in 2014, China had 36 multipurpose industrial robots per 10,000 employees in the manufacturing industry vis-à-vis an average world robot density of 66. However, it is slowly bridging the gap as indicated by its procurement of more than 57,000 robots in 2014, twice of that sold in Japan, the next biggest robot market.[20] China's ability to compete with other industrialized nations can also be evaluated by its 22.6% share of high-tech exports in the total exports.

Initiatives undertaken by the government and companies are a clear indication that China is actively working towards upgrading to Industry 3.0 and 4.0.

Chinese Government is spearheading the Industry 4.0 initiative

The Chinese government understands the need for digitization and heavily supports it through its policies.

- **Integration of Industry and IT**: In 2007, the Ministry of Industry and Information Technology started pursuing the 3i strategy – Integration of Industry and IT. This 5-year plan set the strategy of utilizing IT as the engine for industrialization to leapfrog in productivity by achieving high economic efficiency, low consumption of materials, low environmental pollution and sustainable development.[34]

- **Made in China 2025**: In 2015, the government announced the Made in China 2025 Program. The aim of this 10-year plan is to level the playing field between China and western industrial nations with respect to Industry 4.0. During these 10 years, Chinese companies should significantly improve overall manufacturing quality, enhance creativity and productivity, and integrate industrialization and information. The goal is to comprehensively upgrade China's industry to make China the world's leading industrial nation by 2049, which marks the 100th anniversary of the founding of the People's Republic of China.[35]

  As part of the program, nine tasks have been identified as stated priorities – (1) improving manufacturing innovation, (2) integrating technology and industry, (3) strengthening the industrial base, (4) fostering Chinese brands, (5) enforcing green manufacturing, (6) promoting breakthroughs in 10 key sectors, (7) advancing restructuring of the manufacturing sector, (8) promoting service-oriented manufacturing and manufacturing-related service industries, and (9) internationalizing manufacturing.[36]

  The plan also proposes to asses a company's maturity in Industry 4.0 by defining various measurements. For example, the program requires large manufacturing companies to increase their percentage of R&D spend from 0.95% in 2015 to 1.68% in 2025. It also proposes to increase the value adding ratio of the manufacturing sector by 4%, increase the use of CNC machines by 30% and decrease energy consumption by 34%.[35]

- **Launch of Internet Plus plan**: Last year, Premier Li Keqiang unveiled the Internet Plus plan to integrate mobile internet, cloud computing, big data and the Internet of Things with modern manufacturing, to encourage healthy development of e-commerce, industrial networks and internet banking, and to get internet-based companies to increase their presence in the international market. As part of the program, the government has proposed to speed-up the building of information infrastructure, the development of core chips and high-end servers, the application of cloud computing and big data, and the procurement of cloud computing services by the government. It has also proposed to launch a pilot project to publish data on government and public services, and to encourage national innovation platforms to open up to

enterprises. It has also emphasized on maintaining cyber and information security and on helping internet enterprises get listed.[38]

Response from private sector is positive

Having received support from the government, Chinese companies are actively taking initiatives not only to adopt Industry 4.0 technologies but also to develop them.

- **First unmanned factory**: Changying Precision Technology Company, a cell phone module manufacturer, has completely automated its production lines in its Dongguan factory. The production lines now use robotic arms to produce parts of cell phones. The factory is considered to be the country's first unmanned factory run by computer-controlled robots, CNC machining equipment, unmanned transport trucks and automated warehouse equipment. As part of the automation, the number of employees at the factory has reduced from 650 to 60 and defect rates have been reduced fivefold from 25% to 5%.[39]

- **Local production of robots**: Ningbo Techmation, a producer of machinery for plastic industries, launched a subsidiary, E-Deodar, to make robots that are 20-30% cheaper than those provided by the likes of ABB, Kuka and Kawasaki.[40] The company focuses on R&D, manufacturing and service of industrial automation equipment. The company has also planned to invest 150 million yuan, mainly for building a R&D center and a production base for its robots.[41]

- **Bid to acquire Industry 4.0-focused companies**: A few Chinese companies have shown interest in acquiring stakes in Industry 4.0-driven companies in Germany. These bids are driven by the fact that holding a stake in such a company will not only buy access to technology but also make the Chinese firms more comfortable in sharing sensitive data while implementing Industry 4.0 technologies.

  Midea, a Chinese household appliance manufacturer, made a bid for a 30% stake in Kuka, a leading German multifunctional robot manufacturer. Kuka is important for enterprises to upgrade their factories with full automation, latest human-machine interface functionality and machine to machine communication. In January 2016, ChemChina paid €925 Mn for Munich-based KraussMaffei machine tools, in part, because of their advances in Industry 4.0. Other smaller Chinese acquisitions in the German machine tool industry include the partial acquisition of H.Stoll by ShangGang Group and of Manz by the Shanghai Electric Group.[42]

- **Hardware and software companies are actively taking part**: In 2014, SAP had launched a number of marketing events – Shanghai Forum, Beijing Select and Shenzhen Forum. One of the main objectives of these forums was to provide information about SAP IoT solutions through theatre presentations, demo booths and messages in key notes.[43] Huawei and NXP Semiconductors have decided to collaborate for technical cooperation and joint innovation to create an open, robust and secure Industry 4.0 ICT platform. The partnership will bring together Huawei's ICT infrastructure and connectivity solutions and NXP's secure connectivity solutions to develop applications like logistics 4.0, factory automation and sensor networks.[44]

  Huawei and KUKA have also signed a partnership agreement to explore opportunities in smart manufacturing across European and Chinese industrial markets. As part of the partnership, the major focus will be on the use of Internet of Things, wireless and 5G network, big data solutions in manufacturing and factory environment and the use of Huawei's Infrastructure-as-a-service (IaaS) solutions for developing cloud-based smart manufacturing services.[45]

- **Interest shown by PE firms:** Private equity companies like AGIC Capital are investing in this space. AGIC Capital has invested in companies with high value-add technologies related to Industry 4.0 that significantly increase industrial productivity and efficiency, enable new applications and manufacturing methods and drive innovation. AGIC Capital has already raised USD 1 billion to invest in German SMEs which focus on developing China's next generation of industry.[46]

5. South Africa

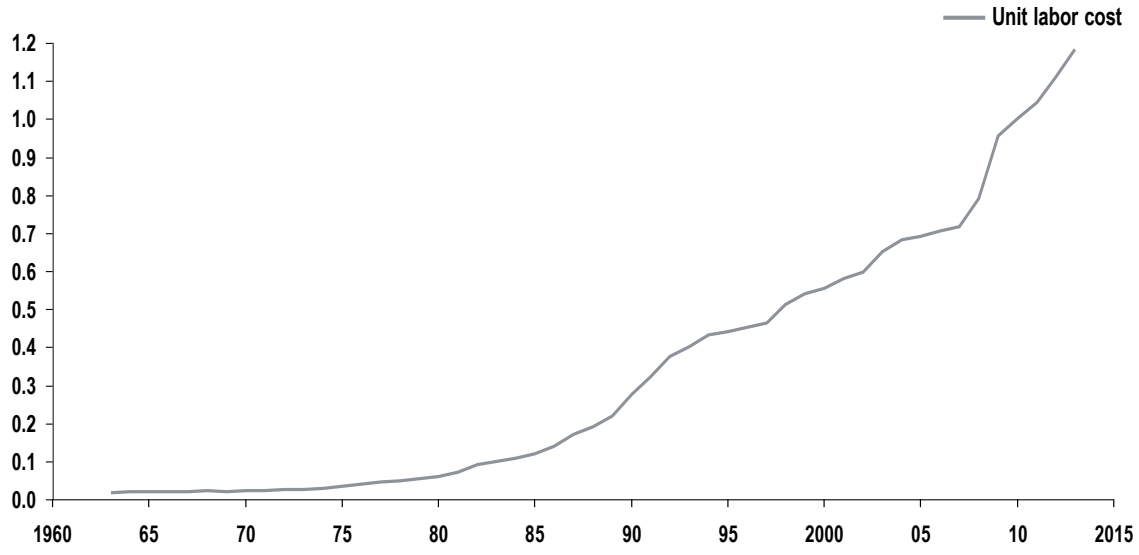
Manufacturing – In a state of flux

South Africa's share in the global GDP has almost remained constant at around 0.5% over the last few years and its contribution in global manufacturing value add has declined to 0.5% in 2014 from 0.6% in 2000. Moreover, South Africa's manufacturing sector has not been able to attract a high number of global manufacturing companies. Due to this, manufacturing's contribution in South Africa's GDP has remained low – in 2014, manufacturing contributed 14.6% to the GDP of USD 329 Billion.

South Africa has seen an increase in labor force over the years. In 2014, around 20 million people were part of the labor force while only 13.3 million people formed the labor force in 1994. However, as compared to other emerging nations, labor participation is low at 56.6%. In South Africa, the services sector has been a major employer of the labor force and industry has employed around 18% of the labor force. In terms of labor productivity, each employee in manufacturing contributed to around USD 24,400 of value add.

The manufacturing sector has been fraught with challenges which include high input costs resulting from high labor costs and low efficiency and a lack of application and implementation of supportive policy on industrialization defined by the government, in particular by the Department of Trade and Industry (DTI). Labor costs in South Africa have increased at a faster rate than its global peers, and there has not been a commensurate increase in labor productivity. Infrastructure also poses an important challenge – despite significant advances made in this space, relatively poor connectivity and accessibility continues to be a challenge for the implementation of digital elements of Industry 4.0.

Figure 24: Total Unit Labor Cost in Manufacturing, South Africa



Source: Federal Reserve Bank of St. Louis – Economic Data

Note: Index 2010 = 1, Not seasonally adjusted

Adoption of Industry 4.0 will help in improving the quality of products manufactured and increasing the quantum of manufacturing activity. Such initiatives might drive global companies to set-up a manufacturing base in South Africa as it will also open up a gateway to access the African region.

A sporadic, disperse movement

A number of companies have shown active interest in adopting Industry 4.0 solutions. However, activities seem to result from a company specific economic perspective or are initiated by large international players like GE, Schneider etc.[47] Even though Industry 4.0 is a topic that industry leaders and government are slowly acknowledging and discussing, the adoption at current state is fairly low as compared to other BRICS nations.

The automotive industry, which is dominated by global players in South Africa, is the pioneer in adopting Industry 4.0 technologies like robotics, sensors and advanced analytics.

Figure 25: Factsheet: South Africa

Key Facts

Parameter	Value
Gross Domestic Product (GDP)	$328.7 Bn
Share of Global GDP	0.56%
Share of Manufacturing in GDP	14.63%
Share of Global Manufacturing GDP	0.49%
Share of Manufacturing in Exports	41.29%
Labor Force	20 Mn
Labor Force Participation Rate	56.6%
Hourly compensation (2015)	$5.77
Robots per 10,000 employees	22
Number of M2M connections	5 Mn

Key Findings

Overall status: Low Adoption

- Share of global GDP has remained constant and share of global manufacturing value add has declined in 2 decades
- Share of manufacturing in GDP has also gone down
- SA is not a first choice for setting-up manufacturing plant due to low productivity and expensive labor force
- Active interest by a few private sector players resulting in individual initiatives for Industry 4.0
- Nation-wide Industry 4.0-related push is absent
- Robot density comparable to China

Source: World Bank Data; IFR; ILO; Roland Berger analysis

In terms of expenditure in R&D, South Africa ranks 33rd at global level, investing around 0.95% of GDP, which amounts to USD 6.49 billion in PPP terms.[48] South Africa has made good progress on adopting robots in its shop floors. In 2014, South African manufacturing companies had employed 22 robots per 10,000 employees. Though it is very well placed as compared to other BRICS nations, the number is significantly lower when compared to developed nations. South Africa's lack of competitiveness in the global market is also indicated by a small share of high-tech exports (~2.4%) in its total exports.

Initiatives like providing country-wide access to Wi-Fi have been taken to promote digital technology.[49] In some industries like aviation, efforts have been made to promote information and data sharing across the supply chain to track components and production processes and to monitor machines and perform predictive maintenance.[50]

A comprehensive government strategy is missing

In South Africa, individual elements of Industry 4.0 have been implemented by companies without major support from the government.

- **Investment in Industry 4.0-related research**: Since 2014, the South Africa's public sector has made investments to the tune of USD 24.5 million in research and development related to 3D printing. The Department of Science and Technology (DST) has committed to invest around USD 2.15 million on research programs related to additive manufacturing.[51] 'Aeroswift' is one of the flagship programs of DST, where in Council for Scientific and Industrial Research (CSIR) has collaborated with Aerosud, an aeronautical engineering and manufacturing company, to design and develop a large 3D printer for titanium parts. The 3D printer developed is capable of producing large, complex metal parts in addition to large volumes of smaller metal parts.[52]
- **Advanced Manufacturing Unit established**: The 'Technology Innovation Agency (TIA)', which is a parastatal South African agency, has established an Advanced Manufacturing unit. The main objective of the unit is to promote investment in innovation to enhance the knowledge intensity of manufacturing in South Africa. It represents a planning and implementation initiative that defines, prioritizes and co-ordinates innovative, high-impact, collaborative research and development and economic actions to

achieve the objectives of TIA. The unit also aims to build technological and industrial capabilities, and knowledge networks. In addition, TIA has also proposed to make investments in the areas of additive manufacturing, automation, advanced electronics, photonics and aero-structures while continuing to promote development of advanced manufacturing sectors like Aerospace.[53]

- **Integration of supplier's value chain**: Aerosud, and other similar companies in Aviation industry, have developed technologies to continuously track the production at a supplier's shop floor and help in efficiently planning their production.[50]
- **Partnership to set-up Advanced Manufacturing Center**: South Africa's leading power and utilities company has signed a strategic partnership with CSIR to focus on advanced manufacturing. As part of the collaboration, a joint center for Advanced Manufacturing and Repair Technologies will be established. The center will perform research in fields like robotics and unmanned vehicles for maintenance. The collaboration will also see both the entities taking initiatives for skill development and jobs creation.[54]
- **Establishment of Special Economic Zones (SEZ)**: The South African government is spearheading the process to establish various 'Special Economic Zones' (SEZs). The aim of these SEZs is to promote the competitiveness of South African enterprises by leveraging investment in export-oriented manufacturing industries and promoting the competitiveness of South African firms through the export of value-added manufactured products. One of the key objectives of these SEZs is to attract advanced foreign production and technology methods in order to gain experience in global manufacturing and production networks through attracting foreign direct investment (FDI). The SEZ program also offers relief from custom duties at the time of importation, simplified custom procedures, fiscal incentives and subsidized infrastructure.[54]

Challenges in adoption of Industry 4.0

A lack of country-wide central strategy to drive Industry 4.0 is one of the primary reasons of low adoption amongst companies. As a result, there is no alignment between the initiatives by the government and those by industry. Additionally, investment in research, development and innovation in advanced manufacturing technologies is low.

The culture of manufacturing innovation is predominantly observed in international companies and not as much in local South African companies. Moreover, when international companies exit operations in South Africa, they take their proprietary innovation with them, leaving South Africa in the lurch – which makes the need for home-grown innovation even more critical.

Despite a flourishing technological innovation-driven entrepreneurial ecosystem that boasts of an active venture capital and startup environment in IT and digital, there is limited interest in innovation in manufacturing. Concerns related to information security, lack of uninterrupted power supply, negative perception around cost of the technology and return on investment, obsolete IT infrastructure and the absence of a robust digital infrastructure have often been cited as other key deterrents for Industry 4.0 adoption in South Africa.[56]

Skill readiness of labor for Industry 4.0 in BRICS Nations

The success of any industry depends not only on the machines deployed for manufacturing the products but also on the labor force employed. It is important that the employees have the required skill sets to operate machines efficiently and to ensure that the processes are running as per standard operating procedures.

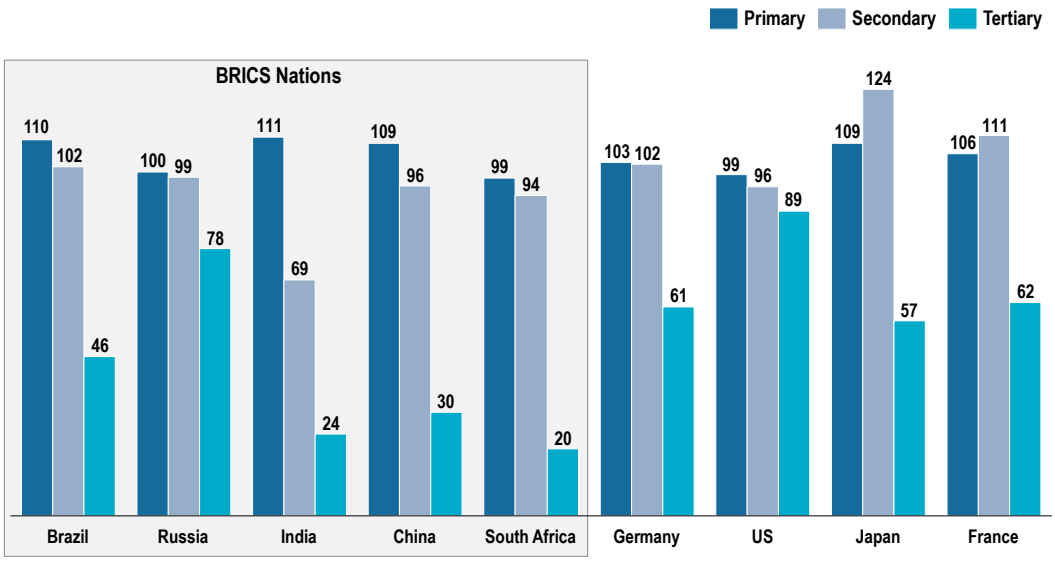
1. Current skilling level

Education plays an important role in ensuring skill-readiness of the labor force. General education as well as vocational education have a critical role to play in making labor force industry ready. BRICS nations face a dual challenge of a lack of highly-trained employees and non-employability of a large section of educated labor force due to skills mismatch.

In order to understand the current skilling levels, it is important to look at the performance of BRICS nations in the education space. Education is primarily divided into 3 levels – primary, secondary and tertiary. Gross enrolment ratio, which is the ratio of number of students enrolled at a level to the number of potential students, is a good indicator of the participation of students at different levels. At primary level, all the BRICS nations have a high Gross Enrolment Ratio (GER), comparable to that in the developed nations (Figure 26). All the BRICS nations have more than 100% enrolment ratio at primary level.

At secondary education level, except for India, which has a very low gross enrolment ratio of 69%, all the other

Figure 26: Gross Enrolment Ratio at various education level, in percentage, 2013



Source: UNESCO Institute of Statistics

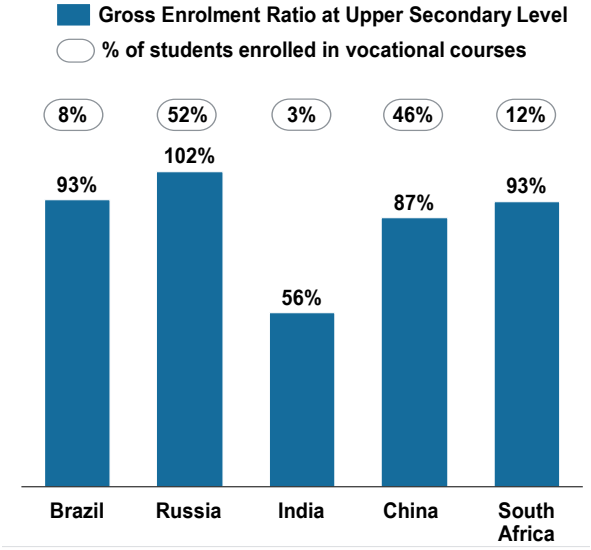
Note: Gross Enrolment Ratio = No. of actual students enrolled / Number of potential students; This also includes the grade repetition and hence it can be more than 100%

BRICS nations have a ratio close to 95%. In India, the primary reason for such a low participation is that a number of students leave school after the completion of the primary level education to join the work force, mainly in the agricultural sector.

At tertiary education level, which corresponds to higher education (post-secondary) such as engineering, etc., only Russia, amongst the BRICS nations, has a gross enrolment ratio comparable to that of developed nations. The enrolment ratio for India, China and South Africa is almost half or less than half of that in developed nations, which have gross enrolment ratios of around 60%.

In most of the BRICS nations, vocational education is introduced at secondary education level. Secondary education is further divided into lower and upper secondary levels. Though Brazil and China offer some vocational courses at lower secondary level, in most of the countries, including other BRICS nations, vocational education is introduced at upper secondary level. All BRICS nations, except for Russia, have a lower gross enrolment ratio at upper-secondary education level (Figure 27) as compared to enrolment at secondary education level. India has the lowest enrolment ratio of 56% at upper-secondary education level amongst the BRICS Nations, almost in line with its low secondary level enrolment.

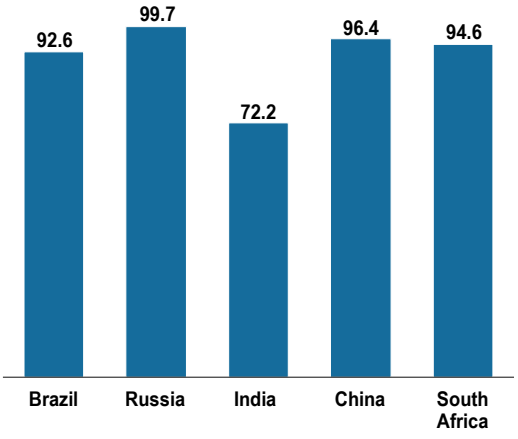
Figure 27: Gross Enrolment Ratio at Upper Secondary Level, in percentage, 2013



Source: UNESCO Institute of Statistics

In 2013, the percentage of upper-secondary students enrolled in vocational courses in Brazil, India and South Africa stood at 8%, 3% and 12% respectively, which means that a very small percentage of students entering upper-secondary education level opt for technical and vocational courses. Russia and China, however, have higher participation in vocational education at upper secondary level – 52% and 46% respectively, comparable to other developed nations like France and Germany which have an enrolment rate of around 45% in vocational courses at upper-secondary level.

Figure 28: Literacy Rate amongst people with 15+ years of age, in percentage, 2015

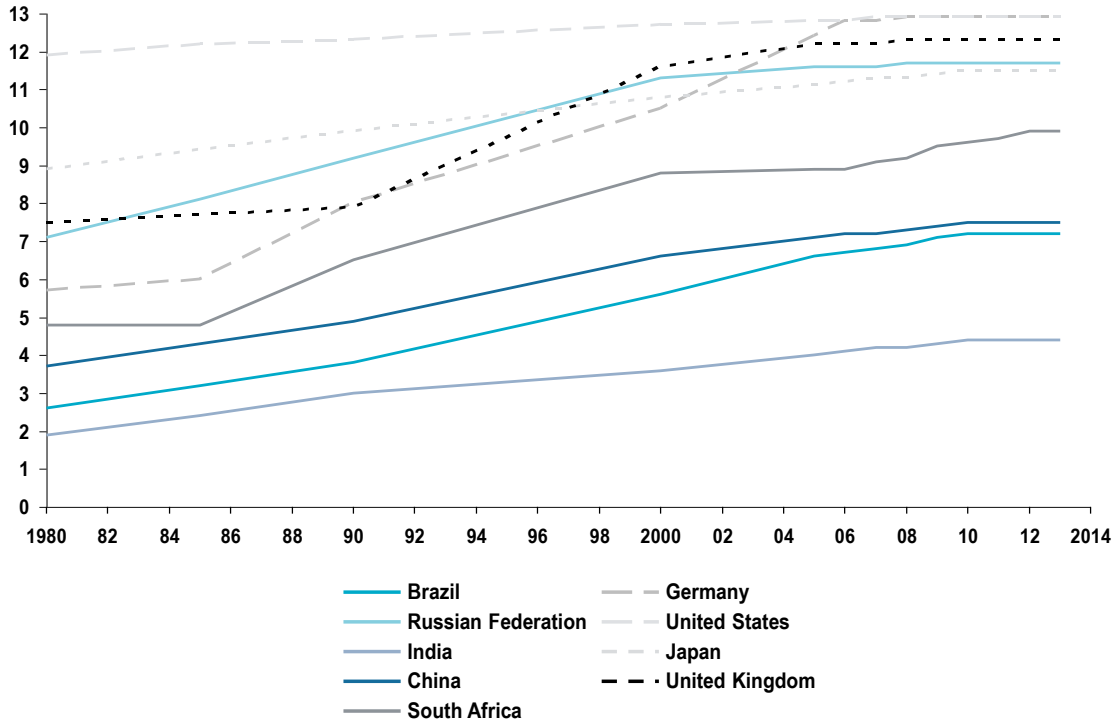


Source: UNESCO Institute of Statistics

In terms of basic ability to read and write, BRICS nations, except India, have a high literacy rate amongst the people with more than 15 years of age and can be considered to have reached universal literacy to a great extent. India, however, has a literacy rate of 72.2% as compared to more than 92% of other BRICS nations.

By law, all the BRICS nations require students to mandatorily attend at least 9 years (8 years for India) of education. Average number of years of education received by students in Brazil, India and China is 7.2 years, 4.4 years and 7.5 years respectively while South Africa has 9.9 years of education on an average. Russia, on the other hand, is the only country amongst the BRICS nations which has mean years of education of 11.5 years, comparable to 11 to 12 years in other developed nations.

Figure 29: Mean years of education received by people above 25 years of age



Source: Human Development Report, United Nations Development Programme

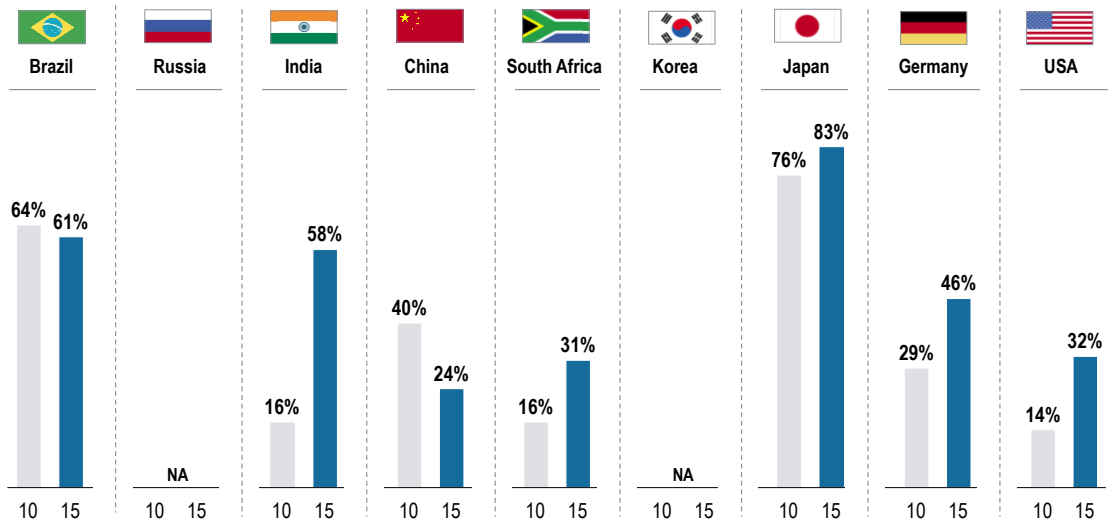
Given that introduction of Industry 4.0 will require high level of skills, low enrolment ratio in secondary and tertiary education is something that countries should be concerned about and should work to improve upon. Even though the primary focus of skills required in Industry 4.0 will be on applied and technical skills (like basic knowledge of IT, data analytics etc.), it would be important for the labor force to have basic skills on equipment operation and troubleshooting to be able to adapt and learn the new skills.

2. Challenges faced by companies in finding skilled workforce

With skills required for the jobs changing faster, companies across the world are facing challenges in finding skilled workforce at current skill levels. Technology is evolving faster than ever before and the talent pool through which employers have to select workers is shrinking due to declining workforce.

As per a survey conducted by Manpower Group, globally 38% of the employers face some kind of difficulty in filling the job vacancies. While the difficulty is less in South Africa (31%) and China (24%) as compared to global average, the challenge is higher for companies in Brazil (61%) and India (58%). At the same time, developed countries like Germany (46%) and Japan (83%) are also facing some challenge in finding skilled workers. However, this could be due to people opting for alternate jobs.[57]

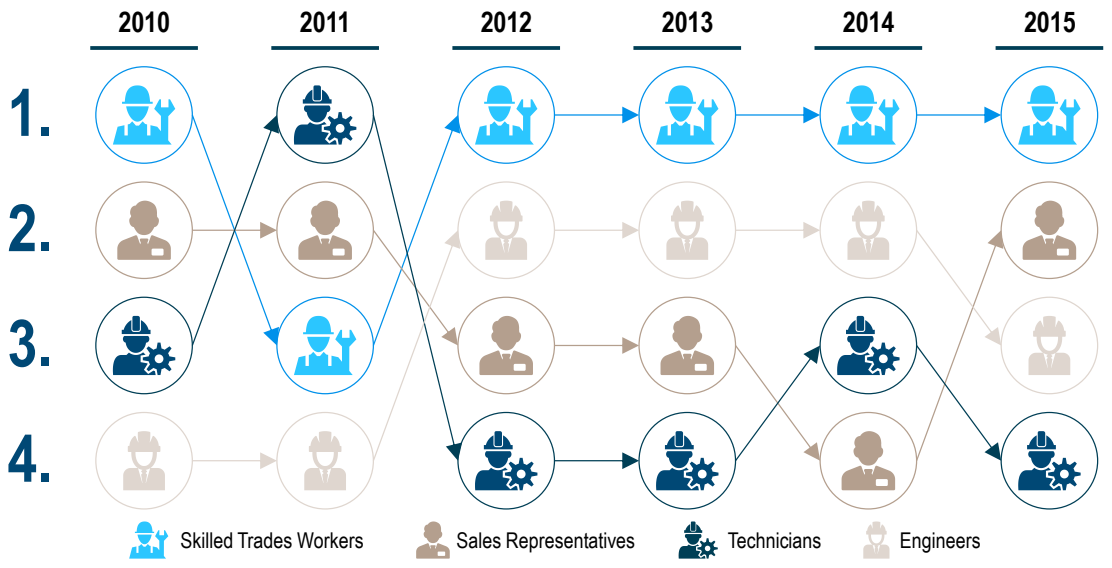
Figure 30: Percentage of companies having difficulty in filling jobs [%; 2010 & 2015]



Source: Talent Shortage Survey 2011 &2015, Manpower Group

According to the same survey which interviewed more than 41,700 hiring managers across 42 countries, finding suitable candidates for job roles like skilled trade workers, technicians and sales representatives remains a big challenge. Skilled trade workers, in particular, have been the people most difficult to find over the last 4 years.

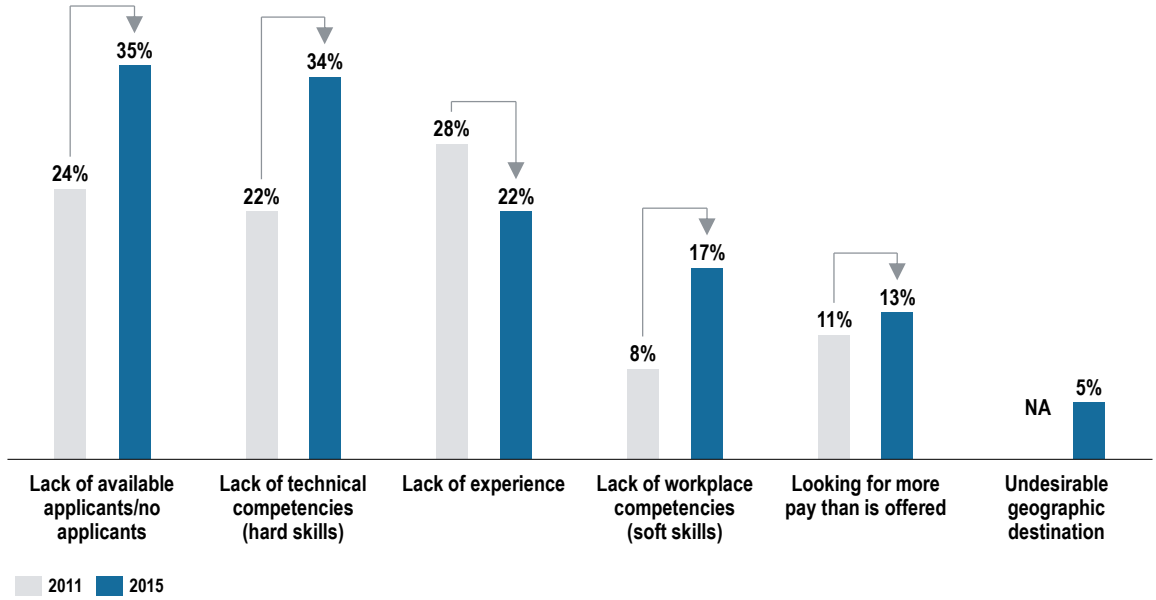
Figure 31: Top 4 jobs employers are having difficulty in filling [2010-15]



Source: Talent Shortage Survey 2015, Manpower Group

A number of reasons exist for this shortage of talent. In 2015, around 35% of the employers quoted lack of available applicants as a major reason for the difficulty experienced in filling the jobs. 34% of the employers mentioned lack of candidates with required technical competencies (hard skills) as the next major reason for the talent shortage while around 20% of the employers reported lack of experience and lack of workplace competencies (soft skills) as the other main reason for the same.

Figure 32: Reasons for difficulty in filling jobs (global) [% of employers; 2011 & 2015]



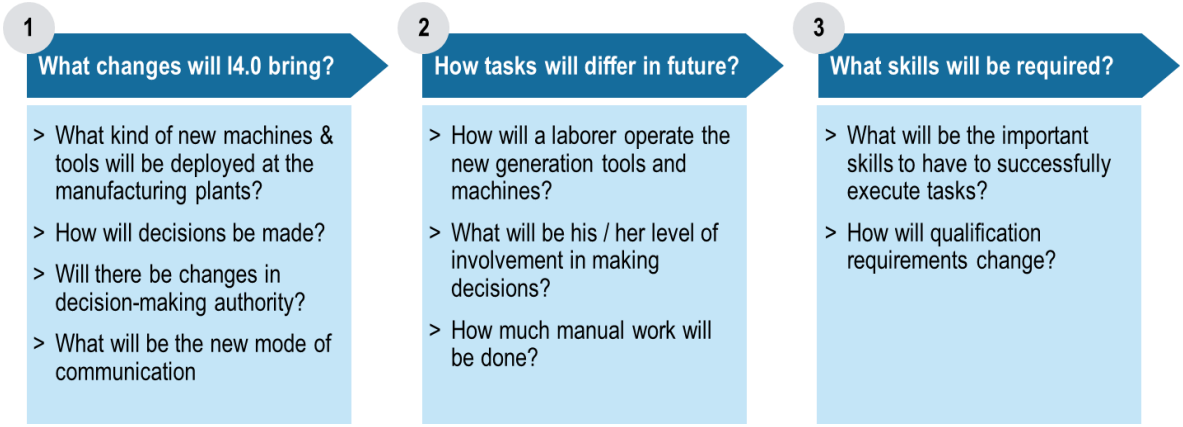
Source: Talent Shortage Survey 2015, Manpower Group

In order to overcome the above mentioned difficulties, companies have been resorting to developing capabilities of their existing workforce, developing new recruitment channels and tapping into labor pools of different countries. With the increase in adoption of advanced manufacturing technologies, the problem is bound to become even more severe. Not only will there be a lack of manpower with the desired skill sets but employers will have to make high capital investment in re-skilling or up-skilling their existing workforce to suit their requirements.

3. Skills for the future

It is very important to understand what changes Industry 4.0 will bring in the current manufacturing setup, what the new tasks that an employee would have to do will be, how it is going to be different from what he or she has been doing and what additional skills would be required to carry out those tasks successfully.

Figure 33: Framework for deriving skills required in Industry 4.0

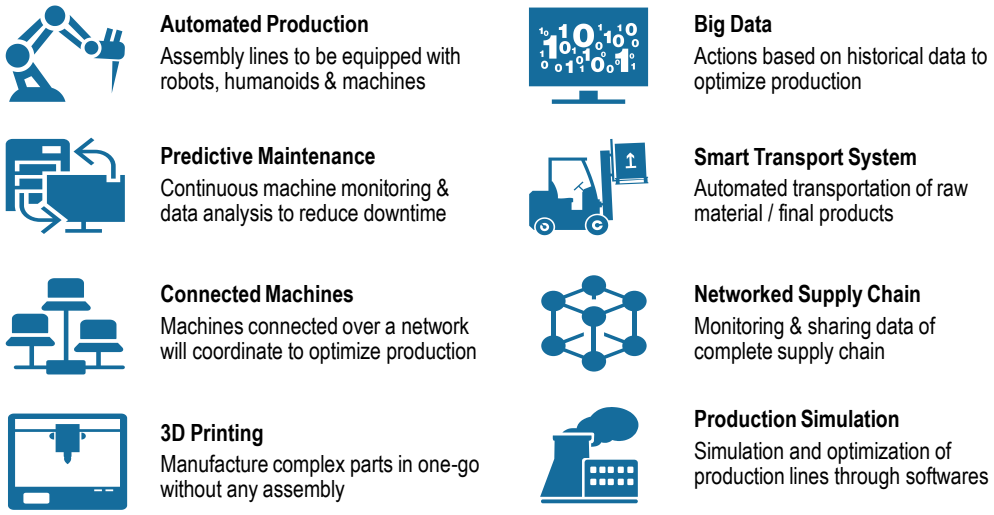


Source: Qualifications and Skills in the Factory of Future, VDI and ASME

3.1. What changes will Industry 4.0 bring?

The next industrial revolution will bring higher level of automation and interconnectivity in the manufacturing process. The tools, technologies and machines to be used are expected to be different from what is present today. Smart machines will coordinate manufacturing processes by themselves, smart service robots will collaborate with workers on assembly line and smart transport systems will transfer goods from one place to another. Smart devices like tablets, wearables, etc., will be used to gather and analyze real-time information.

Figure 34: Examples of changes with adoption of Industry 4.0



Source: Roland Berger

New machines and tools: Machines deployed in the plants will involve higher automation and will be interconnected on a base network. Data and information will be collected and analyzed on a continuous basis. Machine parameters will be adjusted based on quality requirements and historical data. Condition based monitoring will become an important part of maintenance activities. Predictive maintenance will dominate preventive and reactive maintenance activities – just before the breakdown of machines, maintenance personnel will be intimidated about the maintenance job for better planning. The supply chain will become more efficient. From the point raw material comes into the store to the point the final product is dispatched, production and product will be tracked. Production plans will be developed based on the demand and inventory levels at distribution centers and retail stores.[58]

Decentralized and flexible structure: The organization structure of the future manufacturing plants will become more flat, flexible, decentralized and changeable. Different production areas will become interconnected. Workers, capable of handling data and using IT, will not necessarily be bound to a certain production area like paint shop or weld shop and will be able to move from one shop to the other based on the requirement. Increased focus on using IT will improve the chances of job rotation and enrichment.[58]

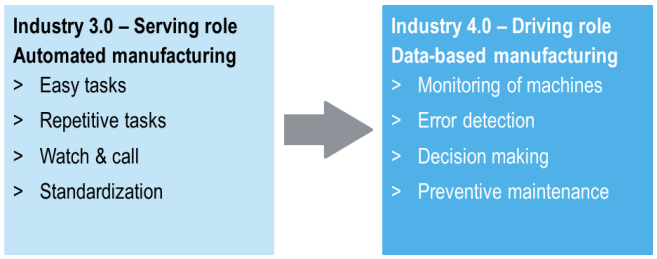
3.2. How tasks will differ in future?

Skilled labor will have the opportunity to take part in greater task variety and will no longer be associated with only one particular type of job. There will be a significant reduction in monotonous and ergonomically challenging jobs. Employees will have to share the space with intelligent robots. Assistant systems will support work significantly but the final decisions have to be made by skilled employees. Team work will be central, not only throughout the horizontal and vertical levels, but also at the actual working place with these assistant systems.

Information and data will be the key elements which the employees will have to process in their day-to-day jobs. Artificial intelligence will enable collaboration between humans and machines. And the interaction will not only be limited to pressing or touching buttons, but also by voice and gesture. Workers will use devices like

smartphones and tablets for communication and machine operation. New jobs will require the employees to be a part of the planning process and to be involved in process improvement and optimization activities. employees would be required to do less of manual work and more tasks of control and supervision of the processes.

Figure 35: Change in role with Industry 4.0

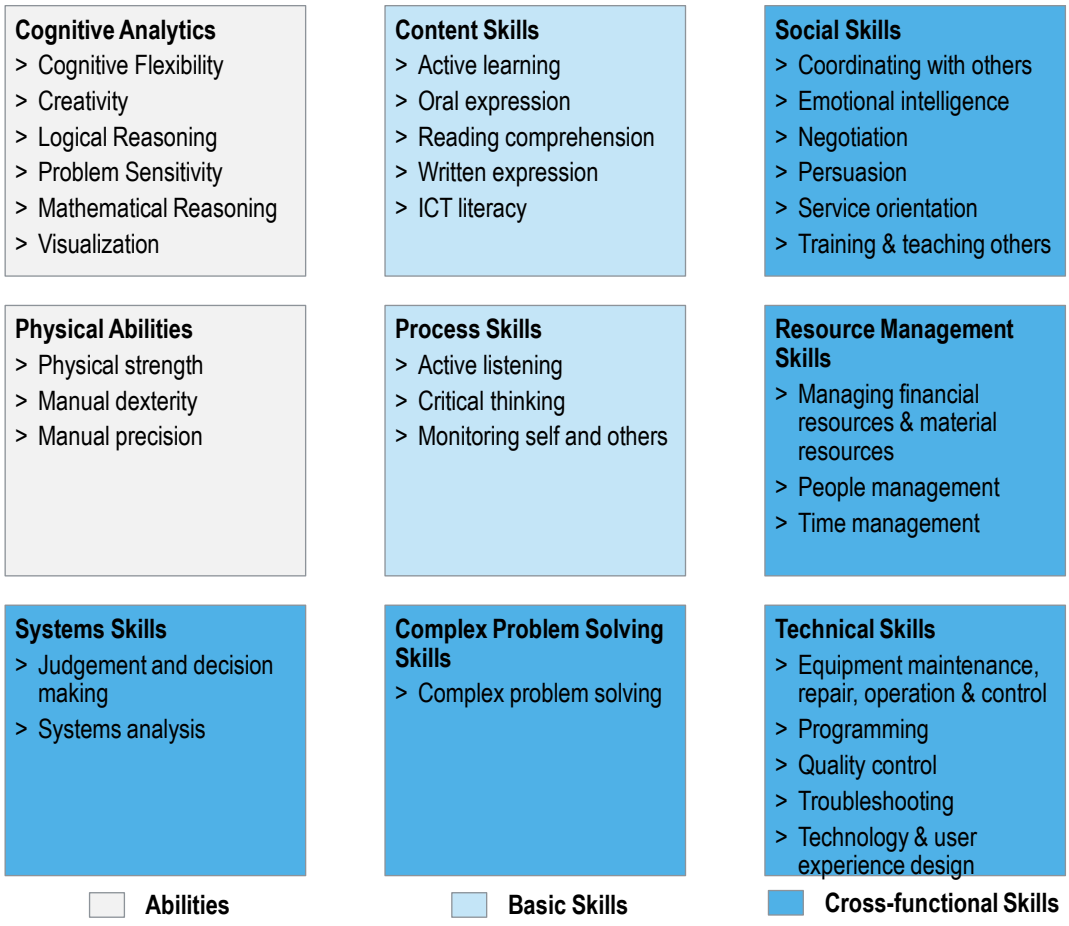


Source: Festo Didactic

3.3. What skills will be required?

With the change in work environment and tasks expected to be carried out by workers, the skill required will also change. These new skill sets will not replace the existing skill sets. Rather, these new skills will be required in addition to the skills that are important in current scenario. Core work related skills can be classified into 3 categories and 9 sub-categories as shown in Figure 36.

Figure 36: Categorization of skills into skill family



Source: World Economic Forum, based on O*NET Content Model

As per the 'Future of Jobs' survey conducted by the World Economic Forum, it is expected that a number of skills that are not considered to be significant in today's context will form one-third of the desired core skill sets of most occupations in 2020. Such a shift in the skill requirement is expected with increased digitalization. The ability to work with data and make data-based decisions will play a major role in the jobs of future.[59]

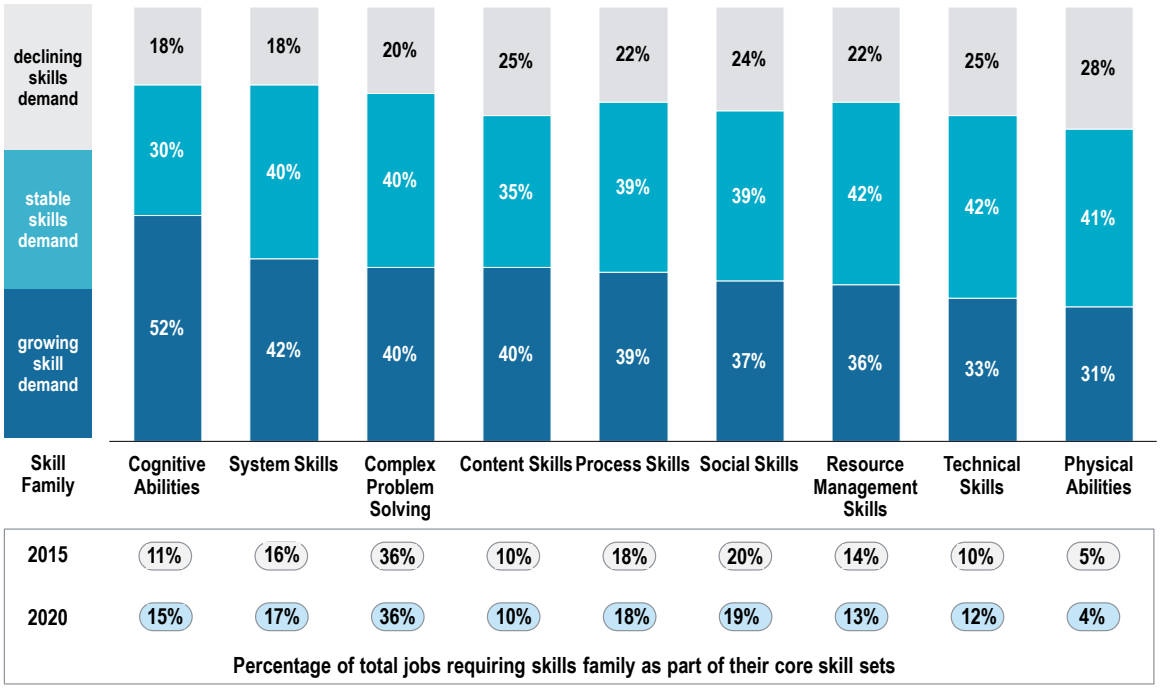
With adoption of automation and artificial intelligence, a number of tasks involving technical skills like troubleshooting machine problems, etc. and resource management skills like people and time management would be eliminated. As per the mentioned survey, it is expected that percentage of jobs requiring Technical Skills and Resource Management Skills as part of their core skill sets will go down from currently 14% and 14% respectively to 12% and 13% respectively in 2020. However, demand for technical skills required for repairing and maintenance operations will increase. The percentage of jobs requiring Cognitive Abilities as a core skill will rise to 15%, from a current level of 11% (Figure 37).

Manufacturing dominated industries like Automotive are expected to see an increase in demand for cognitive abilities, content skills, system skills and process skills in the future. This can be attributed to the fact that Automotive industry is at the forefront of adopting Industry 4.0 technologies and will be the first to experience Industry 4.0 at a bigger scale.

Though skills demand at an aggregate industry level is expected to evolve as mentioned above, the degree of change in skill requirements within individual job families is even more significant (Figure 37). For example, among all the jobs requiring cognitive abilities as part of their core skill sets, 52% of the jobs do not have such requirements now and are expected to have growing demand by 2020. In 30% of the jobs, the demand currently is high and are expected to have stable demand. The remaining 16% of the jobs which require high cognitive abilities today will see a decline in importance of cognitive abilities.

Cognitive abilities, system skills and complex problem solving skills are the top three skills expected to be high in demand and will continue to remain important.

Figure 37: Change in demand for core work-related skills, 2015-2020, all industries

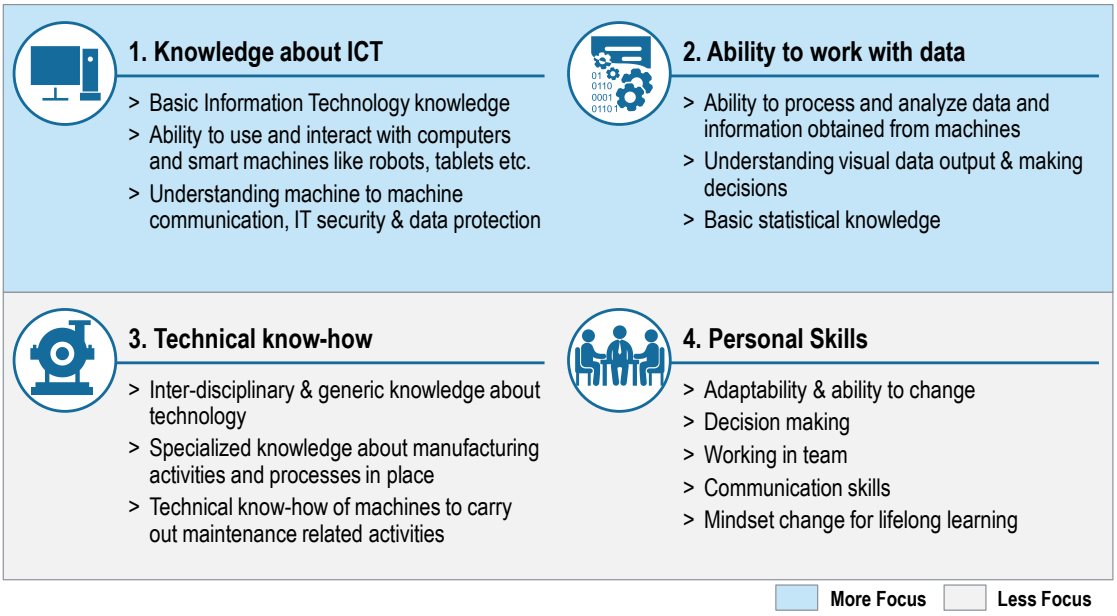


Source: Future of Job Survey, World Economic Forum

Note: In above chart, the percentage in bar chart indicates the percentage of jobs indicating growing / stable / declining demand for a particular skill family as core skill set.

In the context of Industry 4.0, even though it is expected that employees will have to gain new skills, the core qualification and skills imparted in the current technical and vocational education will still remain important and will have to be updated with the evolution of industry technology. Important skills that will be required can be classified into four main categories (Figure 38)

Figure 38: Important qualifications & skills to have for Industry 4.0



Source: Roland Berger

4. SKILL RELATED CHALLENGES COMPANIES WILL FACE WITH INDUSTRY 4.0

With the advent of Industry 4.0, the companies will not only face challenges in finding the skilled employees but also a few other challenges related to their exiting workforce and skill development programs as mentioned below:

- **Up-skilling**: Companies will have to up-skill their workforce via in-house or external training centers. For example, an assembly line worker involved in manually fitting a part will be required to operate a robot or other tools to do so. He / she should develop the skills to be able to operate the new tools efficiently.

- **Re-skilling**: Industry 4.0 is expected to result in job displacement to a certain extent. A number of jobs will cease to exist. And a number of new jobs will be created. Companies will have to make the investment in re-skilling of the labor force to prepare for this expected shift.

- **Continuous Learning**: Technologies will become obsolete at a faster rate. Continuous professional development strategies will be required to easily adapt to the changes that technological advancement brings.

- **Mindset change**: Given that the labor force will have to adapt to a number of changes, they will resist and oppose implementation of newer technologies. This will require companies to plan for mindset change of its employees to facilitate smooth transition to advanced manufacturing processes.

5. CHALLENGES FACED IN SKILL DEVELOPMENT BY BRICS NATIONS

All the BRICS nations have realized the importance of skill development in achieving economic growth in the future and have taken various measures to bridge the skill gap. From increasing education expenditure to increasing network of vocational trainers by launching nation-wide programs, initiatives have been launched to make the labor force industry-ready.

- **Demand supply mismatch**: Currently, vocational education and skill development in BRICS nations is primarily supply driven, i.e., the skills imparted by training institutes may not be in line with the industry requirement. Historically, in many countries, enterprises have not taken part in the defining the training programs as per industry requirements. This has resulted in a high mismatch between the skill sets applicants have and the skill sets they are expected to possess, resulting in low employability among the youth of these countries. To overcome this problem, companies have been running in-house training institutes / programs to impart the necessary skills, which drives up the cost.

- **Access**: Lack of access to vocational education has also contributed to the skill gap that exists today because a number of students are unable to pursue vocational education as sufficient number of vocational schools and training institutes across the country do not exist. Among the BRICS nations, Russia and China have historically emphasized on vocational education and have been successful in ensuring high enrolment ratio in vocational courses at upper secondary level by making vocational institutes accessible. Brazil, India and South Africa, on the other hand, see very little participation in the vocational education as a result of low existing capacities.

- **Lack of industrial training**: Except for Brazil and China which have some exposure to vocational education at primary and lower secondary level, vocational education in BRICS nations is primarily introduced in the upper secondary level. At present, the vocational education comprises of courses in vocational schools and apprenticeships are not included as a mandatory part of educational programs. As a result, students lack the practical exposure which helps in quick adaption of technical skills and graduate without much workplace learning. This is due to the weak industry linkages across BRICS nations, resulting in lack of apprenticeship opportunities for all the students.

- **Quality**: BRICS nations also face challenges in terms of having inflexible and outdated curricula, shortage of qualified teachers and trainers and unavailability of proper, up-to-date infrastructure (building and equipment).

- **National Qualification Framework (NQF)**: NQF organizes qualifications according to a series of levels of knowledge, skills and aptitude. Each of these levels is defined in terms of learning outcomes which a learner must possess regardless of whether are obtained through formal, non-formal or informal training. As a result, any person possessing the skill sets as defined by these levels will be eligible to hold the certificates for the same. The NQF makes the progression pathways transparent so that institute, students and employers are clear about what the certificate holder can and cannot do. It plays an important role in facilitating workers' mobility from vocational education to general education. Lack of standards results in non-uniformity in the outcomes associated with different qualifications across institutions. Russia, India, China and South Africa have a National Qualification Framework. However, every country is at a different stage. Brazil currently lacks a national qualification framework and is dependent on the generic certification system, in which a student is provided a certificate after completion of a vocational course, which cannot be related to a qualification level.[60]

- **Lack of resources**: Skill development efforts are hindered by funds availability. Government of all the BRICS nations allocate a significant percentage of public expenditure on vocational education and skill development. In some countries, even private sector contributes to a certain extent in raising funds. However, these funds remain insufficient to bridge the skills gap that exist in these BRICS nations.

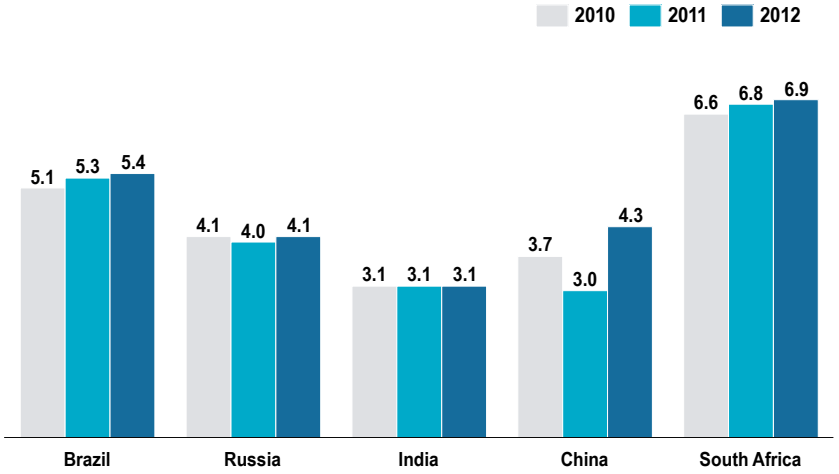
- **Negative image at secondary level**: In some countries, Vocational Education and Training (VET) is considered by the public and parents as a career choice for students who are less qualified academically. The VET track suffers from a negative image, i.e., VET is for school drop-outs rather than a way of training workers. Such a negative image exists predominantly because the students are admitted to general or VET courses based on examination results or grades at the end of the lower secondary education. The problem of negative image of vocation courses is much more severe at secondary level. At tertiary level, technical education is one of the most sought after courses across the BRICS nations.

6. SKILL DEVELOPMENT INITIATIVES UNDERTAKEN BY BRICS NATIONS

In order to bridge the skill gap that exist, several initiatives have been undertaken by BRICS Nations. Though some initiatives have been undertaken at the federal / central level, a few nations amongst the BRICS are collaborating bilaterally with developed nations to further strengthen their efforts in skill development.

Across BRICS nations, expenditure on education as a share of GDP has increased over the years and has become a major part of country's total public expenditure, accounting for more than 10%. For example, in 2012, Brazil and South Africa spend around 5.5% and 6.5% of their GDP respectively on education. Other BRICS nations – Russia, India and China – spend around 3% to 4% of their GDP on education.

Figure 39: Share of public expenditure on education to GDP, in percentage



Source: BRICS Statistical Survey, 2015

BRICS nations have prioritized skill development as a national agenda and have taken various initiatives to develop skills of their citizens to meet industry requirements.

As part of its National Policy on Skill Development, India has established the National Skill Development Corporation (NSDC) and Sector Skill Councils. It has also launched National Skill Qualification Framework (NSQF). Russia undertook the 'Skill Development for Industrial Growth' initiative under the Agency for Strategic Initiatives to bridge the gap between industry's skill demand and supply and to further strengthen the industry links. China has joined hands with Germany through the Sino-German Collaboration to accelerate its skill development program. Brazil, with the launch of its federal education and training program – PRONATEC, has significantly improved the VET quality and network. South Africa has been collecting a skill development levy (1% of all the worker's pay) from all the companies to raise funds to undertake skill development activities through its SETAs (Sector Education and Training Authorities) and federal training institutes.

6.1. Initiatives by Government of Brazil

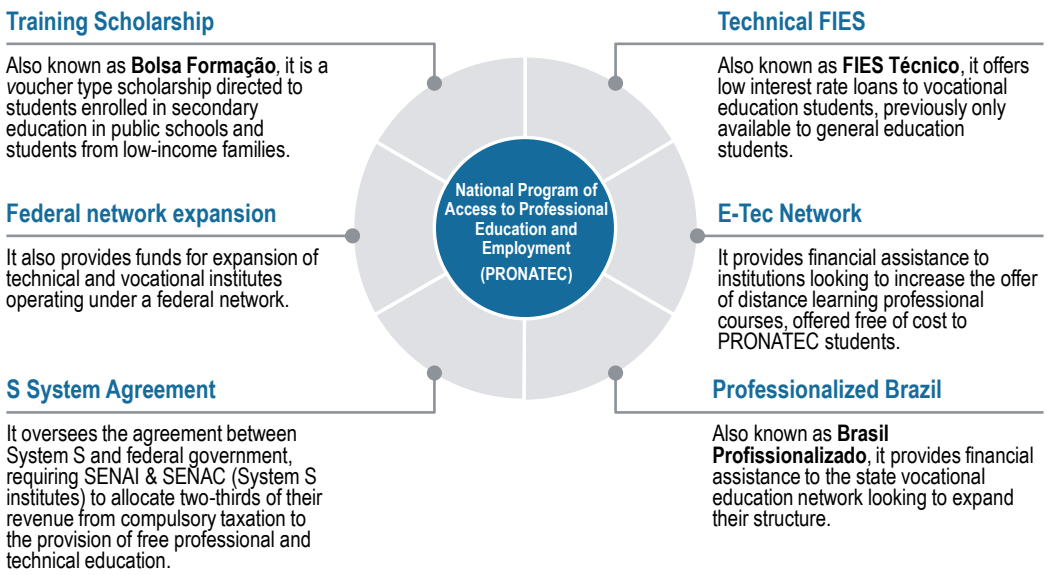
In Brazil, Sistema S has played an important role in the skill development since its inception in the 1940s. Though institutes established under Sistema S are not new initiatives undertaken by the Brazilian private sector with support from the government, it is important to record the unique mode of operation it has and the

contribution it has made in skill development in Brazil. In 2014, the institutes under Sistema S were responsible for provision of 43% of the professional and technical education in Brazil.

Sistema S is a group of 10 non-profit private institutes, classified as autonomous social services, that undertake activities related to public interest like training, skill development, support service for micro and small enterprises, etc. Each institute is associated with a particular sector and is responsible for (1) improving quality of life of workers within that sector and (2) providing technical and professional education to meet the industry demand of qualified workers. Among these institutes, SENAI and SENAC are the two most important institutes which oversee industrial and commercial training, respectively. Sistema S institutes are funded primarily by public money, raised by collecting mandatory payroll taxes from the firms in their associated sectors. These funds are then efficiently mobilized by the institutes to provide vocational education through its institutes. One of the important reasons of high effectiveness of these institutes is their private control and management.

In terms of the major initiatives undertaken for skill development, in 2011, the federal government of Brazil created the National Program of Access to Professional Education and Employment (PRONATEC). PRONATEC is the main initiative related to VET in Brazil. PRONATEC's primary objectives are to (1) expand supply of vocational education at federal and state level, (2) increase workers' educational opportunities from initial training to professional qualification, (3) increase the quantity of pedagogical resources, and (4) improve the quality of secondary education. To achieve these objectives, it has been increasing the number of VET institutions, increasing the number of openings in a course and offering financial assistance to students from low-income families through six major programs as shown below.

Figure 40: Program and initiatives under PRONATEC (Brazil)



Source: Assessing Advances and Challenges in Technical Education in Brazil, World Bank Study

As of mid-2014, PRONATEC had served approximately 7.27 million students and had set a goal of enrolling 12 million students between 2015 and 2018. During the period of 2011-14, investment of approximately R$ 24 billion was made as part of the program.

6.2. Initiatives by Government of Russia

The government of Russia has set up the Agency for Strategic Initiatives (ASI) as a non-profit organization to implement a number of measures in the economic and social sphere. In an effort to prepare Russia ready for the future, ASI has launched the Skill Development for Industrial Growth initiative. The main purpose of the initiative is to provide staffing support to the Russian industry by creating a quality monitoring system for staff training and by developing a range of measures aimed at improving secondary vocational education.

Figure 41 lists down the skill development initiatives undertaken by Russia. The ASI has also developed an 'Atlas of Emerging Jobs' which lists down the occupations that are bound to get outdated and outlines the prospective new jobs. As part of this initiative, jobs and competencies have been mapped for 25 sectors and is expected to act as a guide to young people in selecting their desired career path.

Figure 41: Skill Development for Industrial Growth Initiative, Russia

Source: Agency for Strategic Initiatives website

As part of the initiative, Russia, in 2012, has joined WorldSkills International. WorldSkills is an international movement which aims to increase the prestige of skilled jobs and to promote development of vocational education through harmonization of top practices and global professional standards. To build awareness of skills excellence and qualification development within the Russian Federation the *Agency of Development of Professional Communities and Skilled Workers – WorldSkills Russia Union* – was established by the Ministry of Education and Science, the Ministry of Labour and Social Protection and the Agency for Strategic Initiatives. WorldSkills in Russia is supported by international equipment and technology suppliers like FESTO, Lincoln Electric, Samsung, DMG MORI and other Global Partners of WorldSkills International. The main state corporations, aviation and shipbuilding holdings, nuclear power industries and other major employers (United Shipbuilding Corporation, JSC United Aircraft Corporation, Rostec, Rosatom, Chelyabinsk Tube Rolling Plant etc. also support WorldSkills Russia.

WorldSkills Russia focuses on the following key areas:

1. **Multi-level WorldSkills Russia Competition System development**
   - Junior Skills for early professional training and skills competition for schoolchildren aged 10 – 17
   - WorldSkills competition for students to increase the attractiveness and quality of VET
   - WorldSkills Hi-Tech Competition for young workers to increase labor productivity
2. **Educational and in-company training systems development**
   - Infrastructure for global WorldSkills practices transfer
   - Regional Standard for Skills Development and Industrial Growth
   - International Exchange Development Projects
3. **WorldSkills Academy**
   - Training and certification of experts and trainers
   - Developing educational and methodical materials
   - Generation of proposals to update educational standards and qualification requirement for workers in 50 most demanded occupations
4. **Future skills forecasting and development**
   - Research & forecast of future demand for skills, and transformation that will be required in education & training system to match this demand
   - Future skill verification in Future skills lab and workshops at Worldskills competition

- Description of technologies demanded, existing skills gap and future job profiles

In 2014, Russia also implemented the Dual Education project in 13 pilot regions. 105 educational institutes and 1005 companies have participated in the project and approximately 21,000 students and 5,600 mentors were engaged in the dual education projects. The initiative has also provided financial support to the tune of USD 6.9 million to the students of STEM discipline to pursue studies in 332 qualifications in 227 educational organizations in 27 countries.[10]

6.3. Initiatives by Government of India

The government of India, as part of its 12th five-year plan, formulated a National Policy on Skill Development in 2009 with the objective to create a workforce empowered with improved skills, knowledge and internationally recognized qualification to gain access to decent employment and ensure India's competitiveness in the dynamic global labor market.

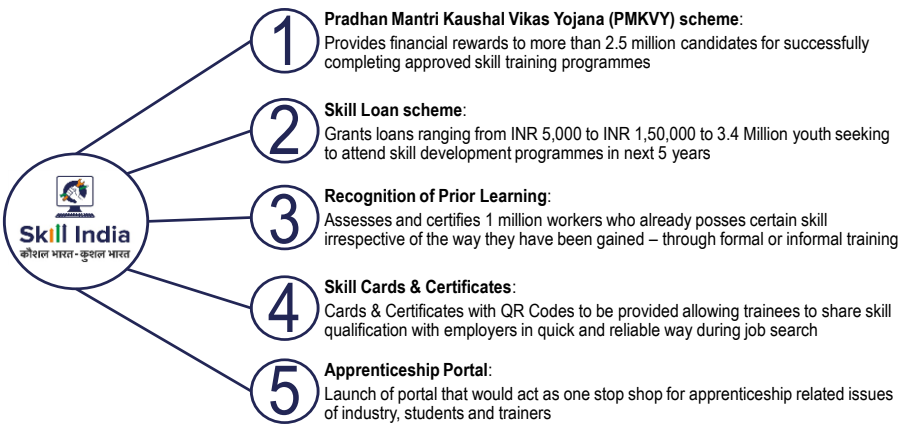
In line with the policy, the National Skills Development Corporation (NSDC) was established as a one of its kind public private partnership in India to fulfil the growing need for skilled manpower across the sectors and to narrow the existing gap between demand and supply of skills by focusing on expansion of the vocational education network. It promotes creation of large, quality, for-profit training institutions by providing funding in the form of equity, debt and grants. Since its inception, NSDC has partnered with 267 training providers to set up 6,952 training institutes, which have trained approximately 8 million people and have got placement offers for close to 3 million people.

NSDC has also facilitated establishment of around 40 Sector Skill Councils (SSC). SSCs play a vital role in bridging the demand-supply skill gap. Each SSC represents a particular sector and has a number of industry representatives on board. Based on industry demand, SSCs decide the national occupation standards and qualification levels and design the training curriculum that is then used in training institutes established through NSDC. These SSCs are also responsible for assessing and certifying the trainers employed by training institutes.

In 2013, India launched its National Skill Qualification Framework (NSQF). NSQF organizes qualification into 10 levels based only on knowledge, skills and aptitude and not on years of education. The levels are defined in terms of learning outcomes which the learner must possess regardless of whether they were acquired through formal or informal training. SSC took the responsibility of defining the National Occupational Standards (NOS) and qualification packs for each job role. These NOSs define the measurable performance outcomes required from an individual engaged in particular task at a particular NSQF level.

Prime Minister Narendra Modi made skill development a key point after assuming the office and launched Skills India initiative in July 2015.

Figure 42: Initiatives undertaken as part of Skills India

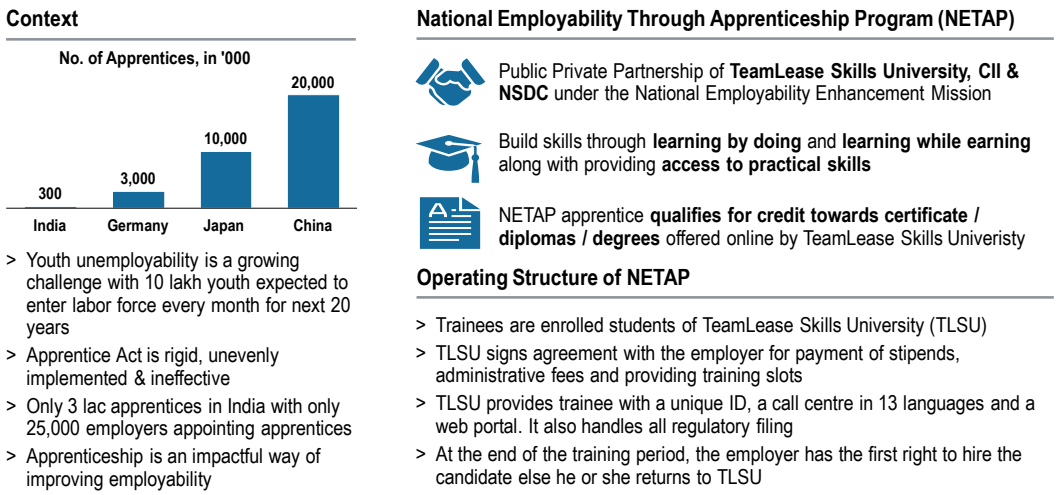


Source: Government of India

In order to improve industrial training scenario, India has also launched the National Employability Enhancement Mission (NEEM). The objective of NEEM is to offer on-the-job training to enhance employability of a person pursuing his or her graduation / diploma in any technical and non-technical stream. These trainings are also provided to a person who has discontinued studies of degrees or diploma course.

In 2016, NSDC also launched the India Skills Competition with the objective to promulgate skills in the society, to motivate youth to pursue vocational education and to champion skills and learning for work through local, regional and international skills competition. A team of 192 participants in 24 skill categories represented from each state took part in the competition.

Figure 43: Case Study: NETAP, India



Source: NETAP Website

6.4. Initiatives by Government of China

China has historically seen a high participation in vocational education programs. In July 2010, China's Ministry of Education released guidelines for education reform and development over the next 10 years and recognized vocational education a key area to focus on. As per the national plan, China had set the target of enrolling around 23.5 Million people by 2020 in vocational education at secondary level.[61]

In an effort to eliminate financial barriers that exist in vocational education, the Chinese government offered a subsidy of CNY 1500 (USD 230) per year to students in VET schools to offset their fees. In 2009, China also launched an initiative to make tuition free for upper secondary vocational school students.

Unlike other BRICS nations, in China, the main responsibility for VET rests with the government, i.e., the Ministry of Education and the Ministry of Human Resources and Social Security. A major part of the funds for developing vocational education in China comes from the government.

6.5. Initiatives by Government of South Africa

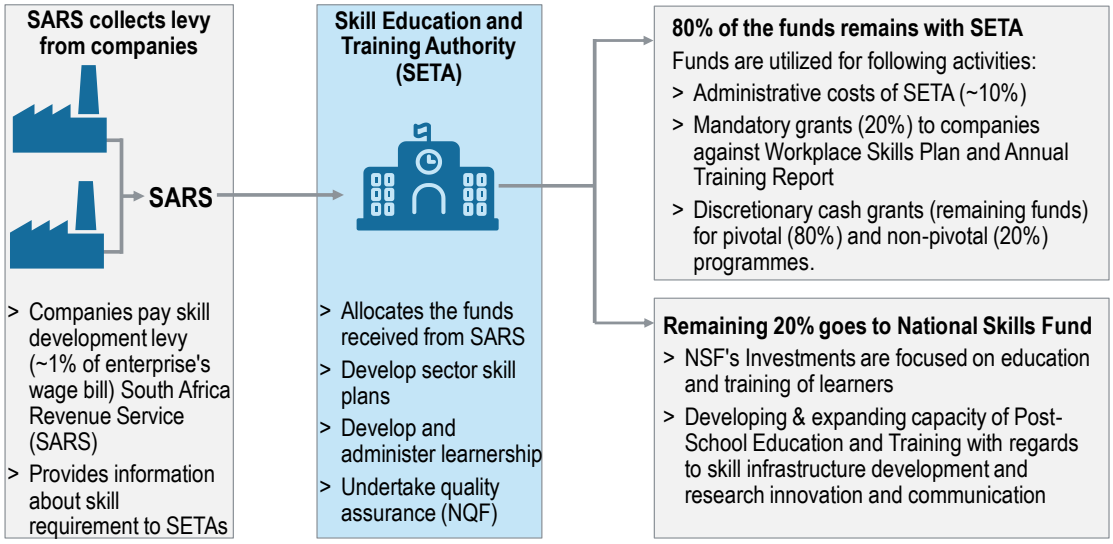
Since 2000, the Department of Higher Education and Training (DHET) has developed three National Skill Development strategies for the period 2001-2016. The latest strategy – as covered under NSDS III – is to increase access to high quality and relevant education and training for skill development. It provides direction for sector skills planning and implementation in the Skill Education and Training Authority (SETAs). It also provides a framework on how SETAs should utilize the funds generated by levying a skill development tax on the companies.

South African government has identified five key skill development priorities – (1) develop a sector labor market intelligence system, (2) continue and increase focus on artisan development, (3) facilitate strategic

partnership that will impact availability of funds and quality of skill development, (4) increase the flow of newly skilled workers, and (5) develop skills of the existing workforce as this is of primary importance for the development of the sector.[62]

SETAs were established as part of NSDS strategy in 2000 to provide training to broaden South Africa's skills base. Since then, SETAs have played an important role in expanding the vocational training network across the country. There are currently 21 SETAs, each representing a sector.[63] Each SETA is responsible for managing and creating internships, unit-based skilling programmes and apprenticeships within its industry. Other objectives of these SETAs are to allocate the funds (for skill development activities) collected by the South Africa Revenue Service (SARS) by imposing a levy.

Figure 44: Functioning of SETA



Source: South Africa government website

Unlike Brazil where funds collected through a skill development levy are managed by a non-profit private organization, in South Africa, public authorities –SARS – are responsible for collection and disbursement of funds raised through the tax.[65]

Currently, DHET is in the process of developing new National Skill Development Strategy – NSDS IV. Key proposals of the fourth plan are – (1) to transform SETAs into Sector Education and Training Advisory Boards with permanent status, functioning as delivery units of DHET, (2) to reduce the functions of SETAs to focus only on developing the skills of those in existing workplaces, and (3) to retain the present number of 21 with some possible variation in the scope of coverage.[66]

7. BILATERAL / MULTILATERAL COLLABORATION FOR SKILL DEVELOPMENT

Amongst the BRICS nations, China and India have collaborations with other countries for skill development of their labor force. These collaborations allow these countries to introduce, after modification as per local requirement, best practices of collaborating countries.

7.1 Sino-German Collaboration

A pioneering example of strong collaboration in education between two countires is the notable Sino-German partnership. Germany and China have been cooperating intensively in the fields of higher education and vocational education and training. As part of the collaboration, the Chinese Education Ministry and the German Federal Minister of Education and Research (BMBF) have been holding regular strategy talks on education policy since 2004.

Chinese companies are keen to secure a supply of skilled workers and are also interested in the German dual system of initial and continuing vocational education with its company-based practical training. There are numerous cooperation projects involving German companies that provide successful dual training schemes in China. This partnership is beneficial to both sides: Chinese students and professionals receive comprehensive, practical vocational training enabling them to secure employment and German companies are able to secure their future supply of skilled labor, which would be valuable given Germany's shrinking population. As of today, German companies experience a shortage of skilled staff and specialists in individual branches of industry, particularly in technical vocations such as mechatronics, automation technology, energy and electro technology as well as a shortage of experts in the fields of informatics and software development. Hence, a partnership of this kind helps bridge that gap.

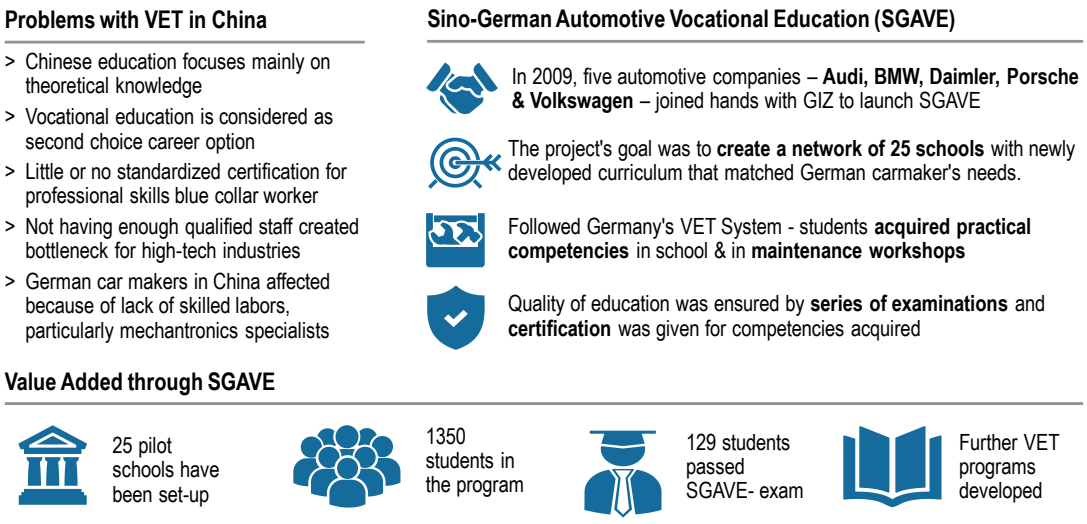
A wide array of collaborations

The Higher Education Compass of the German Rectors' Conference listed 1,130 cooperation projects between German and Chinese higher education institutions in December 2015.[67] Germany and China promote the work of joint institutions such as the Sino-German College at Tongji University in Shanghai. Germany has also drafted a new China Strategy to encourage the mobility of students and researchers.

Additionally, Germany enables the recognition of prior vocational qualifications in China. Special counseling centers are being set up at eight 'German Chambers of Commerce Abroad' (AHKs) or 'Delegations of German Industry and Commerce', under a new project 'Pro Recognition – Professional and Vocational Qualifications for Germany' wherein German counselors inform and advise skilled workers intending to come to Germany about the opportunities for having their vocational qualifications recognized. In the case of the AHK Shanghai, the main target groups are Chinese skilled workers wanting to work in Germany for a certain period of time and to subsequently apply the know-how gained in Germany back home in China. It is beneficial to both countries that Chinese experts spend a phase of their careers working in German companies.

The AHKs contribute their expertise as well as the networks which they have established in the target countries. The 'Association of German Chambers of Commerce and Industry' (DIHK) and the 'Chambers of Commerce and Industry' (IHKs) are also involved. They contribute their process know-how regarding the dual system of vocational training, save results and ensure transfer under the project.

Figure 45: Case Study: Sino-German Collaboration for Skill Development in Automotive Industry



Source: World Economic Forum; Bertelsmann Stiftung

Partnership for Skill Development for Industry 4.0:

The Chinese Education Ministry and German BMBF also agreed to expand cooperation in the field of *Industry of the Future*, particularly in the context of smart production processes and joint research and innovation

funding procedures. The 'Deutsch-Chinesische Allianz für Industrie 4.0 e.V. (DCAI4.0)' partnership constitutes a non-profit agreement to interlink Germany's Industry 4.0 strategy with China's 'Made in China 2025' initiative.

Under this partnership, German and Chinese firms will cooperate in the field of intelligent manufacturing and digital networking of production processes and develop collaboration on standards, security and intellectual property. Thus far, there have been state-led investments in 10 key industries including robotics, information technology, aerospace, railways and electric vehicles, and China will establish 15 manufacturing innovation centers by 2020, and 40 by 2025.

7.2 India-UK partnership for 'Skills for Jobs' program

The Department for International Development (DFID) of United Kingdom has supported Skills for Jobs program in India. The program builds on the approach of promoting participation of the private sector in improving the status of skill development in the eight states of the country. The program has been conceptualized with an objective of supporting Indian skills market to enable employment of the poor through private sector engagement and participation. The project has six components

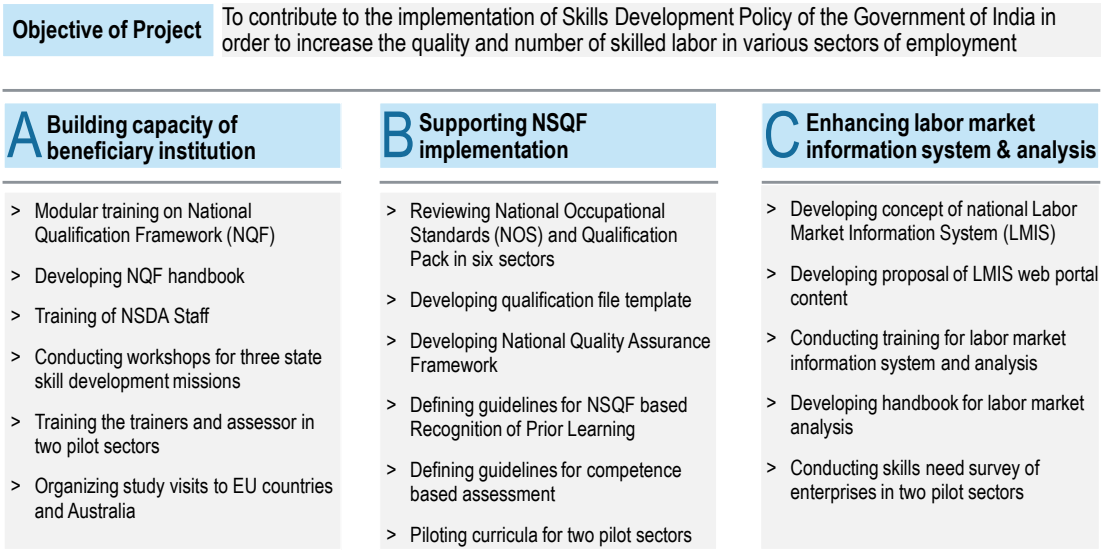
- Facilitating access to credit to trainees
- Developing entry level Qualification Packs
- Capacity Building of two Sector Skill Councils
- Capacity building of NSDC and NSDC training providers
- Capacity Building of two State Skill Development Missions
- Program management support to DDU-GKY (*Deen Dayal Upadhyaya Grameen Kaushalya Yojna*) under Ministry of Rural Development

Out of the above 6 major components, Federation of Indian Chambers of Commerce and Industry (FICCI) has undertaken 3 components – development of 100 pro-poor qualification packs, creation of two pro-poor Sector Skill Councils and capacity building in two State Skills Mission

7.3 India-EU Skill development project

In 2012, the European Union and India launched a skill development project. The project will receive 6 Million Euros assistance from the European Union over the four and half years of project duration. The collaboration has been launched in line with the Europe 2020 strategy and Indian National Skill Development Mission.

Figure 46: Case Study: India-EU Collaboration for Skill Development



Source: India-EU Skill Development Project Website

As part of the project, the European Union will assist the National Skills Development Agency, selected State Skill Development Missions and Sector Skill Councils in defining and implementing policies to skill Indian men and women to improve their employability and entrepreneurship, as a precondition of economic and social development. The main objective of this partnership is to support the development of the National Skills Qualification Framework in three key economic sectors in pilot states and to gather the information about the needs of industry for skilled labor force.

The project involves 6 Sector Skill Councils (Plumbing, Beauty and Wellness, Logistics and Transportation, Capital Goods, Construction and Healthcare) and 3 State Skills Development Missions (Karnataka, Himachal Pradesh and Uttar Pradesh).

Apart from the India-EU Skill Development Project, India has also become a part of Germany's VETnet program. As part of the program, the Indo-German Chamber of Commerce (AHK), in association with Don Bosco Private Industrial Technical Training Institute, has launched its first one year VETnet training programme. The aim of the Indo-German VETnet initiative is to efficiently match the skills of workers with the requirements of industry, thereby benefiting companies and apprentices. The idea is to promote the German system of Dual Vocational Education and Training in India.

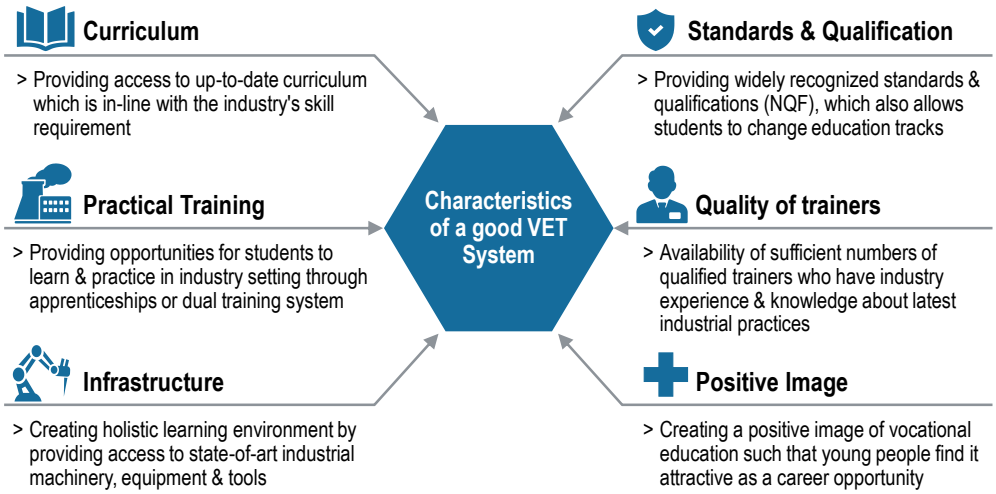
7.4 India-China Collaboration

In 2015, India and China signed a Memorandum of Understanding to establish a skill and entrepreneurship development institute in Gujarat. As part of the MoU, India and China will cooperate and share best practices and knowledge in the field of vocational education and skill development. India and China will work towards capacity development and delivery of vocational education in India.

8. BEST PRACTICES FOR SKILL DEVELOPMENT

There are several different models of vocational education across nations – some are education based, some are employment based and some are hybrids. Before we deep dive into the best practices followed by some of the developed countries, it is important to look into the characteristics of an efficient VET system.

Figure 47: Characteristics of a good VET System



Source: Roland Berger

8.1 Germany's dual vet model

Germany's dual training has played a major role in building a quality vocational education system. The dual system is the largest provider of education and training at upper secondary level. Almost 75% of the people enrolled in VET participate through the dual training model.

Training under this model is provided at two places – at vocational schools and at a company's premise. Approximately 70% of the training duration is spent at a company offering apprenticeships. The curriculum for this practical training is developed as per the requirements of the participating company and is monitored and controlled by the respective chamber. The chamber further arranges for conducting interim and final examinations to evaluate a student's performance. Certified corporate trainers guide the students during the training period. The remaining part of the dual training is spent at vocational schools where the students are given theoretical instructions to add to the on-the-job learnings.

8.2 National Qualification Framework

A National Qualification Framework (NQF) is a quality assurance framework which acts as a nationally integrated education and competency based skill framework providing multiple pathways, horizontal as well as vertical, among vocational education, general education and technical education. A NQF is a result of a shift from input based education to outcomes based education. It classifies a person's proficiency in a skill into multiple levels based on a person's knowledge irrespective of the way it has been acquired – through formal or informal learning. Each level is defined and described in terms of competencies that need to be developed.

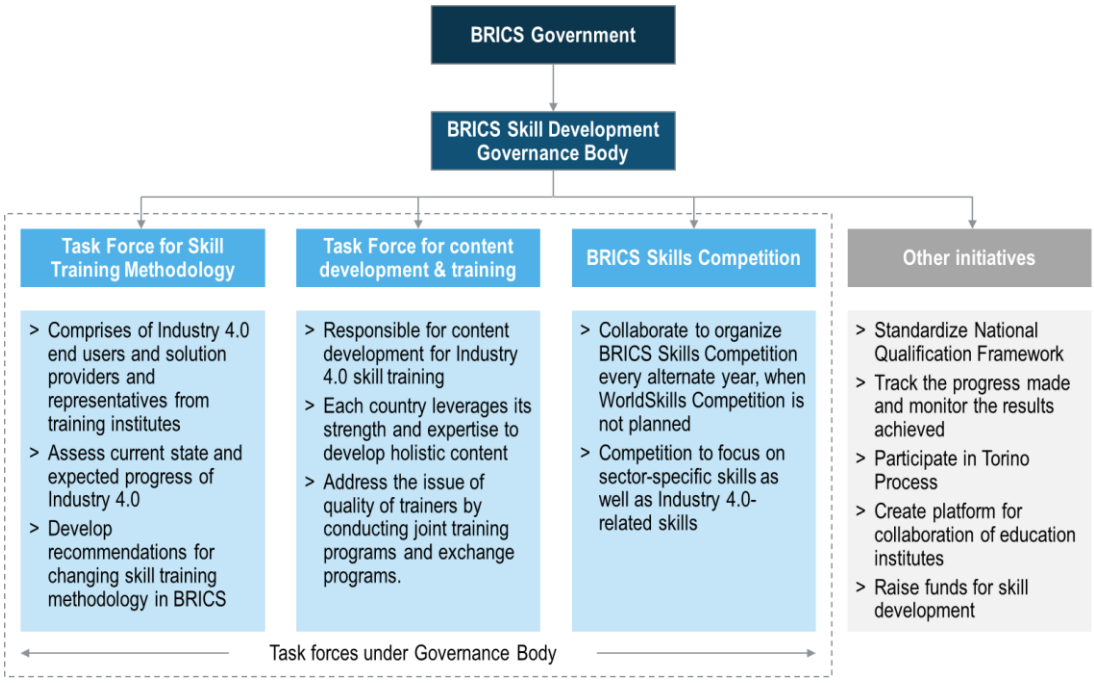
The key elements of an efficient NQF are:

- Recognition of skill proficiency and competencies at different level leading to international equivalency
- Multiple entry and exit between vocational and general education
- Opportunities to promote lifelong learning and skill development
- Partnership with industry / employers

Recommendations for Skill Development

Though each of the BRICS nations has undertaken skill development initiatives, the current system of vocational education is not efficient to train the labor force for the factories of future. There exists an opportunity for the BRICS nations to leverage their strengths to overcome challenges in skill development and collaborate to make their labor force Industry 4.0-ready.

Figure 48: Structure and functions of Skill Development Governance Body



Source: Roland Berger

Preparatory phase: Assessment of future skill demand

As part of the preparatory phase, a BRICS Skill Development Governance Body should be established. The governance body should be formed with the collaboration of the various BRICS governments. The governance body will oversee skill development of the labor force in the BRICS nations.

A Task Force should be commissioned under the governance body, which should have representation from Industry 4.0 end users and solution providers and from the training institutes in each of the BRICS nations. This task force will be responsible for assessing the current state and expected progress of Industry 4.0 adoption. This will entail deliberations on how the industry is going to change in the future, what new jobs will come into existence with technological advancement and what affect these changes are going to have on skill requirement. Based on the discussions, the task force will develop a set of recommendations revolving around the changes required in training curricula and methodology for meeting the industry demand at various stages of adoption of Industry 4.0 by various sectors. These set of recommendations will then be passed on to the respective bodies (SENAI in Brazil, NSDC in India, SETAs in South Africa, etc.) involved in skill development in the BRICS nations for implementing changes in the skill training methodology to ensure that Industry 4.0-related skills are imparted. Collaboration across BRICS nations will ensure that the skill training is in line with international skill requirements.

The governance body will oversee the functioning of the task force and will be responsible for coordinating with the skill development bodies for tracking the progress made and monitoring the results achieved with the implementation of recommendations given by the task force. It will also be responsible for facilitating cross-sharing of the learnings and challenges faced in skill development by the BRICS countries.

The governance body will also be entrusted with the responsibility to frequently assess and create a database of the strengths, competencies and weaknesses of the BRICS nations in terms of skill sets. This database will be shared amongst the BRICS nations and will act as a guidebook for collaboration opportunities.

As part of the preparatory phase, the BRICS nations should also partner with European Training Foundation (ETF) and should actively take part in the Torino Process. ETF is a European Union Agency, which works with its members for lifelong development of individuals' skills and competences through the improvement of vocational education and training systems. As part of these efforts, ETF organizes Torino Process, which is a participatory review of progress in vocational education and training (VET) policy carried out every two years by all ETF partner countries.[68] The aim of the Torino Process is to provide a concise, documented analysis of vocational education and training reform in each country, including identification of key policy trends, challenges, constraints, best practices and opportunities. The adoption of Industry 4.0 in European Union and other countries will increase focus on bringing elements of advanced technology in the skill development and vocational education system. BRICS nations can significantly benefit from actively taking part in Torino Process as it will help the BRICS nations to learn and adopt the initiatives and best practices followed by the other countries for skill development for Industry 4.0. At present, amongst the BRICS nations, only Russia is a member of the Torino Process. Other BRICS nations, represented by bodies which will constitute the BRICS Governance Body, should also join the process by becoming member of ETF. Inputs received from these processes should then be shared with the governance body and the task force for creating recommendations that are in line with the international skill development activities.

Infrastructure: Improving quality of course content and trainers

In a number of BRICS nations, the curricula used for skill training is developed without the involvement of the industry. As a result, the gap between skill sets demanded and skill sets supplied keeps on increasing. BRICS nations should involve the industry in the skill development process as they play an important role in the job market. Efforts should also be made to involve Industry 4.0 solution providers in this process as they can provide valuable inputs related to technologies that will come into existence in the future, based on which the training curricula can be modified and improved further. SETAs in South Africa and Sector Skill Councils in India are good examples of how nations can benefit from the participation of industry in the skill development process. The BRICS governance body can support the development of these councils in the BRICS nations by facilitating sharing of best practices, challenges, policies, methodologies, etc. Industry's involvement is also required to promote dual training / apprenticeships so that the students are exposed to experiential learning and do not have only theoretical knowledge.

The BRICS Governance Body can also establish joint training institutes, similar to SETAs, to undertake skill training activities related to Industry 4.0 technologies like robotics, system integration, etc. in the BRICS nations. These institutes can be established across the BRICS countries where each of the BRICS nations can contribute in training the local labor force.

A separate task force should be established under the BRICS Governance Body to oversee the joint collaboration for content development for skill training related to Industry 4.0. Based on the skill sets identified for future, BRICS nations can collaborate together through the task force for developing course content. This course content can be uploaded on BRICS cloud (using digital technology) and shared across the nations. The task force should also take the initiative to develop an online simple portal for the labor force and promote the same to increase the access of skill training. Given that the labor force will have to be trained in numerous skills to make them Industry 4.0-ready and that none of the BRICS nations are expert in all the technologies expected to form Industry 4.0, each of the BRICS nations should leverage their strengths and expertise to develop a holistic course content. For instance, while India can leverage its knowledge in IT, Russia can provide valuable inputs in the field of Robotics. Similarly, other BRICS nations can support in developing content for other Industry 4.0-related technologies.

This task force should also support in addressing the issue of quality of trainers available in the market. Just how each BRICS nation will use their expertise to develop course content, the nations should also collaborate to train the faculties or trainers. The BRICS nations can jointly conduct classroom learning sessions and collaborate with industry bodies to ensure practical learning of the faculties and trainers. Exchange programs

where trainers are exposed to industrial set-up of other countries should also be launched. Such collaboration will ensure that all the BRICS nations are able to benefit from the expertise of each other.

BRICS nations should also work together to set up a platform for collaboration of their institutes and universities. For example, TU Braunschweig and BITS Pilani are working together to set-up, at BITS Pilani, a learning factory for Industry 4.0 technologies. On the similar lines, the skill development institutes across the BRICS nations can collaborate to innovate and develop learning tools related to Industry 4.0.

Implementation: Promote vocational education and increase its reach

Another important element of skill development is to efficiently provide skill training to the youth. BRICS nations face significant challenge in terms of the reach of skill development institutes (vocational training schools), which is directly related to availability of funds. BRICS nations can collaborate and raise funds to support skill development initiatives. Alternatively, they can also raise funds from the New Development Bank (BRICS Bank) established to support infrastructure projects. A trust dedicated to support BRICS wide initiatives in skill development, proposed by BRICS Council's Skill Development Working Group in 2015, can be instrumental towards that end. BRICS nations can use these funds raised for establishing institutes, which will help in increasing the reach of vocational training. In India, similar to the model proposed, NSDC received around USD 1 billion from Asian Development Bank for setting up the skill development institutes.

Also, initiatives like PRONATEC of Brazil have played an important role in promoting vocational education across the country. As part of the program, the government provides scholarships and loans for vocational education and funds for expansion of technical and vocational institutes. Other BRICS nations can also look at launching similar program to promote and increase reach of vocational education through financial incentives.

In line with the WorldSkills competition, the BRICS Governance Body can take the initiative to jointly organize BRICS Skills competition for the five nations every alternate year, when WorldSkills competition is not planned. The aim of the WorldSkills competition is to promote technical and vocational education amongst the citizens of its participating countries by raising the skilled professional worldwide. The WorldSkills competition focuses on all types of skills across the sectors. Similarly, the BRICS Skills competition can emphasize on basic sector-specific skills as well as Industry 4.0-related skills like mechatronics, data analytics etc. Such a competition will not only promote VET amongst the BRICS nations but also support skill development for Industry 4.0.

Opportunity: Standardization for increasing mobility within and across BRICS nations

National Qualification Framework (NQF) plays an important role in every country as it follows an outcome based approach and helps in defining the career progression track. If a worker has a particular level of certification, he or she can anytime go back and continue his or her education for the next level of qualification. All the BRICS nations except Brazil have their own national qualification framework, which provides workers with the mobility to shift education tracks from general to vocational education and vice versa. However, if a worker goes outside his or her country to other BRICS nations, he or she has to undergo certification programs again.

In order to provide easy mobility across the European Union, the European countries have established a common European Qualification Framework (EQF), which acts as a translation device to make the national qualifications of a particular European country readable in other European countries. Such a standard EQF facilitates mobility across European nations and supports lifelong learning.

The BRICS Governance Body can oversee the development of a standard qualification framework for the BRICS nations. This will help countries in standardizing the outcomes of learnings and occupational standards across the five nations. Such a standard qualification will support a worker's mobility from one BRICS nation to another BRICS nation and, at the same time, will allow him or her to pursue education for the next level of qualification, avoiding any repetition.

The qualification framework should also be modified to include elements of Industry 4.0 to ensure that a labor at particular level possess certain Industry 4.0-related skills, in addition to the technical skills he or she is expected to have based on the industry demand.

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