Regional Conference on Industrial Development



Unlocking the Potential of Industry 4.0 for Developing Countries

Report from the 1st Regional Conference on Industrial Development

Asia Pacific







MINISTRY OF FOREIGN AFFAIRS REPUBLIC OF INDONESIA









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Comments

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ABBREVIATIONS

ASEAN Economic Community
Asian Productivity Organization
ASEAN Political Security Community
ASEAN Socio-Cultural Community
Association of Southeast Asian Nations
Business Advisory Council (ASEAN)
Gross domestic product
Third industrial revolution
Fourth industrial revolution
Industry 4.0
Internet of Things
Industry Transformation Maps
Least developed countries
Micro, small and medium-sized enterprises
Regional Conference on Industrial Development
Research, Innovation and Enterprise 2020
Economic Development Board (Singapore)
Sustainable Development Goals
Small island developing states
Small and medium-sized enterprises
Technical and vocational education and training
United Nations Industrial Development Organization

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FOREWORD BY A.M. FACHIR

Vice Minister of Foreign Affairs, Republic of Indonesia

We are witnessing an industrial revolution of unprecedented speed. Just as we finish putting together the puzzle of the third industrial revolution (4IR) or Industry 4.0 waiting to be unpacked. Among its challenges are inequality of income and job losses due to automation. No one can accurately foresee how it will unfold in the coming decades, though any change will undoubtedly be uncomfortable for some. The breadth and depth of change herald alterations of entire systems. But one thing is crystal clear: we cannot resist it. Otherwise we may find ourselves on the wrong side at this moment of global reset, and rather than thriving, the Asia Pacific region may find itself left behind.

The good news is that Industry 4.0 comes with immense potential: technological advances ensure effective production, leading to a supply-side miracle. Boundless communication platforms ease human interaction and reduce transportation costs. Everyone can contribute, participate and make a difference in this era of innovation. All of this causes economic growth to accelerate, poverty to decline and human living standards to improve.

We need to release this potential in the people's best interest. We should anticipate its reverberation with a comprehensive, inclusive and concerted response. Developed countries have been the biggest beneficiaries of industrial development. But the balance may shift if developing countries take the necessary measures to upgrade regulations, adjust the unsettled innovation climate, develop digital infrastructure and invest in human capital, including in incentives for creativity. All in all, creating a pro–Industry 4.0 environment and navigating the anticipated development can turn our country into a competitive nation. President Joko Widodo regards Industry 4.0 as an opportunity to enrol Indonesia among the 10 biggest economies by 2030.

Indonesia has supported technological innovation, the soul of Industry 4.0. The country has allotted vast special regulatory space as a safe harbour for tech-based startup industries, and we can already see the results.

Of seven "unicorn companies" (privately held startup companies valued at more than US\$1 billion) in Asia, four are from Indonesia: Tokopedia, Traveloka, Go-Jek and Bukalapak. Such industrial transformation, heralded by the fourth industrial revolution, is too complex to be handled by governments alone and calls for inclusiveness. The private sector, civil society, multinational development institutions and academic institutions need to be on board to yield the maximum return, ensure equal opportunities and provide equitable distribution of the benefits to all portions of society.

In this interconnected world, a shared commitment by the global community is needed to ensure that developing countries catch up. The transfer of knowledge and technology is necessary for a smooth transformation in which no countries lag behind. And the political will of each and every country is required. In this connection, the United Nations Industrial Development Organization can play an increasingly important role to help developing countries and economies benefit from Industry 4.0 by providing a framework enabling cooperation through increased confidence between developed and developing countries. There is no space for zero-sum games; it is a place for win-win solutions. The fourth industrial revolution should be our tool in achieving the global tasks, the 2030 Agenda and the United Nations Sustainable Development Goals.





The 1st Regional Cor on Industrial Devel

FOREWORD BY LI YONG

Director General, United Nations Industrial Development Organization

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We are on the verge of the fourth industrial revolution. Smart autonomous systems capable of self-cognition, self-optimization and self-customization are revolutionizing industrial production. The impact of Industry 4.0 will reach all economic sectors, disciplines and economies, and will bring multiple opportunities and challenges along the way. The challenges will prove difficult to overcome, especially for developing countries. Although leapfrogging is a real opportunity in some sectors and for some countries, developing countries-particularly least developed countries (LDCs)—have a mixed record in adopting frontier technology. Many developing countries still lack preconditions such as modern infrastructure, an adequate knowledge base and the skills to harness these technologies.

Industry 4.0, with its potential for disruptive technological change, will trigger a new wave of outsourcing and in-shoring. This will bring a new division of labour and structural transformation to the global economy. New technologies, such as 3D printing, may render some outsourcing unnecessary. In-shoring could become a new trend in developed countries, depriving developing countries of job opportunities. Industry 4.0 can cause polarization of the labour force, increasing the share of employment in high- and low-wage jobs and decreasing the share in middle-wage jobs. In this scenario, a concentration of low-paid jobs in developing countries is likely, given that high-wage jobs will require improved digital skills while weak education systems in developing countries often fail to provide basic literacy and numeracy skills. To address these challenges and harness the enormous benefits of Industry 4.0, governments must ensure that their countries are well prepared through concerted efforts at the national, regional and international levels. Technologies and the exponential technological progress they bring present many opportunities to meet the Sustainable Development Goals and realize economic, environmental and social returns, namely:

- *Economic returns* including increased revenues from lower transaction costs, more reliable output and increased productivity, higher product quality and increased market share and profits.
- *Environmental returns* resulting from effective use of material resources and energy, cuts in carbon dioxide emissions, better access to electricity and water and better waste management. Industry 4.0 technologies are enabling the transition to a circular economy, in which used-up products are reused, remanufactured and recycled to avoid waste.
 - Social returns stemming from increased food security as well as the health and safety of workers, more jobs in small and medium-sized enterprises and their inclusion in the global economy, advancements in education and training systems and enhancement of creativity and innovation. Cities, where most of the world's population will live, will also benefit greatly from Industry 4.0 and will become more sustainable places to live and work.

But to tap into these potentials, inadequate capacities that hinder inclusive and sustainable development in developing countries need to be overcome through a coherent policy response addressing issues such as creating jobs, upgrading skills, providing access to adequate infrastructure, adopting regulatory and institutional reforms, setting new standards and mainstreaming science, technology and innovation. Developing countries need to primarily focus on human resource development and the implementation of Industry 4.0 at the firm and institutional levels. While this might be costly, failing to make the necessary investments is likely to hamper productivity, competitiveness and long-term sustainable development. The right response may include creating effective training systems for a new generation of engineers and entrepreneurs who can absorb disruptive Industry 4.0 technologies.

The commitment to transition towards Industry 4.0 is already visible in the Asia Pacific region, where growth rates in emerging markets, such as China, India and ASEAN member countries, are approaching sustainable levels. The Asia Pacific region is in a prime position to take advantage of next-generation manufacturing technologies, since its Industrial Internet of Things market has the potential to grow nearly fivefold between 2015 and 2020. In Asia, several countries are already implementing their vision of Industry 4.0 through well-thought-out strategies, such as China's Made in China 2025 and Singapore's Skills Future Initiative. Further, China, Japan, the Republic of Korea and Singapore are among the world's largest exporters of high-tech goods. Countries in the region are also ranked among the world's most digitally ready. The World Economic Forum's 2018 Readiness for the Future of Production Report identifies Singapore as an

"early leader" in its manufacturing transformation. Singapore's Smart Industry Readiness Index is the world's first Industry 4.0 tool developed by a government for nationwide transformation of industrial sectors. The government of Japan has launched the Society 5.0 initiative, which invites all stakeholders to respond with innovative ideas to societal challenges brought about by the convergence of technologies.

For developing countries in the region, trade, investment and knowledge flows in global and regional value chains can provide mechanisms for rapid technological learning and innovation. Linking to leading players in global value chains potentially offers developing countries greater prospects to enter new markets; gain access to new skills, knowledge and technology; and upgrade their industrial capabilities. Technological advances, such as using the latest technologies to reduce crops' vulnerability to disease and climate change and to increase their nutritional value, offer developing countries an opportunity to leapfrog, comparable to Africa's introduction of mobile phones, which by and large bypassed infrastructure requirements such as landlines. Partnerships between developed countries, companies, research institutes and developing countries in the Asia and Pacific region are vital to the successful adoption of Industry 4.0 technologies. In the spirit of cooperation, this report draws on the lessons learned by countries in the region that are successfully implementing Industry 4.0.









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Unlock of Indi for De

FOREWORD BY AIRLANGGA HARTARTO

Minister of Industry, Republic of Indonesia

Industrial sectors today depend on businesses transforming themselves towards Industry 4.0. That transformation, in both the international and the domestic economy, will be central to every country's competitiveness. Efficient and effective changes towards digitization can connect firms to domestic and international markets through reliable supply chains. But they can also disconnect firms in countries that fall behind in transformation and face high costs, making it difficult to compete.

Industry 4.0 refers to the current technological trends of blockchain, cloud computing, Internet of Things (IoT), improved automation, machine-to-machine learning, human-to-machine interface, artificial intelligence, digitized manufacturing and use of more advanced technologies. Challenges extend beyond manufacturing to processing raw materials, ensuring sustainability and including small and medium-sized enterprises in the transformation. In the era of Industry 3.0, convergence began between financial services, innovative technologies and manufacturing, where IoT enabled human-machine and machine-machine communication.

For Indonesia, sustainability in Industry 4.0 implies a circular economy where the industrial value chain focuses not only on production, but also on design, raw materials, distribution to consumers and reuse of the balance of recycled material in manufacturing. A new challenge today involves reorienting payment regulations from banking sectors to technology providers, who are no longer providing back-office services to financial institutions but are at the forefront of financial services. In the past it was easy to distinguish financial from industrial services, but now they are integrated.

The economics of globalization will also leave people behind. The old school of economics created social security support. But the new evolution and economic growth may create inequality that outstrips the capacity of the old support systems. The fourth industrial revolution creates a new opportunity challenging the competition between the old industrial giants based on economies of scale. Today, the old automotive companies and Fortune 500 companies can be challenged by startups in electronics to produce electric cars or electric motors.

Supermarkets and department stores can be challenged by e-commerce platforms, where everybody, even small-scale producers, can sell. Digitization can change many aspects of business and create opportunities for value creation, which business leaders of course look to.

The government is not only a regulator anymore. It is not in the backseat watching what happens to the market focusing on market value. With the fourth industrial revolution, the government should shape objectives and lead as an accelerator. This is crucial, because the revolution is changing people's lives and the ways they work.

In Indonesia, the fourth industrial revolution is proceeding at the same time as other revolutions. The country has adopted a document launched by the president, "Making Indonesia 4.0," which aims to make the Indonesian economy the world's 10th largest in 2030. It projects doubling productivity and increasing Indonesian exports to 10 percent of GDP. By improving human development capabilities, Indonesia can create 150 billion–200 billion more economic opportunities, so long as it trains about 17 million Indonesian workers in digital literacy. Making Indonesia 4.0 prioritizes five sectors —textiles, electronics, automotive, food and beverages and chemicals (including biochemical) —that are the basis of 60 percent of world trade.

Indonesia can collaborate with the United Nations Industrial Development Organization (UNIDO) to support other countries learning about those five sectors. In this context, the UNIDO Director General faces the challenge of helping Indonesia create Indonesia 4.0. To pursue this educationally, Indonesia promotes vocational training to link vocational schools and industry, and is also working with such countries as Germany and Switzerland on a dual system of vocational education and apprenticeships for millions of Indonesian young workers, who will become assets in the transformation to Industry 4.0.



THE DIGITAL TRANSFORMATION OF INDUSTRY AND THE FOURTH INDUSTRIAL REVOLUTION

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Moderator

Mr. Tri Purnajaya, Director for Trade, Commodities and Intellectual Property, Ministry of Foreign Affairs, Republic of Indonesia

Speakers

Mr. Ravi Gupta, Co-Founder and CEO, Tambourine Innovation Ventures (TIV) Inc.

Ms. Shirley Santoso, Partner and President Director, A. T. Kearney

The fourth industrial revolution in a snapshot is the current trend of automation and data exchange in manufacturing technologies (figure 1.1). It includes cyber-physical systems, the Internet of Things (IoT) and cloud computing. The first industrial revolution used water and steam power to mechanize production. The second used electric power to create mass production. The third, the digital revolution that has been occurring since the middle of the last century, used electronics and information technology to automate production. Now the fourth industrial revolution is building on the third.

There are three reasons why today's transformations represent not merely a prolongation of the third industrial revolution but rather the arrival of a fourth and distinct one: *speed*, *scope* and *systems impact*.



- The *speed* of current breakthroughs has no historical precedent. They are evolving at an exponential and multidimensional, rather than a linear, pace.
- The *scope* covers almost every industry and business model in every country.
 - Entire *systems* of production, management and governance are being transformed. Billions of people are connected by mobile devices with unprecedented processing power, storage capacity and access to knowledge. Breakthroughs in fields such as artificial intelligence, robotics, the Internet of Things, autonomous vehicles, 3D printing, nanotechnology,

FIGURE 1.1 THE FOURTH INDUSTRIAL REVOLUTION



biotechnology, materials science, energy storage and quantum computing are multiplying.

The fourth industrial revolution will also affect people outside factories in sectors such as agriculture and health. In health care for instance artificial intelligence will better detect tumours and will help doctors in very remote parts of developing countries providing health care. Blockchain technology may help governments with land registration.

The multifaceted impacts demonstrate how challenging it will be for governments to manage the complexity of the fourth industrial revolution. It fuses technologies and blurs the lines between the physical, digital and biological spheres. The exponential curve of change makes it extremely difficult to make sense of what is happening. We are at the beginning of the exponential curve.

The key frameworks of the fourth industrial revolution include interoperability, decentralization and convergence. Today some of the most valuable companies of the world create products that are intangible. By contrast, the value of companies that produce tangible products lies far lower. This shows the importance of intellectual property.

These value chains span the globe. Most of the value created in them, especially for intangible products, lies in the United States, where the intellectual property is created, which is different from where it is used. Innovation and creating intellectual property make it possible to compete in Industry 4.0.

A great challenge Industry 4.0 presents is income and distribution inequality. In the previous industrial revolutions that produced tangible goods, many more workers were usually employed and wealth was thus spread. But nowadays high-valued startups based on intellectual property can be owned and operated by very few people. This has consequences for future social contracts. The nature of work will change, 9-to-5 jobs will not be the main work model and we will have to rethink pension systems and other social supports.

THE FOURTH INDUSTRIAL REVOLUTION AND MANUFACTURING

The fourth industrial revolution is bringing unprecedented change. In manufacturing, the customer can now interact at the design level, aided by new technologies. Mass production is changing to much more flexible production, with fewer steps taken faster. You can even have a batch size of one. The earlier global supply chains are seeing such changes as re-shoring for distributed production and for on-location production and use. The way we consume, the way we sell and distribute, the type of skills we need and the nature of work are changing. If we think about the fourth industrial revolution, we think about the technologies that are particular to this change.

The fourth industrial revolution has at its heart five core technologies: the Industrial Internet of Things (IIoT), industrial artificial intelligence (IIAI), advanced robotics, enterprise wearables, and 3D printing (table 1.1). These technologies can unlock value across any dimension: an up to 30 percent reduction in factory cost, an up to 25 percent increase in firm revenues, billions of dollars in net industrial value created, progress toward sustainability and new skills to improve productivity.

Reaching the opportunities depends on how fast technology matures. There are five tipping points:

- *Technological readiness:* Different technologies have different technology maturity curves.
- *Affordability:* Unit selling prices need to drop by about one-third for adoption to spread.
- *Connectivity:* To drive adoption, 40 percent of the production processes need to be connected.
- *Customization:* A quarter of products require customization.
- *Services replacing products:* Pay-per-use services replace consumers acquiring the technology.

TABLE 1.1 THE CORE TECHNOLOGIES OF THE FOURTH INDUSTRIAL REVOLUTION

Technologies	Layer	Impact
Internet of Things (IoT)	Connectivity layer	Today, 85 percent of production assets are still unconnected. The number of IoT devices will grow, so there will be up to 31 billion by 2020. North America leads in IoT, but the Asia Pacific region is also growing
Artificial Intelligence and Industrial Artificial Intelligence	Logical layer	Al is nascent in manufacturing but expected to grow rapidly. It will change the entire value chain, from consumers (who already have human-machine interaction, as in Amazon's Alexa) to factory maintenance. It will also affect government and administration
Advanced robotics, enterprise wearables, 3D printing	Physical layer	Most industries are still in the early stage of adopting these technologies. But they can improve operational productivity, speed training and reduce the time to market

Source: World Economic Forum (WEF) 2018.

TRAJECTORY OF THE FOURTH INDUSTRIAL REVOLUTION

The projected status the fourth industrial revolution by 2030 is uncertain. Unknowns include the rate of technological advancement, the external environment and the speed with which technology will be embedded in core production. Four possible scenarios for 2030 would be digital disruption, deterred disruption, damaged diffusion and dispersion (table 1.2). We need to develop regulations and foster skill development to meet them.

A.T. Kearney has partnered with the World Economic Forum to develop a country readiness assessment for the fourth industrial revolution. Using that assessment, this study examines the readiness of countries based on two major dimensions:

Drivers of production: Factors such as technology and innovation, human resource readiness, global trade and investment, institutional frameworks, sustainable resources and environment.

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Structure of production: The complexity and scale of a country's production base. Countries with a larger and more complex structure of production harness the fourth industrial revolution more easily.

TABLE 1.2POSSIBLE FOURTH INDUSTRIAL REVOLUTION RESULTS BY 2030

Digital disruption		Deterred disruption		Damaged diffusion			Dispersion			
• • •	Rapid technological advancement Encouraging regulation and policy that enable technological advancement Cross border diffusion of innovation and knowledge sharing, joint innovation Upskilling of the workforce Widespread consumption of diverse	•	More isolated progress, where stronger economies drive the advancement of technology Tension between political systems and government support to stabilize some of the manufacturing sector Segmented consumption patterns and high technological costs	•	Impeded information and technological proliferation Protectionism and economic nationalism Worker population within protected industries safe, others at high risk for dislocation Slow growth of the economy and a low trade level	•	Slower adoption of technology, technological advancement taking place at local level Evolution of policymaking at the local level Customers preferring locally produced products			
•	Pervasive adoption of new technologies									

Source: World Economic Forum (WEF) 2018.

For each dimension, we look at multiple indicators and factors, including the availability of technological platforms, the country's ability to innovate, human capital (the current and future labour force), trade and investment, trade infrastructure, the institutional framework, regulatory friendliness to the fourth industrial revolution, environmental sustainability (energy, emissions, water) and demand and structure of consumption.

The analysis produced a model with four types of countries (figure 1.2):

- *Leading:* Countries with a strong production base, well positioned to harness the fourth industrial revolution.
 - 25 countries, including the United States, European countries and some Asian countries such as Japan, Singapore and the Republic of Korea.
- *Legacy:* Countries with a strong current production base that are at risk due to unfavourable drivers of production.
 - 7 countries, including India, the Philippines and Thailand.
- *High potential:* Countries currently with a limited production base but strong prospects for the future due to favourable drivers of production.

- Countries such as Australia, Hong Kong and New Zealand.
- *Nascent:* Countries with a more limited production base and less favourable drivers of production.
 - 58 percent of countries are at this stage.

Even leading countries will need to make efforts to remain in that category. Countries in other categories will need to try to leapfrog into a higher category by choosing the drivers of production to be assigned priority: human capital, trade and investment or the institutional framework. This can lead to a concrete strategy on how to harness the fourth industrial revolution.

COUNTRIES IN ASIA AND THE PACIFIC ON THE FOURTH INDUSTRIAL REVOLUTION TRAJECTORY

While Europe is embracing the fourth industrial revolution with favourable drivers and structures of production, Asia is also getting there, particularly China, Japan and the Republic of Korea (figure 1.3). And in Southeast Asia, where the rate is lower, some countries are leading, such as Singapore, and others are at either the legacy or the nascent stage. The leading countries in that region offer many learning opportunities to countries at other stages to leapfrog ahead.

Excitingly, Asia and Pacific countries are unlocking the full potential of the fourth industrial revolution. Many speak to that, such as:

- China: The Made in China programme launched in 2015 has a very specific strategy of trade regulation, a policy mandate, investment subsidies and very specific targets-a 50 percent reduction in operating costs, improved production cycles and productive factories by 2025 and up to 14 innovation centres by 2025.
- Indonesia: The Making Indonesia 4.0 programme was just launched with the intention of raising GDP, increasing the manufacturing contribution to GDP and harnessing the potential of the fourth industrial revolution. (See section 2 for more on Making Indonesia 4.0).
- Singapore: Recognizing the importance of human capital in the fourth industrial revolution, the country promotes lifelong learning programmes so workers are ready. It created the Singapore Skills Future, a methodical approach to understanding the skillsets workers will need in the next five years, what they should learn and how they should be trained to not be left behind. (See section 3 for more about Singapore.)

Countries must think about their strategy for harnessing the fourth industrial revolution. One key element is the changing nature of work due to the fourth industrial revolution, on top of changing demographics.

Cisco and Oxford Economics, in a study across the Association of Southeast Asian Nations (ASEAN), found that technology can displace workers but can also create new demand for them.¹ Across the sectors of agriculture, mining, manufacturing, the business sector and wholesale and retail trade, some will face more displacement, especially those

FIGURE 1.2 TYPES OF READINESS FOR THE FOURTH INDUSTRIAL REVOLUTION



Source: World Economic Forum, A.T. Kearney 2018, Readiness for the Future of Production Report 2018.

Note: Average performance of the top 75 countries (weighted average driver score, weighted average structure score) is at the intersection of the four quadrants to create the model borders.

FIGURE 1.3 ASIA AND PACIFIC COUNTRY READINESS FOR THE FOURTH INDUSTRIAL REVOLUTION



Structure of production score (0-10)

Source: Readiness for Future of Production Report 2018, World Economic Forum, A. T. Kearney.

Note: Not all countries are covered due to unavailability of data.

that have more routine tasks. The displacement will be challenging for the traditional Asia factory model. But other sectors will have increased demand for workers because of increased productivity. In manufacturing and wholesale and retail trade, additional jobs will be created due to increased productivity through technology. Upskilling in a combination of technical skills and soft skills will be needed. ASEAN countries need 1.7 million workers with foundational skills and 1.9 million with better interactive skills, whether for persuasion, leadership or negotiation. They need more workers with better cognitive skills and with very good management skills and 750,000 with specialized technology skills such as applications programming and big data. This needs to be understood at both the country level and the organizational level. How do we upskill and reskill workers to prevent job displacement and shift workers to new and more value-added work?

It is up to the governments to create an enabling environment in which creators can monetize their inventions. At the same time the interests of the public at large must also be taken into consideration. The region needs some kind of harmonization, lest push and pull factors between countries allow businesses to move from higher to lower pressure areas. To achieve a level playing field, regional collaboration is crucial.

Key learning for UNIDO Member States:

- Technology and innovation are important, as are how a country and region collectively drive efforts to improve the access and affordability of key technologies.
- Upskilling and reskilling must be continuous to make labour pools ready.
- A multistakeholder approach should include a regional network of players: policymakers, companies, academics and public-private partnerships.
- Funding and governance can jump-start activity with innovative investment sharing both risk and reward but also require a proper monitoring mechanism.

2

INDUSTRY 4.0: CHALLENGES, OPPORTUNITIES, DRIVERS AND OUTLOOK

Moderator

Ms. Shirley Santoso, Partner and President Director, A. T. Kearney

Speakers

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Dr. Ngakan Timur Antara, Head of Agency for Industrial Research and Development, Ministry of Industry, Indonesia

Mr. Jouke Verlinden, Associate Professor for Augmented Fabrication, University of Antwerp

The fourth industrial revolution is revolutionizing industry. Its development and growth are exponential. It includes digital interconnectivity, the use of big data and cloud computing. Beyond these distinctive features, industry has become more interconnected in a pervasive environment where production is no longer confined by geographical and political borders.

Industry 4.0 disrupts almost every industry. Whether or not we accept its characteristics, they will affect us in changing the systems by which physical and virtual systems and people interact (figure 2.1). How well we respond will affect our industry, our country and our performance in an



international setting. We need an integrated and comprehensive approach.

Whatever we do—for instance, however the government formulates some relevant regulation—we should follow a multistakeholder approach. Decisions cannot be taken exclusively by one entity but must be comprehensive and inclusive.

Some characteristics of Industry 4.0:

- Interoperability.
- Virtualization.
- Decentralization.
- Real-time capability.

FIGURE 2.1 SYSTEMS OF INDUSTRY 4.0



Source: Fraunhofer.

- Service orientation.
- Modularity.
- Convergence.
- Cost reduction and efficiency.

CHALLENGES AND OPPORTUNITIES

What does the Asia Pacific region have to gain from Industry 4.0? The region is diverse in politics,

Technical SystemTechnical machineryEmbedded SystemHardware and softwareCyber-Physical SystemMerging of physical and virtualCyber-Physical-Production SystemApplication to manufacturingSmart Factory

Network of people, machinery and resources

industry and society—raising even more challenges for a common response. Industry 4.0 will:

Increase wealth by reducing the distance between inventors and markets: Everybody can invest and can market products and services. Micro and small entrepreneurs can use new technologies to market products directly, despite their small scale. Imagination is the limit, thanks to 3D printing and the possibilities it offers, boosting the creative economy (see box 2.1).

BOX 2.1 THE CREATIVE ECONOMY

The exponential technological progress of the fourth industrial revolution puts a high premium on local innovation capabilities and creativity. People now need to be more agile to develop new ideas and knowledge and to commercialize them quickly. The digital transformation and technological convergence necessitate creativity- and knowledge-based economic activities for creating new job opportunities, particularly for women and youth, and micro, small, and medium-sized enterprises. *(continued)*

The creative economy is globally one of the most dynamic industries, more than doubling its value between 2002 and 2015 to reach \$509 billion. It centres on the interactions between creativity, arts, culture, business, economics and technology. It concentrates around cultural value, market objectives, and products and services.

The creative economy requires the cooperation of culture, society, technology and the economy for stimulating growth. Technological progress enables new creative activities in the arts and entertainment industries. For example, artificial intelligence helps to create new content in film, games, music and fashion; 3D printing advances the textile and garment industries; and the Internet of Things and 3D printing help publishers and designers use technology to cater to new audiences. Augmented and virtual reality offer three key value propositions for the creative economy. They will provide a new medium for storytelling, lower the barriers to entry for creators and offer new modes of experiencing content that could bring about a more empathetic and informed society.¹

The creative industries are among the most lively sectors in the world economy. They are a major source of innovative ideas contributing to upgrading industry and creating new products, services and jobs and raising the economy's innovative potential and economic diversification. The creative industries provide new opportunities for developing countries to leapfrog into emerging high-growth areas of the world economy. Creative services, an important element of the creative economy, are also growing and are likely to become one of the biggest future growth areas. Creative services can be resilient to economic pressures and are heavily enmeshed with emerging e-commerce.

Building a sound business environment and digital and innovation ecosystems are prerequisites to capturing the benefits of the growing creative economy and its intersection with fourth industrial revolution technologies. Creative professionals and entrepreneurs will need the skills and ecosystem to integrate new technologies into their creative work. Where those are lacking, innovation from the creative sector might not produce the necessary value added or contribution to economic development.

To leverage the benefits of the intersection of fourth industrial revolution technologies and the creative economy, collective action through strategies, policies and programmes is needed to foster collaboration, technological learning and innovation system building. The World Conference on Creative Economy (WCCE) was held 6–8 November 2018 in Bali, Indonesia, to raise awareness of the potential contributions of the creative economy to inclusive and sustainable industrial and economic development.

UNIDO's technical cooperation programmes promote creative industries through business environment reforms and innovation and ecosystem building. They aim to identify industry creative clusters, establish their networks and help entrepreneurs upgrade product design and marketing to ensure sustainable job creation in those industries.²

Notes

1. WEF 2018. Creative Disruption: The impact of emerging technologies on the creative economy, p.14. http://www3. weforum.org/docs/39655_CREATIVE-DISRUPTION.pdf.

2. https://www.unido.org/news/cultural-and-creative-industries-lever-development.

Source: WEF, UNCTAD, UNIDO Seminar on Industry 4.0 and the Creative Economy: Promoting Inclusive Ecosystems in the Digital Era, 8 June 2019, UNIDO.

- Increase productivity: Industry 4.0 is expected to unleash \$220 billion in Association of Southeast Asian Nations (ASEAN) countries and increase ASEAN internal trade to \$625 billion.
- *Expand consumer choices:* It will also create a new way people connect to each other, making the economy more inclusive. The creative economy offers the best example of how people are connecting in their needs and supply.
- *Create new forms of financial services:* To get a loan from the bank, a borrower no longer has to go to one but can apply online. The financial technology market is expanding rapidly. Industry 4.0 is changing not just industry but other spheres of life, including education.
- Empower small and medium-sized enterprises: Small and medium-sized enterprises (SMEs) form the backbone of the economy in the Asia Pacific region. Industry 4.0 creates connectivity between them and between SMEs and big businesses. These advantages also create pressure for efficiency and productivity due to competition with other companies and producers.

Industry 4.0 also creates disruption in the labour market in these ways:

- Technologies such as artificial intelligence and robotics will increase productivity. This will threaten low-skilled labour, especially repetitive jobs.
- Automation will create job losses in ASEAN countries. According to the International Labour Organization, 56 percent of jobs in five of them (Cambodia, Indonesia, Philippines, Thailand and Viet Nam) are at high risk of disappearing.
- The region will have to find ways to maintain competitiveness through cheap labour to attract foreign direct investment (FDI).

Industry 4.0 also reduces the attractiveness of making foreign direct investments in manufacturing. Because production can be re-shored, less FDI could flow to the region. And Industry 4.0's knowledge-based economy will push countries to remain competitive.

All these challenges will require a response from the government. Top-down approaches to developing policy will no longer work. One major question is how to balance the interests of the public at large and continuing support for innovation and technology development. Governments need to improve their agility, and regulators must be able to correct policies and regulations in real time, continuously adapting to fast-changing environments. Inclusiveness and collaboration among stakeholders are musts.

How does Industry 4.0 address the Sustainable Development Goals (SDGs)?

It does not exist in a vacuum but faces conflict, crisis, climate change, water scarcity, food insecurity and the lack of access to clean energy. SDGs cannot be pursued in isolation from each other, but the specific SDG to which Industry 4.0 is most closely linked is SDG 9: to build resilient infrastructure, promote inclusive and sustainable industrial development and foster innovation. Others with clear relevance are SDG 3, good health and well-being; SDG 4, quality education; SDG 7, affordable and clean energy and SDG 8, decent work and economic growth.

INDUSTRY 4.0: AN OUTLOOK FOR INDONESIA

At the beginning of 2018, Indonesia's government launched "Making Indonesia 4.0," a strategy to guide government implementation of Industry 4.0. It involved many ministries and stakeholders (figure 2.2).

In Indonesia, industry is the major sector contributing to GDP. The country ranks 9th in the world in manufacturing value added (MVA). The economic growth rate is constantly above 5 percent a year. Every year around 1.6 million–2 million workers enter the market. GDP growth is supported by

FIGURE 2.2 INDONESIA HAS SET 10 NATIONAL PRIORITIES FOR "MAKING INDONESIA 4.0"

10 National Priorities

1 Reform Material Flow	6 Attract Foreign Investments
• Enhance domestic upstream material production ; e.g. 50% of petrochemical is imported	 Engage top global manufacturers with attractive offers and accelerate technology transfer
2 Redesign Industrial Zones	7 Upgrade Human Capital
 Build a single nationwide industry zoning roadmap (e.g. industry belts); resolve zoning inconsistency challenges 	 Redesign education curriculum under 4IR era Create professional talent mobility programme
3 Embrace sustainability	8 Establish Innovation Ecosystem
 Grab opportunities under global sustainability trend; e.g. EV, biofuel, renewables 	 Enhance R&D&D² centers by government, private sector and universities
4 Empower SMEs	9 Incentivize Technology Investment
 Empower 3.7 million SMEs¹ by technologies; e.g. build SME e-commerce, technology bank 	 Introduce tax exemption/subsidies for technology adoption and support funding
5 Build Nationwide Digital Infrastructure	10 Reoptimize Regulations & Policies
 Advance network and digital platform; e.g. 4G to 5G, Fiber speed 1Gbps, Data center and Cloud 	 Build more coherent policies/regulations by cross-ministry collaborations

Source: A. T. Kearney, Ministry of Industry. Note: Including micro enterprises.

consumer and government spending. The economy was the 16th largest in the world in 2016 (figure 2.3). The country aspires to become a global top 10 economy by 2030 by regaining net export advantage, increasing the share of GDP from manufacturing and competing in productivity, as a result of advances in technology and innovation. Industry 4.0 offers the way to achieve this aspiration.

Indonesia has to act now to reap the benefits of Industry 4.0 in the long term and to realize its goal for 2030. Human resources, especially the younger generation, are crucial. Until 2030, Indonesia will enjoy a demographic dividend, when the ratio of the working population to the dependent population is increasing. That status is highly correlated with a country's economic growth, but in every country that has passed the period of the dividend (such as China, Japan, Singapore and Thailand), economic growth has declined. Indonesia's challenge now is how to maintain economic growth and ensure that the workforce of the demographic dividend is upskilled and re-skilled so it can remain transformational over the following years. Some jobs might be lost in the manufacturing part of the value chain, but new jobs may be created in other segments, such as research and development, raw material analysis, innovation and branding, distribution and after-sales services. Industry will require data analysts and data engineers. More services in proportion to industrial activity will be created.

The role of schools and universities will need to change as well. The labour force skills required by industry need to be matched by the training offered by educational institutions. For example, Indonesia has developed a learn-and-match programme and vocational training programmes and cooperates with many stakeholders, associations, universities and industry to provide upskilling to the workforce.

FIGURE 2.3 INDONESIA'S VIRTUOUS ECONOMIC CIRCLE HAS MADE IT A LEADING ECONOMY



Source: Based on data from the World Bank, International Monetary Fund and A. T. Kearney.

Note: According to data from the International Labour Organization, average Indonesian earnings increased by 115 percent between 2004 and 2015.

Industry 4.0 can revive the manufacturing sector. Though exports decreased over recent years, Indonesia aims to increase net exports to up to 10 percent of GDP by 2030. The country wants to improve its financial strength, government spending and government investment. That should help build a robust economy with a solid labour market.

The ecosystem for Industry 4.0 requires some important preconditions. In order to support sustained innovation, research and development spending should become at least 2 percent of GDP. The Ministry of Industry has proposed two types of incentives:

- Tax incentives for companies with their own research and development.
- Support for companies that offer their own training.

Furthermore, the government is planning to build the digital infrastructure necessary to enable connectivity. Regulations have to be developed cooperatively with local policymakers, and regional and national regulations have to be harmonized. Otherwise Indonesia will not be able to attract FDI.

The Ministry of Industry must work hand in hand with other ministries, such as the Ministry of Agriculture, Ministry of Education, Ministry of Transportation, Ministry of Foreign Affairs and Ministry of Energy and Mineral Resources. All these ministries will have to participate in an inclusive and holistic approach to creating the preconditions for Industry 4.0. Engagement with associations, universities and the private sector is also required (figure 2.4).

DRIVERS OF INDUSTRY 4.0

Industry 4.0 focuses on smart industry, especially innovative production processes. But it can also affect the product itself and the process of design. Projects currently in the making at universities in the Netherlands and Belgium include a metal 3D-printed bridge made from stainless steel and ultra-personalized products and services. The University of Delft has been working on a 3D-printed dress for a fashion designer in Amsterdam, using natural fibres and plastics in a process that combines several methods. Another example combines a 3D printer with a welding robot. Product design 4.0 links three different aspects:

- **Production process:** This may use 3D printing, robotics, command and control methods (industry 3.0 methods are still included) and other technologies such as 3D scanning sensors. Flexibility is important—a factory should be built to produce more than just one thing. And since physical things need to be made, polished and improved, the human worker remains prominent on top of digital technologies and automation.
- **Product:** Products may employ additive manufacturing, parameterized design, batch sizes



Dr. Ngakan Timur Antara, Head of Agency for Industrial Research and Development, Ministry of Industry, Indonesia



FIGURE 2.4 MAKING INDONESIA 4.0 NEEDS TO BE COORDINATED WITH MANY STAKEHOLDERS

Source: A. T. Kearney.

Note: Illustrative-not exhaustive and not representative of final stakeholder cohort.

of one and digital models. 3D printing allows for creating microstructures with which new materials that behave differently can be created, leading to completely different products.

• **Design:** Anything—industrial or cultural can become part of heritage. A product can, surprisingly, end up in a museum. Considerations of aesthetics and ergonomics, especially tailoring products for individuals, become prominent.

A human can be a user or a designer of a product. Sometimes the user and the designer are the same person, and no skilled and trained individual is needed. The role of the worker is also changing through connectivity and changing products.

About five years ago, 3D printing was only able to create rapid prototypes, but now it can do more. The technology is accessible and can create actual products, beyond just prototyping. Technologies can also be combined for use in sectors such as medicine and aerospace.

To a certain extent all this is already realized. 3D printing could be very profitable for small and medium enterprises. The initial investment is not too great, compared with that for casting and moulding tools. The cost of small quantities of units produced is actually better than the cost of traditional production. (If the quantity increases beyond a certain point, traditional production processes become more economical.) Even though additive manufacturing is not always the most cost-effective today, it may become cost-effective as technology becomes more affordable and accessible.

Industry 4.0 can make the world of industry more accessible. For instance, designers can provide furniture designs online as open source material. Consumers can download the designs free of charge and build their own furniture. Another example is the digital knitting machine, which is available for about \$5,000 and is simple to programme. Users can make their own designs and can produce clothing in the sizes they desire. In robotics, new robots are being produced that are very simple to manoeuvre, another way of making technology accessible as user interfaces become easier to grasp and technical knowledge, though required for development, is not required for use (for example, the Franka Eminka robot).

Ultra-personalized products are another area. Invisalign clear tooth aligners (orthodontic devices that are a transparent, plastic form of dental braces used to adjust teeth), for instance, in orthodontics, changes the role of the orthodontist. Hearing aids in the West that are 3D-printed are cheaper than hearing aids produced with traditional manufacturing. In general, making ultra-personalized products has four phases: analysis, design, production and testing. It requires 3D scanning and then shifting from the scan to a 3D model, which is not straightforward.

The next things will be soft-robotics and 4D printing using elaborate meta-materials. Soft robotics construct robots from highly compliant materials like those found in living organisms. It draws heavily on the way living organisms move and adapt to their surroundings. In 4D printing, a 3D printer makes objects that change their shape when removed from the printer. Invented at MIT in 2013, its purpose is to make things self-assemble when exposed to air, water or heat due to the chemical interaction of the materials used in their manufacture. High-speed printing is also important to develop, since 3D printing is slow. Therefore, there is still a lot of room for improvement in the technology. Making it more accessible and affordable is one way: with many 3D printers, printing can be faster. There are already mega-printers. And different printers can be used for different processes. Will every hospital, every library and even every home have one?

We should not automate, we should augment (if that question is left to companies, it might produce a lot of worker displacement). There are four suggestions (figure 2.5). First, we augment our senses through augmented reality or virtual reality, which will allow us to get a better feel of the social, natural or urban environment. Second, we can augment our environment with robotics or actuators. Third, as deep learning, machine learning and artificial intelligence (AI) supersede human reasoning, they augment human reasoning and decision making. Designers should make sure that AI has an interface with our mental capabilities—as both individual and as corporate entities. The fourth tier is design, where not just a designer, but anyone designs. As tools help people design their surroundings, the process can be called co-making and co-creation. At the end is augmented well-being, with the human at the centre.

FIGURE 2.5 AUGMENTED WELL-BEING



Source: Jouke Verlinden (TU Delft), as presented in Bali.



INDUSTRY 4.0 FOR DEVELOPING COUNTRIES: STRATEGY AND IMPLEMENTATION



Moderator

Ms. Olga Memedovic, Deputy Director and Chief, Business Environment, Cluster and Innovation Division, Department of Trade, Investment and Innovation, UNIDO

Speakers

Mr. Sanghoon Kim, Korea Institute for Industrial Economics and Trade

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INDUSTRY 4.0 AND THE REPUBLIC OF KOREA

Many economists in the Republic of Korea have commented that they never heard of the third industrial revolution, so what is the fourth industrial revolution? Even in 2016, there was some sort of controversy, including debates in the Korean parliament, about the definitions. Connection is important: the shift from the third to the fourth industrial revolution meant a hybrid connection between information networks, physical things and human force. The third industrial revolution developed information technology and collected varied information from everywhere, but networks were not yet connecting with each other, so human force was needed to integrate the information to tackle problems. But when you connect the human force and the physical things together, they can form an ecosystem. That process is called automatization rather than automation.

Today, we are developing technology for the Internet of Things (IoT) and big data with the help of artificial intelligence, which form a cyber–physical system. Our efforts mimic the physical world, often referred to as the digital twin. The terms Industry 4.0 and the fourth industrial revolution are now used interchangeably, but originally, they were not. Industry 4.0, coined in 2011 by Germany at the Hannover Messe trade show, focused on manufacturing. When the process is presented in a diagram, information technology becomes a background layer or enabler that combines manufacturing, energy, services and so on (figure 3.1). Industry 4.0 concerns industry and, more narrowly, manufacturing, but the fourth industrial revolution concerns broader innovation.

The fourth industrial revolution is also not just IT. Digital transformation creates convergence between IT and operational technology (OT). Without OT, there is nothing to digitize. In the Republic of Korea, this presents an issue because many people think about IT but not about the actual industry or technology. Because the actual target is manufacturing, as in the steel or automotive industry, it is crucial to engage IT and OT simultaneously and cooperatively.

Historically the first industrial revolution increased productivity by sacrificing product variety. The third industrial revolution, with information technology, allowed a sort of mass customization, restoring initial products and variety without products evolving much. The fourth industrial revolution takes a further step from mass customization to optimal individualization (figure 3.2).

FIGURE 3.1 INDUSTRY 4.0 AND THE FOURTH INDUSTRIAL REVOLUTION: THE ROLES OF INFORMATION TECHNOLOGY AND PRODUCTION IN MANUFACTURING INNOVATION



Source: Kim 2016.

FIGURE 3.2 MANUFACTURING TRANSFORMATION



Source: Kim Sanghoon, based on Koren and Ulsoy 2004; Koren 2010.

This kind of evolution has been predictable for some time, perhaps 10 to 20 years. In the early 1990s, Germany thought it faced a crisis because of widening competition from countries such as China, Indonesia, the Republic of Korea, and Viet Nam. So, between the mid-1990s and the early 2000s, Germany began to remake its industry strategies, especially industrial engineering, and redesigned its framework for the manufacturing industry.

The Republic of Korea has tried to focus on a people-centred economy, incremental growth and competition, and innovation advances. Some strategies are very controversial, but the current government has contributed to transforming Korea's growth from catching-up to a leading position.

Two relevant ministries in the Republic of Korea are science and technology, and industry. Their

focus is on industries specific to the Republic of Korea—called "goods industries." Goods industries are not very visible but underlie all the other industries. They include casting, plastic forming, and heat and surface treatment. These industries are referred to by the three Ds: dirty, dangerous and difficult. But to create new and more advanced industries and move from catching-up to a leading position, advancement of the goods industry should be tackled. The Republic of Korea is pursuing this, as is Japan.²

The smart factory advancement project started in 2013, and the objective was to make as many smart factories as possible, producing a support system for 50,000 factories throughout the country. In order to do that, the government tried to make a smart factory framework and reference model for the manufacturing industry (figure 3.3), because compatibility between factories is very important. In some ways, the framework is

FIGURE 3.3 KOREAN SMART FRAMEWORK AND REFERENCE MODEL FOR MANUFACTURING INDUSTRIES



Source: Sanghoon Kim. Public private partnership smart factory group (2015). Original data available from https://www.smart -factory.kr/datum/dataWarehouse.do (in Korean).

working nicely, but for small and medium-sized enterprises (SMEs), it still has more to accomplish.

The government tried to focus on SMEs rather than the big companies and large enterprises, but many SMEs are not so keen to invest in smart factories because they are focused on daily operations and do not have time to think about the future. Technical levels are polarized, with some companies very low and others very high. Therefore four levels have been made in a single multitier support system, where the lowest level is an enterprise resource planning implementation (ERP), without which making a smart factory is impossible.

Engineering is crucial for smart factories, but for Korean SMEs, much engineering software and many engineering solutions have been imported. For example, product lifecycle management, ERP and supply chain management come from more advanced countries. Since it was realized that without its own engineering solutions, a smart factory cannot be made, the country has begun to focus on engineering, but not for everything. The focus has been on solutions that have not yet been imported, such as computer-aided engineering and simulation, computer-aided manufacturing and some manufacturing execution systems. And in many trials by enterprises, the government and research institutes aimed to implement the systems in specific Korean SMEs.

The Republic of Korea also found that financing high tech-based SMEs produced a very different performance, such as increased profit and value added, compared with financing ordinary SMEs and therefore started to view high-tech or innovative-tech SMEs as important to support. Korea's SME governance shifted from protection to supporting competitiveness in the industry. To select SMEs for financing from among so many with different technologies and markets, the Korean government implemented the Korean Technology Rating System (KTRS). In 2006 the government began an almost 10-year development of KTRS. The system has been used by the government and many private banks and upgraded as appropriate. It is now being implemented by the government of Viet Nam, and the European Union decided in September 2019 to use it for policing SMEs, as well.

INDUSTRY 4.0 AND SINGAPORE

Singapore has a core strategy with a vision to become a smart nation. The Singapore Economic Development Board (EDB) is the lead agency under the Ministry of Trade and Industry (MTI) tasked with designing and executing Singapore's economic development strategy. EDB's activity includes investment promotion and industrial development, with a focus on sectors that contribute about a third of Singapore's GDP. EDB's work covers the manufacturing and tradable services sectors. Manufacturing contributes 21 percent of Singapore's GDP (figure 3.4). The sector is diverse, with process industries; energy and chemicals; biomedical and pharmaceuticals; semiconductor manufacturing; aerospace; and maintenance, repair and operations. Manufacturing brings value to research and development and other service sectors.

Although Singapore is widely known as a garden city, its foundations are built on a strong industrial base. When Singapore became independent in 1965, it was too small to rely on a domestic market and so shifted from import substitution to export-led industrialization. Manufacturing started with fishhooks, matches, mosquito coils and television sets. EDB took the lead in engaging companies and learning what they require when they want to manufacture in Singapore. The government developed industrial areas, reformed labour laws and brought in institutions to provide technical education.

Over the past 50 years, manufacturing in Singapore has evolved, taking on more complex, capital-intensive and knowledge-intensive products such as semiconductors, energy, chemicals, pharma and biomedical goods. Since Industry



FIGURE 3.4 MANUFACTURING CONTRIBUTES 21 PERCENT OF SINGAPORE'S GDP

Source: Singapore Ministry of Trade and Industry, economic survey, February 2019.

4.0 is already transforming manufacturing and global supply chains, to enhance competitiveness and achieve the government's goal of maintaining manufacturing above 20 percent of GDP, the country needs to continually invest in new capabilities and accelerate the transformation of manufacturing. Like the Republic of Korea, Singapore focuses on SMEs, which make up 80 percent of its manufacturing sector.

Over the past two years, EDB, together with its industry partners, has developed "industry transformation maps" (ITMs) based on deep dives across 23 sectors spanning both manufacturing and services. These sectors account for close to 80 percent of Singapore's GDP. Each ITM will outline the key strategies and priorities for jobs and skills (what these will be in the future), innovation (how to achieve productivity in the sector), and exports (how companies in the sector export their products and services). Key examples of manufacturing industries with ITMs are aerospace, chemicals, electronics and the marine and offshore industry.

To establish a common language and build awareness amongst the manufacturing community about the opportunities and challenges of Industry 4.0, EDB developed the Smart Industry Readiness Index (SIRI) as a self-diagnostic tool that enables companies to evaluate their manufacturing operations and find out their readiness level. Developing the SIRI was a nine-month journey undertaken by EDB in partnership with a network of leading technology companies, consultancy firms and industry and academic experts. It comprises a suite of frameworks and tools to help manufacturersregardless of their size and industry-start, scale, and sustain their manufacturing transformation journeys. SIRI's developers observed three core principles: (1) it had to be comprehensive, covering the key principles of Industry 4.0; (2) it had to strike a healthy balance between technical rigor and usability; and (3) it had to be relevant to all companies, regardless of industry, size, profile or Industry 4.0 maturity. SIRI was modelled after the reference architecture [model] for Industry 4.0 (RAMI 4.0).

EDB organized a panel of experts from industry and academia to help refine the index, and piloted it in 16 companies to validate it. The index was launched in November 2017, and EDB has conducted many public workshops with more than 2,000 participants and 500 companies. The reception has been mostly positive.

The index has three levels (figure 3.5). The top consists of three building blocks: process, technology and organization. Although most people think Industry 4.0 is all about technology (robots and equipment), if the process is inefficient, automating and digitizing it will not yield desirable outcomes. Redesign and organization become important, including the organization of people to be ready and trained to take on new processes and technology. So, all three building blocks are needed to harness Industry 4.0 opportunities.

Underpinning the three building blocks are eight pillars (see figure 3.5). For example, supporting the technology block are the three pillars: automation, connectivity and intelligence. To use the human body as an analogy, automation would be the muscles-they move things around, and bring products from place to place. Connectivity is the nervous system, which allows data to flow throughout the body. Intelligence would then be the brain, which processes the data and activates change. Underpinning the pillars are 16 dimensions. Companies can use the index to evaluate the readiness of their facilities for Industry 4.0. The assessment matrix doubles as a step-by-step improvement guide, because each dimension will provide intermediate steps to guide companies to improve.

Using the index to design its roadmap for improvement, a company can progressively deliver solutions and can measure and refine initiatives over several years. The index can also serve as a living blueprint for a company to monitor ongoing progress, as Industry 4.0 is not a one-time effort to create a smart factory. At the very least, the index describes key concepts and builds a common language for companies to use when they talk to their technology providers, partners or suppliers.

FIGURE 3.5 THE SMART INDUSTRY READINESS INDEX



Source: The Singapore Smart Industry Readiness Index Whitepaper (2017), Singapore Economic Development Board, Ministry of Trade & Industry

LEVERAGING MULTISTAKEHOLDER PARTNERSHIPS FOR BUILDING THE REGION'S MANUFACTURING ECOSYSTEMS

EDB also highlighted the fact that having a network of partners is critical to transform Singapore's and the region's manufacturing ecosystems. To kickstart the establishment of such a community, in October 2018 EDB launched the Index Partners Network at ITAP (Industrial Transformation Asia-Pacific), currently with 11 partners in four categories.

When EDB polled SMEs, affordable financing appeared as a key need, so local banks were brought on board as the first category partners. They offer financing programmes and schemes supporting Industry 4.0 transformation projects.

Technology partners and solution partners are a second category, to support company organization. Both larger and smaller companies such as AUK Industries and PBA Group are participating to offer modularized, simple plug-and-play solutions for SMEs. The third category of partner is training providers. The national university of Singapore continuing education school is developing a curriculum according to the index's 16 dimensions so that when a company does its diagnostic and recognizes the need to focus on a particular dimension, it can get the people to provide retraining or reskilling.

The fourth category is international outreach partners. EDB wants to work with the Asian Productivity Organisation (APO), which promotes productivity improvement in its member countries and has endorsed the index. It is publicizing the index to its member countries.

To develop Industry 4.0 talent, all stakeholders —governments, companies and unions—need to come together. Workers are aware that changes are happening in the workforce and on the shop floor. However, they are doubtful of redeployment, if they take a break from work for re-skilling and re-training. In these uncertain times, governments, companies and unions all need to encourage workers to really upskill and retrain themselves. SMEs have limited funding and skillsets. SME academies have been created in other regions, such as in the European Union as part of Horizon 2020. Providing incentives to SMEs and connecting them with big companies, technology providers and experts are also important, as is connecting all the different players from government, the private sector and academia to tap into available knowledge.

The Netherlands has field labs within the smart industry programme—centres of excellence for a particular kind of industry, where academia and other education systems work together with industry. They are mostly funded by industry, and supported by the government through tax breaks. There are about 32, and there will be 65 next year. These centres allow people to talk to a scientist and to experience Industry 4.0 and what it means for them. The United States of America has another solution in the national accelerator America Makes, with only a few centres.

How can governments encourage the private sector to participate in building this innovation ecosystem? They can incentivize new vocational training and research and development. In the end, the aim should be for companies to develop their own drive. For that, an enabling environment needs to be created. SMEs need to be the catalyst of change. Champions of the private sector can serve as role models for other companies to show what Industry 4.0 can bring.

SKILLS DEVELOPMENT AND TRAINING TALENT: LESSONS FROM SINGAPORE

Industry 4.0 will transform the nature of work as jobs change and new skills emerge. And the demand for Industry 4.0-ready talent will continue to grow. In the short term, 75 percent of firms will probably try to borrow digital capabilities by outsourcing, but in the long term, more than 50 percent will want to build in-house digital competence. Looking ahead, given that Industry 4.0 will be pervasive by 2020 according to the standard narrative across all reports, the talent topic concerns all companies.

Singapore has a multipronged approach for training talent. Industry transformation maps have examined the new skills needed across different job types. For the energy, chemicals and utilities sectors, EDB mapped out these skills all the way from operators to plant managers to investigate programmes that will be needed to support these industries. All of Singapore's ITMs would have this assessment as the first step. In a second step, the government offers support for companies doing continuing education and capability upgrading for their workers.

To support manufacturing companies in upskilling its workforce, Singapore undertook a threeprong approach. The first prong is to identify new skills that are needed. The second is, after the skills are identified, to partner with institutions of higher learning that provide continuing education to develop the necessary programmes and



Speaker Ben Ong, Senior Lead, Economic Development Board (EDB), Singapore

courses. And the third is to partner with community leaders and multipliers such as trade associations, business chambers and unions to broadcast these initiatives and new programmes to the wider community.

This revolution is new for everyone. To identify and conceptualize unknown new skills, the EDB partnered with companies that are equally interested and invested. For example, the EDB partnered with Accenture, a leading professional services company, to map out the emerging digital skills for the energy and chemicals sectors. The skills map, published in 2016 in a white paper, featured both technical skills and soft skills.

THE SKILLS FUTURE PROGRAMME IN SINGAPORE

A nationwide programme for advanced manufacturing called the Skills Future Series was launched in November 2017, aimed at helping the workforce acquire new skills. Spanning three proficiency levels, it offers modular courses that range from IoT management to robotics coordination to artificial intelligence for manufacturing. The modular structure means that workers do not have to go back to school for an extended period of time.

Singapore's Skills Future emphasizes lifelong learning where, even after someone graduates from college, polytechnic or university, learning does not stop and the workforce continues to learn from age 25 to 45 to even 65. The programme divided skills into key domains expected to offer future opportunities and industry areas the government would like to grow. The domains are familiar: data analytics, cybersecurity, entrepreneurship, advanced manufacturing and urban solutions.

For the advanced manufacturing series, the programme circulated skills maps for different industry sectors to all the training institutions from polytechnics to universities and even some private vendors. Could they create learning and training modules based on the skills maps? With the partner institutions, the programme created a comprehensive suite of basic, intermediate and advanced courses. To encourage people to take them, the government should provide healthy subsidies.

Today at the Skills Future Singapore website under advanced manufacturing, there are hundreds of courses people can take based on the skills map. Those who sign up with an accredited training provider can get back some form of subsidy, either from their employers or through the government.

Beyond identifying skills and coming up with training, it is important to let people know that training is available. Many times, in both the public and the private sector, people create fantastic initiatives that will benefit the community but do not reach the right audience. The programmes do not appear in the daily newspapers or on the Internet. So, the Skills Future programme made sure to engage the workforce, the unions and the schools to broadcast the good work of the universities and government in creating materials and courses to help workers become more ready for the future.

To help the community better internalize the relevant materials, the programme distilled information into the "skills framework," creating simple guidebooks for a variety of sectors. For example, *Skills Framework for Energy and Chemicals*, with the self-explanatory subtitle Guide to Occupations and Skills, provides an overview of the future of the sector. The guidebooks should suffice for the foreseeable future. They cover the sectors, employment opportunities and career pathways; describe the occupation and job growth; and highlight, summarize and consolidate all the emerging and existing skills that might be needed.

The guidebooks also feature case studies to illustrate to those taking the leap how to upgrade their skills or gain a new mastery. So, a student or worker using a guidebook can feel more confident, saying, "My peer has done it—gotten a better job opportunity—maybe I want to consider doing it as well." To address gender disparity, the case studies feature women as well as men in manufacturing and engineering.

The guidebooks also feature career guidance, with internships, fellowships and some professional conversion courses that the university provides. They also provide a career pathway overview, showing how someone can start as a technician, chemist or engineer and progress to other roles and gain managerial experience. The guidebook serves as a comprehensive, one-stop shop for everyone.

DRIVING INNOVATION IN SINGAPORE

To drive innovation, Singapore has a systematic approach. Every five years it sets aside a national budget for public research and development called Research Innovation Enterprise. The current programme, running from 2016 to 2020, is called RIE2020. Its budget is 19 billion Singapore dollars, one of the biggest so far. This budget funds public sector research in research institutes and universities. But part of the budget is restricted from use unless the research institutes and institutes of higher learning work with industry companies on research. If this criterion is met, the programme will disburse, together with EDB, the public sector research funding. Of the 19 billion Singapore dollars in RIE2020, 3.2 billion are dedicated to advanced manufacturing engineering. Among other areas are additive manufacturing, robotics,

advanced materials and industrial IoT, along with areas that align with Singapore's industry sectors such as semiconductors and aerospace.

Singapore is small, so it faces a labour crunch. Attention is focused on manufacturing, logistics, health care and transportation. Even the construction industry relies heavily on foreign labour. Because this phenomenon cannot continue, the National Robotics Programme was started in 2016: Singapore wants to double its productivity and reduce the use of labour. In 2017, in the manufacturing sector more than 4,400 new industrial robots were installed in Singapore, an increase of 72 percent from 2016. More than 300 SMEs across a wide range of manufacturing sectors adopted robotics and automation. And the robotics programme is not confined to the manufacturing sector.

Singapore has built model factories within its research institutes and universities to foster innovation. The model factories simulate a real-life production environment for testing new manufacturing. It may be too risky for companies to use their actual production lines to test new solutions, so the model factories allow them to match solutions to the problems described by manufacturers.

Finally, a community in Asia for Industry 4.0 needs to be built based on collaboration between nations, industry sectors, and the public and private sectors.



THE FOURTH INDUSTRIAL REVOLUTION, REGIONAL GOVERNANCE AND THE ROLE OF INTERNATIONAL ORGANIZATIONS



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Industry 4.0 will affect consumer expectations and create cultural transformation. In this new landscape, many regulations will become outdated, and there is a need to assess how to adapt them.

INDUSTRY 4.0 INITIATIVES IN EUROPE

Germany was the first country to create a specific strategy to implement fourth industrial revolution technologies, promoting implementation of technological solutions to increase the competitiveness and efficiency of its manufacturing sectors. While Germany and some other EU members are running their own fourth industrial revolution-oriented programmes (figure 4.1), the European Union has also established an overall research and innovation programme, Horizon 2020, that seeks to ensure that "Europe produces worldclass science, removes barriers to innovation and makes it easier for the public and private sectors to work together in delivering innovation."³ The European Union is allocating US\$80 billion to innovative research projects, as well as running

FIGURE 4.1 EUROPEAN INITIATIVES FOR DIGITIZING INDUSTRY



Source: EU Commission.

innovation-training programmes at leading European universities. The European Union also has a programme called Converging Technologies for the European Knowledge Society. The Russian Federation is developing the National Strategy on Development of Convergent Technologies.

The Netherlands has Smart Industry. Belgium has five different programmes, one of which, called "Flanders Make," is highlighted here. And there are related open source innovation in the Fab lab community and the Fab City initiative.

Smart Industry in the Netherlands is very similar to the German programme Industry 4.0. What the Netherlands adds is the creative industry. Key to policy in the Netherlands are field labs. There are now about 32 of them, each with its own expertise —one covers metal pipe bending; another, molten material 3D printing and others robotics, food and personalized products and services. They are funded by industry, which receives a tax break equal to about 50 percent of the investment. Field labs are unevenly distributed across the country, mostly placed where relevant companies are located. A field lab is like a centre of excellence, so it demonstrates different kinds of technology and provides an opportunity to talk with academics and students. Vocational training is all arranged around the field labs. The collection of field labs is a changing smorgasbord where five will cease to exist and eight new ones will be introduced.

The 3D Building Field Lab in Amsterdam studies wire and arc additive manufacturing through robotic welding. It is sponsored by ABB, Autodesk and building companies such as Heijmans companies. Most of the materials there were not acquired by the field lab but contributed by the partner companies. The 3D Building Field Lab is working on a "moonshot"—the 3D printing of a 12-meter long bridge—combining a huge problem, a theoretical solution and some kind of breakthrough technology. In this case, the breakthrough technology is robotic welding, which has existed for a long time. Although there may be better ways to make bridges, making large 3D prints is still a challenge.

Belgium's fixed setup in the north called Flanders Make is concerned with flexible automation, the Internet of Things and 3D printing and digital fabrication. Unlike field labs in the Netherlands, they are academic labs ("core labs"), which were assigned five years ago, creating a static system. To be more dynamic, Belgium tried mobile or pop-up labs around the country to demonstrate tech spaces and conduct experiments in different locations.

Open source and grassroots initiatives are interesting and inspiring. For example, two websites for sharing files for 3D printing are Thingiverse and Wevovler. People upload their designs, files and so forth. It is a social site where users can find people who have actually assembled the things posted and describe what they do with them. The field of open source and grassroots initiatives talks *not about doing it yourself but about doing it together*, and skill sharing is a key activity.

Fab labs-for fabrication laboratories-started in Boston at MIT and are now all over the world. Three are in Indonesia, all in Java. They are open -not just for government or academia but also to the public. Similar to Fab labs, Makerspaces are all around the world. Makerspace in Munich is heavily subsidized by BMW, a carmaker. BMW employees can go to this place and get a certificate for welding, 3D printing and design, for example. Makerspace is part of BMW's human relations strategy, outsourcing part of their training and having employees work together with students. Anyone walking into this Makerspace sees statistics of how many prototypes were made that day and how many visitors it had. The statistics are based on enterprise resource planning (ERP) software from SAP, which also makes other information available, such as how many hours each

machine in the Makerspace was used and how many prototypes were made.

Next to Fab labs is the Fab Academy, which supports vocational training based on a course called "How to Make Almost Anything." Learners participate in workgroups at local Fab labs anywhere in the world. So, this sort of learning is not confined to universities.

The Fab City initiative is about globally connected cities that produce locally. There are 45 cities involved, some in China, Japan and Korea. The Fab City manifesto has 10 principles that are chiefly about creating a circular economy but include using digital fabrication and, to a certain extent, Industry 4.0 together as an enabling technology.

Institutions considering a Fab lab should connect it to a public place with an existing volunteer network, which would be important to the lab. Incentives can help people cross borders into the place —maybe funding, but also reporting on what has been done and acknowledging champions by giving awards. Fab labs should not restrict themselves to industrial applications, though those may be the starting points.

All these initiatives and programmes require cooperation between academia and industry to nurture the opportunities offered by the revolution of Industry 4.0. They all reach the grassroots to benefit people and emphasize vocational training.

THE IMPORTANCE OF REGIONAL GOVERNANCE

Technological advances in digital technologies artificial intelligence (AI), machine learning, robotics, additive manufacturing (3D printing), the Internet of Things, distributed ledger technology (blockchain) and quantum computers—and their integration with nanotechnology and cognitive, social and humanitarian sciences (also referred to as convergent technologies)—are driving the fourth industrial revolution forward (figure 4.2).



FIGURE 4.2 PEOPLE ARE AT THE CENTRE OF THE FOURTH INDUSTRIAL REVOLUTION

Source: Olga Memedovic, as presented in Bali.

The fourth industrial revolution is the fastest period of innovation ever. Innovation is becoming more complex, multidisciplinary, collaborative, unplanned, unpredictable and disruptive. It is developing at an exponential rather than a linear pace. Innovation cycles are accelerating, collapsing the product life cycle, and are becoming very short. Their implications are widespread and systemic (figure 4.3).

The fourth industrial revolution's exponential technological progress will affect all countries, especially LDCs, all socioeconomic sectors and scientific disciplines, and will blur the differences between them. The convergence of previously fragmented and disconnected scientific disciplines and technologies is self-enforcing, advancing science, technology, and innovation, entrepreneurship and structural transformation, and has the potential to address pressing global challenges such as food security, environmental degradation and climate change and to ensure access to energy and education to all. Growing synergy among emerging technologies has created a vastly expanding arborescence of scientific research, knowledge and emerging technologies.

Exponential technological progress is creating opportunities to decrease pollution, to gain productivity and to increase the quality of life and social inclusion. If the frontier technologies lead to all three returns—environmental, economic and social—the Sustainable Development Goals can be achieved. This may be utopian, but projections suggest the possibilities (figure 4.4).

FIGURE 4.3

EXPONENTIAL TECHNOLOGICAL PROGRESS DRIVING THE FOURTH INDUSTRIAL REVOLUTION FORWARD

WAVES OF TECHNOLOGICAL PROGRESS



Source: Dr. José Ramón Q ELEMENT López-Portillo R.

But accelerating technological progress is also opening avenues for possible negative spillovers and externalities, such as threats of a rising technology gap that can marginalize some countries and population groups, job losses and rising unemployment for some workers, cybersecurity threats to industrial security, ethical issues and threats to global peace and security arising from the military uses of new technologies.

New technologies are developing quickly, but they do not diffuse evenly across countries and industries. Countries with high science, technology and innovation (STI) capabilities will be the first to reap the benefits of breakthroughs in frontier technologies. As a consequence, the technological gap between developed and developing countries will widen. Even developed countries with advanced STI capabilities will find it difficult to sustain their global competitiveness if they underinvest in scientific research that translates into new products; industries; engineering talent; high value employment; science, technology, engineering, arts and math (STEAM) skills; public-private partnerships in research and development (R&D); and linkages in global innovation networks.

In recent decades, a linear innovation model has given way to an open and collaborative one, particularly in developed countries. Innovations in fourth industrial revolution technologies emerge

FIGURE 4.4 EXTRAORDINARY OPPORTUNITIES FOR REALIZING THE SDGS: ENVIRONMENTAL, ECONOMIC AND SOCIAL RETURNS FROM THE FOURTH INDUSTRIAL REVOLUTION



Extraordinary opportunities for realizing the SDGs





- High resource efficiency and effectiveness, particularly energy efficiency
- Significant cuts in CO₂ emissions
- Better access to electricity and water
- New materials and production processes: products and services, can be designed to save natural resources

Source: Olga Memedovic, as presented in Bali.

25% productivity gain

 Higher efficiency, productivity and opportunities

ECONOMIC

RETURNS

- Economic diversification
- Increased revenues from lower transaction costs, increased productivity, higher quality products, increased market share
- Customization at the unit level

Increased quality of life

SOCIAL

RETURNS

- Enhanced human physical and cognitive capabilities
- Improvements in health and safety of workers
- SME inclusion: e-commerce
- Inclusion of women, youth
- A push for changes in education, training systems, as well as for research and innovation
- Government capacity and transparency to increase; better government services

primarily at the junction of scientific fields with the participation of private and public institutions in national and global innovation networks, supported by the funding of basic and applied research and ecosystems building. In many parts of the economy today, new ecosystems engaging multiple fields are starting to nurture new means to meet human needs. Technological progress is making it increasingly possible to leverage new assets, engage a larger number of participants, and coordinate their expertise and activities in more complex ways.

The impact of fourth industrial revolution technologies will differ across and within sectors because of differences in opportunities for innovation in products, processes, marketing and business models. Different industrial sectors need different data and technological building blocks for innovation. Industries and even enterprises have varied capacity and readiness to adopt and diffuse for fourth industrial revolution technology.

Initiatives to create a readiness index include the World Economic Forum Readiness for the Future of Production 2018; McKinsey, KPMG Change Readiness Index, 2017; DII Global Industry 4.0 Readiness Index 2017; and Dell Future Ready Economies, 2016. Other indices focus on innovation and foreign direct investment (FDI), such as the Global Innovation Index developed by INSEAD, Cornell University and the World Intellectual Property Organization (figure 4.5) and a study of FDI in Association of Southeast Nations countries by McKinsey (2014), identifying different types of readiness or competitiveness for the fourth industrial revolution (figure 4.6). These tools show variations of Asia and Pacific countries' readiness for ensuring smooth transformation to the fourth industrial revolution. They should serve as a useful reference to fit the methodological approach to a regional-specific context and serve as a tool to inform the policy.

Smart manufacturing systems are more vulnerable to cyberthreats and cyberattacks. Smart factories use intelligent security responses and leverage new technologies, such as blockchain, to improve computer security and manage the risks of new technologies (figure 4.7).

The fourth industrial revolution technologies may trigger a new wave of outsourcing and in-shoring, resulting in a new division of labour and a structural transformation in the global economy. Other changes to be expected are a reversal in FDI and trade flows due to structural changes in global value chains (GVCs), with consequent job losses and a widening of the technology gap. GVCs will become shorter and more dynamic, flexible, efficient and sustainable, with greater possibilities for customization, personalization and localization. Niche services and localized products can be a new path to growth

FIGURE 4.5 GLOBAL INNOVATION INDEX 2018

Global Innovation Index 2018 rankings

Country/Economy	Score (0-100)	Rank	Income	Rank	Region	Rank	Efficiency Ratio	Rank	Median: 0.61
Singapore	59.83	5	HI	5	SEAO	1	0.61	63	
Korea, Republic of	56.63	12	HI	12	SEAO	2	0.79	20	
Japan	54.95	13	HI	13	SEAO	3	0.68	44	
Hong Kong (China)	54.62	14	HI	14	SEAO	4	0.64	54	
China	53.06	17	UM	1	SEAO	5	0.92	3	
Malaysia	43.16	35	UM	2	SEAO	8	0.66	48	
Thailand	38.00	44	UM	5	SEAO	9	0.71	33	
Viet Nam	37.94	45	LM	2	SEAO	10	0.80	16	
India	35.18	57	LM	5	CSA	1	0.65	49	
Philippines	31.56	73	LM	9	SEAO	13	0.61	62	
Indonesia	29.80	85	LM	13	SEAO	14	0.61	66	
Sri Lanka	28.66	88	LM	14	CSA	4	0.58	78	
Cambodia	26.69	98	LM	17	SEAO	15	0.61	60	
Nepal	24.17	108	LI	6	CSA	7	0.45	107	
Pakistan	24.12	109	LM	23	CSA	8	0.66	46	
Bangladesh	23.06	116	LM	25	CSA	9	0.53	87	

Source: INSEAD, WIPO and Cornell University.

FIGURE 4.6 MANUFACTURING-RELATED FDI BY SECTOR IN ASEAN COUNTRIES, 2009–2013

Manufacturing-related FDI by sectorX≥2010≤x<20								
Group	Industry	ASEAN-6 Total	endonesia	e Singapore	O Vietnam) Malaysia	e Thailand	Philippines
Global innovation for local markets	Chemicals Motor vehicles and components Other transport equipment Electrical machinery	9 9 6 6	5 13 2 2	13 <1 4 3	14 3 4 6	5 3 20 20	6 42 2 3	2 3 9 7
	Machinery, equipment, appliances	4	1	4	6	6	6	4
Regional processing	Rubber and plastics products Fabricated metal products Food, beverage, and tobacco Printing and publishing	5 8 14 <1	8 14 7 <1	2 3 38 <1	1 9 9 <1	5 6 3 <1	14 9 5 <1	2 4 14 <1
Energy-/ resource- intensive commodities	Wood products Refined petroleum, coke, nuclear Paper and pulp Mineral-based products Basic metals	<1 6 1 8 12	<1 <1 <1 19 23	<1 2 <1 5 1	1 26 1 1 1	<1 1 2 6 14	<1 <1 <1 1 2	<1 <1 <1 17 13
Global technologies/ innovators	Computers and office machinery Semiconductors and electronics Medical, precision, and optical	3 5 2	2 <1 <1	3 15 6	<1 1 1	1 4 3	5 3 1	11 11 1
Labor-intensive tradables	Textiles, apparel, leather Furniture, jewelry, toys, other	1 <1	2 <1	<1 <1	2 <1	<1 <1	<1 <1	<1 <1
TOTAL TOTAL, USD Bn		100 225	100 61	100 56	100 45	100 32	100 21	100

Source: McKinsey 2014. Understanding ASEAN: The manufacturing opportunity.

in developing countries, especially the least-developed countries. Open standards and interoperable operating systems are therefore crucial for achieving an inclusive transformation to the fourth industrial revolution. This can change where the value is created in GVCs and where it is captured (figure 4.8a). A smiling curve can be flattened again with the application of additive manufacturing (figure 4.8b).

Fourth industrial revolution technologies depend on data, which in data-driven systems and economies become capital for producing and delivering products and services. Firms can capture huge economic returns from collecting, compiling and analysing data without getting consent from or rewarding those who produce the data, thus creating an asymmetric relationship and a distorted market. Correcting this market failure requires new

FIGURE 4.7 CYBERSECURITY: MOST ATTACKED COUNTRIES, 2018

Top 20 countries by percentage of ICS computers attacked, H1 2018



Source: Kaspersky Lab Industrial Control Systems Cyber Emergency Response Team (KL ICS CERT).

FIGURE 4.8 A NEW TECHNOLOGY MAY RESTRUCTURE DISTRIBUTION OF RETURNS IN GVCS



Source: Märtha Rehnberg and Stefano Ponte, 2016, "3D Printing and Global Value Chains: How a New Technology May Restructure Global Production," Department of Business and Politics, Copenhagen Business School sp.dbp@cbs.dk , GPN Working Paper Series, 2016 .

laws and regulations recognizing data as an asset from which rent can be captured and establishing a legal basis for data ownership. The use of data for public purposes and in algorithms for artificial intelligence also raises ethical and legal issues related to data ownership, privacy and transparency and requires a yet unavailable institutional framework of accountability.

Institutional gaps are widening. While linear change characterizes rules, regulations, norms, values, standards, ethics, culture, leadership and attitudes, exponential change carries I4.0 technologies along. Technological progress far outstrips public policy, and a gap grows between the fourth industrial revolution's rapidly accruing solutions and challenges, and perceived socioeconomic problems.

ROLE OF COLLECTIVE ACTION

As nations are increasingly interlinked due to intensifying globalization, the benefits and risks of the fourth industrial revolution's exponential technological change cross borders. Major scientific and technological breakthroughs have impacts beyond the country that produces them. Problems whose solutions require new scientific and technological competencies expand beyond their country of origin. Developing countries may not benefit even from affordable newly created knowledge and technology, because of their low level of technological capabilities and skill. Inadequate education, infrastructure and finance often clog the absorption of new knowledge generated elsewhere and can widen the technology gap and marginalize some countries.

Collective national and supranational action is therefore needed to put people in the centre, address the trade-offs arising from fourth industrial revolution technologies and create prosperity for all people and all nations, leaving no one behind. No country alone can harness the full potential of emerging technologies and mitigate the associated risks. Individual countries have formulated strategies, policies and programmes for fostering the uptake of fourth industrial revolution technologies, adapting education systems and ensuring multistakeholder participation. Among them are North American countries (Canada and the United States of America), West European countries (Belgium, France, Germany, Italy, the Netherlands, Slovenia, Spain and Sweden), and Asian countries (China, Japan, India, Indonesia, the Republic of Korea, Malaysia, Singapore and Thailand) (figure 4.9).

The Republic of Korea is shifting to a competency-based society with lifelong access to job training through recent policies such as the National Competency Standards and the Work-Learning Dual System. The Philippines recently introduced a K-12 reform that emphasizes cultural responsiveness, flexibility, globalization and technology-based learning in its curriculum. The reform also centres on strong community-industry partnerships. The Made in China 2025 strategy promotes implementation of the fourth industrial revolution by providing financial and legal incentives to companies that are restructuring their manufacturing processes and creating sustainable business models. Grasping the competitive nature of the global market, China is raising its industrial capabilities to a new level in order to remain an industrial rival to Germany, Japan and the United States. In 2014, India established a fourth industrial revolution-oriented framework to "transform India into a global design and manufacturing hub." India is trying to raise awareness of new technologies among manufacturers by advancing its technological development. The initiative aims to "[i]nspire confidence in India's capabilities amongst local potential partners, the Indian business community and partners abroad; provide a framework for a vast amount of technical information on 25 industry sectors; reach out to a vast local and global audience via social media and constantly keep them updated about opportunities, reforms, etc." (Table 4.1 summarizes other national initiatives.)

FIGURE 4.9 ASIAN COUNTRIES ARE MOUNTING INITIATIVES FOR THE NEW INDUSTRIAL REVOLUTION



WHAT SHOULD BE DONE AT THE REGIONAL (ASIA-PACIFIC) LEVEL?

To meet the challenges and reap the benefits of fourth industrial revolution technologies, the Asia Pacific regional community must act promptly to ensure a smooth national and international transition. Without concerted efforts by governments, businesses, academia and the international regional community, the potential of advanced technologies to realize the SDGs, especially SDG 9 on industry, infrastructure and innovation, will not be realized. A holistic approach to address the challenges and tap into the potential of fourth industrial revolution technologies is needed.

Various regional and national initiatives have already been put in place in Asia and Pacific countries, though at differing levels of comprehensiveness and coordination (table 4.2). Key broad areas for further attention include:

• Ensuring strong traditional and modern infrastructure.

TABLE 4.1 MAJOR NATIONAL TECHNOLOGY INITIATIVES IN ASIA

Brunei Darussalam: National Digital Strategy 2016-2020—National ICT White Paper for Brunei Darussalam (2016); Digital Government Strategy 2015-2020 (2015); National Broadband Policy 2014-2017 (2014)

Cambodia: Cambodian ICT Masterplan 2020 (2014); Telecommunication ICT Development (TICT) Policy 2020; Signing of the memorandum of understanding with Microsoft on information and communication technologies cooperation (2016)

Indonesia: Launch of the Making Indonesia 4.0 Roadmap (2017); Indonesia Broadband Plan 2014–2019

Lao PDR: e-Government Development Plan 2013-2020 (2013); Signing of the memorandum of understanding with Microsoft (as part of Microsoft's National Empowerment Plan) (2016); National Strategies for Science and Technology Development 2013-2020 and Vision 2030 (2013)

Malaysia: Development of the National Industry 4.0 Policy Framework (2018); Establishment of Industry 4.0 High Level Task Force (2017); Launch of the Centre of Excellence on Industry 4.0 (2017); Launch of the Digital Free Trade Zone (DFTZ) Initiative and Pilot Project (2017); Malaysian ICT Strategic Plan 2016-2020 (2016); Launch of the National e-Commerce Strategic Roadmap (2016); 11th Malaysia Plan 2016-2020 (2015); National IOT Roadmap (2015); National Broadband Initiative (2006). Malaysia has launched its Redesigning Higher Education strategy to prepare students for the fourth industrial revolution. Programmes range from 2u2i—a mix of university and in-house industry training -to CEO Faculty, a platform for industry CEOs to provide lectures, curriculum development and mentoring at universities. In addition, its Accreditation of Prior Experiential Learning encourages lifelong learning and credits work experience towards further educational study

Myanmar: Development of the Digital Economy Development Masterplan (2017); Universal Service Strategy 2018–2020 (2018); e-Government Masterplan 2016–2020 (2014)

Philippines: Inclusive, Innovation-led Industrial Strategy (i3s) (2017); Philippines Digital Strategy 2011–2015 (2011); National Broadband Plan; e-Government Master Plan 2016–2020 (EGMP 2.0)

Singapore: AI.SG Initiative (2017); Research Innovation Enterprise 2020 Plan (2016); Industry Transformation Programme (2016); Intelligent Nation 2015 (2015); National Robotics Program (2015); Smart Nation (2014); Singapore has co-created a Skills Framework for its workforce by involving industry leaders, unions and government. The framework provides information on each sector —including its future development—and maps out career progression pathways and needed skills. These inform education and training institutions as well as individuals.

Thailand: Digital Government 2017–2021 (2017); Thailand 4.0 (2016); National Digital Economy Master Plan (2016–2020); Digital Economy Master Plan (2015)

Viet Nam: Prime Minister's Directive 16/CT-TTg on Strengthening Access to the Fourth Industrial Revolution (2017); Ministry of Industry and Trade's Decision 4246/QD-BCT (2017); Prime Minister's Decision 844/QD-TTg (2016); 2020 Broadband Plan (2016)

Source: UNIDO and ASEAN Secretariat's compilation from various sources.

- Building the absorptive capacity of developing countries for the uptake of fourth industrial revolution technologies.
- Building regulatory frameworks and establishing guidelines for implementation.
- Addressing skill needs and education reforms.
- Supporting small and medium-sized enterprises' transition to the fourth industrial

revolution and bridging the gender digital divide.

- Building national, regional and sectoral innovation systems.
- Monitoring progress made in sectoral, national and the regional transition to the fourth industrial revolution.
- Enhancing regional coordination to strengthen work on the fourth industrial revolution.

At the level of regional organizations such as the Association of Southeast Asian Nations (ASEAN), various initiatives address the challenges of the fourth industrial revolution across different ASEAN sectoral bodies under the three ASEAN pillars (see table 4.2). ASEAN still needs a collaborative mechanism to firm up cooperation on the fourth industrial revolution and to propose a consolidated strategy and enhanced coordination mechanism for a smooth transformation.

WHAT IS THE ROLE OF INTERNATIONAL ORGANIZATIONS?

As a leading UN specialized agency with a mandate to foster inclusive and sustainable industrial development (ISID), UNIDO addresses opportunities, challenges and risks stemming from fourth industrial revolution technologies and their impact on ISID. As a convener, knowledge and partnership broker, policy adviser and provider of practical technological solutions, UNIDO supports countries with varying levels of economic development in their efforts to ensure a smooth transformation to the fourth industrial revolution and supports developing countries in technology catch up.

To mainstream and enhance the effectiveness of its interventions, UNIDO is introducing a comprehensive strategy for ensuring smooth transformation to the fourth industrial revolution. Development results follow from a mix of UNIDO's four core complementary functions: technical cooperation; analytical and research functions and policy advisory services; a normative function and standards-related activities; and a convening function and partnerships for large-scale investment, knowledge and technology transfer, and networking and industrial cooperation.

UNIDO technical cooperation programmes promote a smooth transformation to the fourth industrial revolution for developing countries and least developed countries (LDCs). The thematic focus promotes smart agrofood, smart energy, smart manufacturing and a smart circular economy; fosters technological learning and innovation among small and medium-sized enterprises, youth and women; develops science, industry and technology parks and areas of innovation; and ensures industrial safety and security and the timely adaptation of institutions (such as norms, standards and regulations) to rapid technology change.

Tailored to the specific region and country context UNIDO technical cooperation projects aim at leveraging fourth industrial revolution technologies for industrial modernization and upgrading focusing on industrial sectors such as agrofood, electronics, heavy machinery, textiles and garments, the aerospace industry and the automotive industry.

The low level of skills, finance and technological capabilities, and inadequate education and infrastructure in developing countries often impair the absorption of new knowledge generated elsewhere. UNIDO therefore plays a crucial role in enabling developing countries to build their capacity for absorbing new technology though systems of innovation and business ecosystem building, thus preventing the technology gap from widening.

The fourth industrial revolution technologies are shaping the future of manufacturing and of work. This creates opportunities for manufacturers to generate new value added, increase capacity, improve margins, cut costs and become energy and material resource efficient. Smart manufacturing employs a high level of automation, uses

TABLE 4.2 ASEAN'S 4IR INITIATIVES

APSC (ASEAN Political-Security Community)

- ASEAN Declaration to Prevent and Combat Cybercrime
 - ASEAN Cyber Centre and Hub
- Memorandum of Understanding (MoU) on Cooperation to Counter
- International Terrorism between ASEAN and Australia
- ASEAN Leaders' Statement on Cybersecurity Cooperation

AEC (ASEAN Economic Community)

- Science and technology: ASEAN Open Innovation and Entrepreneurship Platform
- Consumer protection: Guidelines on Cross-Border B2C for Online Businesses
 UDD: Table a large large system of the Contract (TISC)
- IPR: Technology Innovation Support Centres (TISC)
 Energy: Renewable Energy hub information sharing
- MSMEs: ASEAN SME Academy and ASEAN SME Service Centre
- FAF: Climate Smart Agriculture and Guidelines on Sustainable Forest Management
- E-Commerce: ASEAN Agreement on e-Commerce and ASEAN Digital Integration Framework
- ICT: ASEAN Framework on Digital Data Governance
- ASEAN Digital Integration Framework Action Plan
- ASEAN Innovation Roadmap
 - Guidelines on Skilled Labour/Professional Services Development in Response to 4IR
- ASEAN Declaration on Industrial Transformation to Industry 4.0
- Digitalisation of ASEAN Micro Enterprises

ASCC (ASEAN Socio-Cultural Community)

- Education: ASEAN Cyber University, Online Learning on Higher Education, ICT-ready Teachers, and ASEAN TVET 4.0
- Employment: Regional study on the impact of ICT and outsourcing on employment and on the adequacy of legislations in regulating employment relationship

Source: https://www.asean2019.go.th/en/abouts/priority-deliverables-economic/; ASEAN Integration Monitoring Directorate (AIMD); ASEAN Economic Community Department; AIMD@asean.org.

biodegradable materials and huge volumes of data and interacts with customers for production processes and delivery of products and services with high knowledge content. In a smart factory, machines interconnected in networks are equipped with sensors and software to communicate with people and with each other, becoming smarter as they work out solutions.

UNIDO projects establish demonstration and pilot smart factories and innovation centres that act as knowledge and innovation hubs. In those centres, new technologies are used as tools for technological learning and innovation, often by small and medium-sized enterprises (SMEs). UNIDO cooperates with leading international organizations, private sector technology providers and research institutions to identify the best technological solutions for introducing smart systems such as industrial artificial intelligence in companies undergoing a digital transformation.

By convening countries in a multilateral context, UNIDO contributes to raise awareness on the challenges and opportunities stemming from the fourth industrial revolution and how to address them, and provides important learning opportunities for the exchange of knowledge not only from developed to developing countries but also among developing countries.

UNIDO encourages collaborative partnerships with public and private institutions and organizations in many developed and developing countries to address skills, knowledge and technology gaps. UNIDO's Programme for Country Partnership constitutes a cornerstone of UNIDO's programmatic engagement, advocacy and collaboration. It engages Member States and other countries, international organizations within and beyond the United Nations development system, knowledge partners, the business sector, civil society, financial institutions and environmental financing mechanisms. The programme aims to leverage human, technical, political and financial resources to achieve more scalable and sustainable development.

UNIDO uses its networks and specialized centres, such as the Network of Investment and Technology Promotion Offices, the Private Financing Advisory Network and the National Cleaner Production Centres, to enable interactions and partnerships between public institutions and the business sector and to leverage fourth industrial revolution technologies for impact investments.

5

CONCLUSION: AN AGENDA FOR ACTION FOR THE ASIA-PACIFIC

On the sidelines of the Conference, Indonesian Minister of Industry Airlangga Hartarto and UNIDO Director General LI Yong signed the revised Country Programme, which rearmed the partnership commitment between the Government of Indonesia and UNIDO and which will • help increase efficiency, effectiveness and funding possibilities. The revised Country Programme • highlights the priorities of the Government, with the updated portfolio of ongoing and pipeline projects focusing, inter alia, on poverty alleviation, creative industries, innovation, quality standards, green industrial policy, water stewardship and Industry 4.0.

Based on the discussions during the Bali conference, participating countries agreed on the Bali Industry 4.0 Agenda (annex 1). The Bali agenda urges governments to promote further cooperation in addressing the challenges and seizing the opportunities of Industry 4.0, creating a level playing field in the region and building a knowledge-sharing platform for developing countries to learn from more advanced economies in the region.

Follow-up actions to enable a smooth transition in the Asia and Pacific region to the fourth industrial revolution include:

- Identifying the prerequisites for Industry 4.0 uptake in Asia and Pacific countries, particularly in least developed countries and small island developing states; targeting priority industrial sectors such as textiles and garments; and spreading lessons and good practices from front runners in the priority sectors.
- Assessing the preparedness of industry and small and medium-sized enterprises (SMEs) in the priority industrial sectors and finding

tools to monitor sectoral and SME uptake of Industry 4.0.

- Exploring methods and best practices to support SME digital transformation and bridge the gender digital divide.
- Building national, regional and sectoral innovation systems.
 - Collecting lessons on regional cooperation initiatives from other regions (such as the European Union's Digitizing European Industry initiative).
- Designing training curricula for new workforce skill requirements.
- Building awareness among policymakers and industry associations and allowing crossborder interactions on new standards, infrastructure, operational systems, and regulatory frameworks that need to be developed or mainstreamed to correspond to the requirements of fourth industrial revolution technologies.
- Addressing and allowing cross-border interactions on data issues such as data regulations and management.
- Identifying regional value chains and innovation networks, and setting standards for interoperability.
- Strengthening strategic partnerships with governments, academia, the private sector, civil society, United Nations entities and development finance institutions to leverage financial and technical resources for UNIDO fourth industrial revolution programmes in Asia and Pacific.

UNIDO will continue its efforts to establish a knowledge-sharing platform for building awareness and communicating lessons and good practices from front runners in priority thematic areas relevant to the Asia and Pacific region and ASEAN. The platform will include exchanges of experts, regional thematic conferences and workshops, and study tours on regional cooperation initiatives from other regions. Targeted stakeholders include SMEs, academia, financial institutions and representatives from government, industry, and industry associations. The Industry Analytics Platform will feature a way to assess the uptake of fourth industrial revolution technologies and related pilot studies from Asia and Pacific countries to analyse industry preparedness for a smooth transition to Industry 4.0.

UNIDO can also help Asia and Pacific regional integration initiatives for fostering uptake of fourth industrial revolution technologies along the following thematic areas:

HUMAN RESOURCE DEVELOPMENT

- Developing talent through companies, unions and government cooperation.
- Identifying new skills needed.
- Supporting continuing education, learning and capability building.
- Developing metrics to monitor regional and sectoral uptake of fourth industrial revolution technologies.
- Investing in capacity building to increase the absorptive capacity of developing countries for the uptake of fourth industrial revolution technologies.
- Convening regional forms for research and policy advice to build awareness of the opportunities of fourth industrial revolution technologies.

INNOVATION AND ECOSYSTEM BUILDING

• Promoting the mainstreaming of national, regional and sectoral innovation systems as preconditions of fourth industrial revolution

learning, innovation and development, and addressing widening technology and innovation gaps.

- Establishing model factories to foster technological learning and innovation.
- Promoting open innovation and business ecosystem building for entrepreneurship and startups.
- Addressing fourth industrial revolution technology standards and interoperability of operating systems.

BUILDING PARTNERSHIPS

• Leveraging multistakeholder resources and partnerships for implementing fourth industrial revolution programmes on the ground.

UNIDO's support for ASEAN can include the following key activities:

- Assisting in implementing the ASEAN Digital Integration Framework Action Plan.
- Supporting ASEAN countries in finalizing innovation roadmaps for smooth transformation to the fourth industrial revolution based on innovation surveys at the national, regional and sectoral levels.
- Supporting ASEAN countries in assessing the readiness for fourth industrial revolution digital and other technologies of industrial sectors and micro, small and medium-sized enterprises (MSMEs) in the priority industrial sectors.
- Designing tools for monitoring the uptake of fourth industrial revolution technologies by sectors and MSMEs.
- Designing programmes for digitalizing MSMEs.
- Establishing MSME training, demonstration and innovation centres and sharing best practices.
- Formulating guidelines for digitalizing MSMEs by sector.
- Empowering human capital for the fourth industrial revolution through tailor-made trainings and capacity building programmes.
- Designing training curricula for new workforce skill requirements.

- Supporting the formulation of guidelines on

 human resource development and technical
 and vocational education and training, and
 bridging the gender digital divide.
- Designing and implementing tailor-made technical cooperation projects.
- Addressing the upgrading and modernization of regional value chains and innovation networks and setting standards for interoperability.
- Engaging in joint resource mobilization and multistakeholder partnership approaches for implementing sector-specific and tailor-made technical cooperation projects.
- Producing evidence-based policy research and advice on sector-specific Industry 4.0 priorities in ASEAN member countries in partnership with other intergovernmental organizations.

NOTES

- https://www.cisco.com/c/dam/global/en_sg/assets/ csr/pdf/technology-and-the-future-of-asean-jobs.pdf.
- 2. The Republic of Korea started on the fourth industrial revolution in 2013 in the Ministry of Industry. The Korean government has changed its slogan many times, depending on the regime and the minister, but the actual strategy has not significantly changed. In 2017, President Moon established an independent Committee for the Fourth Industrial Revolution. Four government bodies are geared to the fourth

industrial revolution. First is the president advisory committee. Second is the fourth industrial revolution committee. The other two are the Ministry of Science and Technology and the Ministry of Industry. These four demonstrate the Republic of Korea's increasing interest in the fourth industrial revolution. The efficiency of creating and implementing policy is strong compared with the prior regime, but there are questions about the efficiency of administration.

3. Horizon 2020 website.

ANNEX 1 BALI AGENDA ON INDUSTRY 4.0



We, the delegations of People's Republic of Bangladesh, Kingdom of Cambodia, Republic of Indonesia, Islamic Republic of Iran, Japan, Republic of Korea, Lao People's Democratic Republic, Malaysia, Federal Democratic Republic of Nepal, Islamic Republic of Pakistan, and Democratic Republic of Timor-Leste, having met at the 1st Regional Conference on Industrial Development, "Unlocking the Potential of Industry for Developing Countries (hereinafter referred to as '**RCID**') in Bali, Indonesia, on 8–9 November 2018;

Acknowledging that Industry 4.0 is evolving at an exponential pace with the potential to trigger major structural shifts in the global economy and transforming economies, jobs and even society itself;

Noting that Industry 4.0 has the potential to produce innovations to address global challenges;

Mindful that Industry 4.0 will increase productivity and create structural shifts in global value chains, as factories across the world become increasingly smart, connected and digitized;

Noting that Governments should have appropriate strategic plans to address the challenges and opportunities associated with Industry 4.0;

Recognizing the RCID as a platform for the United Nations Industrial Development Organization (hereinafter referred to as 'UNIDO') member states in the Asia and the Pacific region, key stakeholders and experts to share industrial development policies, experiences, technologies, know-how and best practices related to Industry 4.0, as well as to identify the role of international organizations;

Recognizing the role of south–south cooperation framework in promoting capacity building of Industry 4.0 through triangular arrangement and various kind of assistances;

Mindful that due to the multidimensional nature of Industry 4.0, all countries, including developed, developing and least-developed countries, have to encourage the development of Industry 4.0;

DO HEREBY DECLARE our volition to keep promoting the implementation of Industry 4.0 in the Asia Pacific Region, and:

- 1. Urge the Governments to promote further cooperation in addressing the challenges and seizing the opportunities of Industry 4.0 implementation;
- 2. Call for all stakeholders in the Asia Pacific countries to continuously explore aspects of Industry 4.0 with a view to finding ways for each developing country in the region to implement Industry 4.0;
- 3. Encourage the identification of prerequisites and drivers for Industry 4.0 technology uptake in the Asia Pacific region and in the context of each country;
- 4. Promote identification of lessons learned from successful country cases, particularly in the Asia Pacific region, particularly on how they can be applied in developing countries in the region;
- 5. Encourage Governments' and international agencies' involvement in optimizing framework conditions and support so that as many small and medium-sized enterprises (SMEs) as possible meet the challenges and reap the benefits of Industry 4.0 implementation;
- 6. Encourage Governments to foster policy dialogue among UNIDO member states to seize the opportunities of Industry 4.0 through further cooperation in various sectors;
- 7. Urge UNIDO and other international organizations to provide technical training, certification and financial support for building the capacity of policy makers and industries as well as SMEs in developing countries towards the implementation of Industry 4.0; and
- 8. Further promote technology providers' active participation through Public–Private Partnership to create technology transfer and to support private sectors, industries and SMEs to prepare for and gradually shift their manufacturing processes in accordance with digital transformation.

ANNEX 2 SIDE EVENT ON INDUSTRY 4.0

A side event on Industry 4.0 was organised on the sidelines of the First Regional Conference on Industrial Development. The key purposes of the side event were the following:

- Create a platform for the government and policy makers to share their best practices in preparing for the implementation of Industry 4.0 (specially in the 5 related sectors) through presentations in a workshop.
- 2. Create a business matching platform where leading enterprises (both national and international) can share their experiences and achievements on implementing the Industry 4.0.

The event witnessed the participation of government and private sector representatives from diverse industrial fields and different countries of the Asia-Pacific region. Approximately 30 people attended the side event. Key speakers included:

- 1. Mr. Haris Munandar—Secretary General of Ministry of Industry
- 2. Mr. Ben Ong-EDB Singapore
- 3. Mr. Wei Wen Ng-EDB Singapore
- 4. Mr. Tri Purnajaya—Director of Trade, Commodity and Intellectual Property, MoFA
- 5. Mr. Xavier Denoly—Schneider Electric, Country President

- 6. Mr. Fadli Hari Purnomo—Winteq Astra Otoparts, Plant and Engineering Division Head
- 7. Mr. Volker Schmid—Festo Indonesia, Head of Asia Pacific
- 8. Representative from Enterprise Singapore— Singapore's technology provider

Schneider Electric and Festo Indonesia participated in the booth exhibition. They displayed and explained their technologies to the attendees. Representatives from Winteq Astra Otoparts and Enterprise Singapore also spoke during the side event.



Participants during the side event organised on the sidelines of the RCID conference in Bali



ANNEX 3 SPEAKERS



Airlangga Hartarto Minister of Industry of the Republic of Indonesia

Born in Surabaya in 1962, Airlangga Hartarto was named Minister of Industry on 27 July

2016. Airlangga, an alumnus of the Mechanical Engineering Department, Gadjah Mada University, had served as the chairman of Asosiasi Emiten Indonesia (Indonesian Public Listed Companies Association; AEI), Secretary General of ASEAN Federation of Engineering Organizations (AFEO), Chairman of Persatuan Insinyur Indonesia (the Institution of Engineers Indonesia; PII), Head of Engineers Council of PII, member of Majelis Wali Amanat Universitas Gadjah Mada, Vice President of Keluarga Alumni Gadjah Mada (Alumni Organization of Gadjah Mada University; KAGAMA) and also a member of the KAGAMA Advisory Board. He initiated the Herman Johannes Award for innovative technology in his chairmanship period at Keluarga Alumni Fakultas Teknik UGM (Alumni Organization of Faculty of Engineering GMU; KAGAMA). Before his assignment as minister, Airlangga was a member of commission XI in the Indonesian parliament, in charge of financial, national development planning and the banking sectors. From 2009 to 2014, he was the chairman of commission VI in the parliament, concerned with industry, small and medium-scale business, investment and state-owned enterprises. From 2006-2009, he was a member of commission VII in the parliament. Airlangga also received degrees from Monash University (MBA 1996) and Melbourne Business School, University of Melbourne (MMT in 1997). His awards include ASEAN Engineering Honorary fellow, ASEAN Federation of Engineering Organization in Myanmar (2004); Founding Fellow, ASEAN Academy of Engineering Technology (2004); Australian Alumni Award for Entrepreneurship (2009); Satyalancana Wira Karya from the Republic of Indonesia (2014); Lee Kuan Yew Exchange Fellow (LKY Fellow) in Singapore (2017) and Distinguished Honorary Fellow, ASEAN Federation of Engineering Organizations in Thailand (2017). He has published three books on industrial topics.



A. M. Fachir Vice Minister for Foreign Affairs of the Republic of Indonesia

Born in Banjarmasin, in 26 November 1957, A.M. Fachir was ap-

pointed by President Joko Widodo in October 2014 as the Vice Minister for Foreign Affairs of the Republic of Indonesia. A. M. Fachir has a doctoral degree in religious and cross-cultural studies from University of Gadjah Mada. He joined the Foreign Service in 1984. Before being appointed Vice Minister, he served as an Ambassador Extraordinary and Plenipotentiary of the Republic of Indonesia to the Kingdom of Saudi Arabia. He was appointed by President Susilo Bambang Yudhoyono as the Ambassador Extraordinary and Plenipotentiary of the Republic of Indonesia to the Arab Republic of Egypt from 2007 to 2011. Before becoming ambassador, his foreign assignments included Deputy Chief of Mission, Indonesian Embassy in Kuala Lumpur; Indonesian Mission to the UN in New York and Indonesian Embassy in Baghdad. He also served in several domestic assignments, among them Director General for Information and Public Diplomacy, Head Bureau of State Document and Translation, Office of the Minister of State Affairs and, concurrently as Official Interpreter of President Megawati Soekarnoputri, Deputy Director for Political and Security Affairs, Directorate of International Organizations, and office of Chief Executive Assistant to the Chairman of the Non-Aligned Movement.



LI Yong Director General of United Nations Industrial Development Organization

LI Yong, Director General, United Nations

Industrial Development Organization (UNIDO), has had an extensive career as a senior economic and financial policymaker. As Vice-Minister of Finance of the People's Republic of China and member of the Monetary Policy Committee of the Central Bank for a decade, he was involved in setting and harmonizing fiscal, monetary and industrial policies, and in supporting sound economic growth in China. He advanced financial sector reform and prompted major financial institutions to establish corporate governance, deal with toxic assets and strengthen risk management. He emphasized fiscal and financial measures supporting agricultural development and small and medium-sized enterprises, the cornerstones for creating economic opportunities, reducing poverty and promoting gender equality. He played a key role in China's cooperation with multilateral development organizations, such as the World Bank Group and the Asian Development Bank.



Febrian A. Ruddyard Director General of Multilateral Cooperation, Ministry of Foreign Affairs of Indonesia

Febrian Alphyanto

Ruddyard is the Director General of Multilateral Affairs with the Ministry of Foreign Affairs, Indonesia. He previously served as Deputy Chief of Mission at the Embassy of the Republic of Indonesia in Vienna. He also served in Indonesian missions in New York, Canberra and Riyadh. Previously, he held various notable positions in the ministry such as Director for Middle East Affairs and Director for International Security and Disarmament Affairs. He holds a master's degree in international relations from the University of Birmingham, United Kingdom, and a bachelor's degree in international relations from the University of Padjadjaran, Indonesia.



Ngakan Timur Antara Head, Agency for Industrial Research and Development, Ministry of Industry, Indonesia

Ngakan Timur Antara

was born on 23 November 1959, in Gianyar, Bali. He currently serves as Head of the Industrial Research and Development Agency after serving as Minister of Expert Staff in the Strengthening of Industrial Structures from 2015 to 2017. Starting his career at the Agro Industry Centre in 1985, he was involved in the world of industrial research and development in several positions at the Ministry of Industry, starting as Head of the Baristand Palembang (2002–2004), Head of the Baristand Semarang (2004–2006), Head of the Centre for Ceramics (2006–2010) and Head of the Centre for Pulp and Paper (2010–2014). He has participated in several trainings on industrial research and development and focuses on boosting research and development in industry in order to increase added value. Ngakan Timur Antara completed high school at Singaraja High School, Bali, then studied at the Bogor Agricultural Institute in the Department of Agricultural Product Technology. He completed a PhD in food science at the University of Leeds, United Kingdom, in 1992.



Tri Purnajaya Director for Trade, Commodities and Intellectual Property, Ministry of Foreign Affairs, Republic of Indonesia

Tri Purnajaya has been the Director for Trade, Commodities and Intellectual Property in Indonesia's Ministry of Foreign Affairs since 2016. The Directorate for Trade, Commodities and Intellectual Property has the task of formulating and implementing policies in foreign relations and foreign politics in multilateral cooperation for trade in industrial goods and free trade areas, trade in services and trade facilitation, agriculture and commodity development, as well as handling trade disputes and intellectual property. Before coming to the directorate, Tri held a series of Foreign Ministry posts in the Secretariat of the Directorate General of Foreign Economic Relations; the embassy of Indonesia in Brazil; the Directorate General of Multilateral for Economic Development, where he headed the section on WTO agricultural negotiation; the embassy of Indonesia in New Zealand; and most recently the Association of Southeast Asian Nations. He holds a bachelor's degree from the Christian University of Indonesia and a master's degree from the Global Master of Arts Program at the Fletcher School, Tufts University.



Darmansjah Djumala Permanent Representative of the Republic of Indonesia in Vienna

Darmansjah Djumala is Permanent Repre-

sentative of the Republic of Indonesia in Vienna. Among the capacities he served in are: Head of Presidential Secretariat (2015); Head of Policy Analysis and Development Agency, Ministry of Foreign Affairs (2014); Ambassador to Poland (2010); Head of Centre for Education and Training, Ministry of Foreign Affairs (2006); Deputy Chief of Mission, Embassy in Brussels, Belgium, accredited to Luxembourg and the European Union (2003); Head of Division for Economic Affairs, Permanent Mission to the UN, New York (2001); Deputy Director for UN Economic and Social Council, Directorate of Multilateral Economic Cooperation (1999); Head of Division for Economic Affairs, Consulate General in New York (1996); Head of Section for Economic Affairs, Permanent Mission to the UN, World Trade Organization (WTO) and other international organizations in Geneva (1994); Head of Section for Operational Activities, Directorate of Multilateral Economic Cooperation (1992); staff, Economic Section; Head of Section for Economic Cooperation and Assistant to the Ambassador, Embassy in Tokyo (1988); Head of Section for Investment Cooperation in Europe, Middle East and Africa, Directorate of Investment and Financial Cooperation (1986); staff, Directorate of Investment and Financial Cooperation (1984). He holds a bachelor's degree in development studies from Universitas Sriwijaya, Palembang, a master's degree in international relations from Webster University, Geneva, and a doctoral degree from the School of Governance, Universitas Padjadjaran, Bandung.



Olga Memedovic Chief. Business Environment **Cluster and Innovation Division**, **Department of** Trade Investment and Innovation. **United Nations Industrial Development Organization**

Before joining UNIDO, Ms. Memedovic served as a Project Leader at the Netherlands Economic Institute and a Research Fellow at the Tinbergen Institute of Erasmus University Rotterdam, Free University Amsterdam and University of Amsterdam. She has led research projects that include the EU-LDC Trade and Capital Relations; Global Value Chains and Innovation Networks: Prospects for Industrial Upgrading in Developing Countries; Public Goods for Economic Development and Pursuing Resource Efficiency in Europe and Central Asia. She is the author or main editor of several books, reports and studies on the globalization of labour markets, multilateralism and regionalism, technical barriers to trade, theory and measurement of comparative advantages, global value chains and production networks, industrial energy efficiency, resource efficiency, small and medium enterprise clusters, industrial parks and innovation systems, collective action and industrial policy, eco-industrial policy and others.



Ben Ong Senior Lead of the **Economic** Development **Board, Singapore**

Mr. Ben Ong is a Senior Lead-Strategy at the Economic Development

Board (EDB) Singapore. In 2014, he worked as a consultant at the Regional Plan Association in

New York. From 2008 to 2010 he was Military Counsellor of the Singapore Army. In 2014, he received a master's degree in public administration (MPA) in environmental science and policy at Columbia University in New York. In 2013, he received a BS in ecology and evolutionary biology and a BA in the study of women, gender and sexuality with honours.



Pin Fen Fong Economic Development Board Singapore

Ms. Pin Fen Fong is working as Director, Cities. Infrastructure and Industrial Solutions

at the Singapore Economic Development Board. She oversees the promotion and development of new business opportunities in the Engineering Services, Controls and Automation and the Building Solutions sector in Singapore. Ms. Pin Fen Fong received a master's degree in knowledge management at Nanyang Technological University. In 2000 she received a bachelor's degree in electrical and electronics engineering at Nanyang Technological University.



Sanghoon Kim **Korea Institute** for Industrial **Economics and** Trade

Dr. Sanghoon Kim is an Advisor to the Minister, Ministry of Trade, In-

dustry and Energy. He is an Advisory Board Member, Technology Evaluation & Valuation Control Board under that ministry. In 1999, he received a DPhil in metallurgy and materials science at the University of Oxford. He is a business analyst and

economist specializing in industry policies, business strategy and technology forecasting/evaluation/financing/commercialization issues for metals, finance and knowledge-intensive (engineering service, music and design) sectors with focuses on small and medium-sized enterprises, cross-nation analysis and the fourth industrial revolution (Industry 4.0). He is a materials scientist studying alloy design for light metals and high temperature materials (especially for non-ferrous alloys including tin alloys and intermetallics) and nano scale characterization (including atom probe tomography).



Ravi Gupta Co-Founder and CEO, Tambourine Innovation Ventures (TIV) Inc.

Ravi Gupta is a strategist on innovation commercialization, intellec-

tual property, early stage entrepreneurial finance and private sector development with a focus on technology-based economic development. He has more than 15 years of experience comprising venture capital, technology commercialization, technology transfer and economic development policy, intellectual property strategy and monetization, private equity and innovation policy. He had been responsible for strategic planning for regional local economic development programmes in the United States, particularly in the Midwest. Through multilaterals such as the World Bank and Asian Development Bank, he has advised several governments in Eastern Europe, Latin American and the Caribbean and Asia Pacific and led the creation of innovation policies and establishment of innovation infrastructure, such as technology commercialization facilities, intellectual property marketplaces and venture funds. He is a member of Cornerstone Angels, a Chicago-based angel investment club, and a mentor to several firms in emerging economies through the AAAS (American Association for the Advancement of Science) and the U.S. State Department Global Entrepreneurship programme. He serves as an advisor to the Chicagobased Center for HealthCare Innovation, an independent, non-profit research and educational institute that brings the best and brightest health care leaders from all over the world together to share their ideas and expertise on topics related to innovation in health care. His past experience includes working in tech transfer offices at U.S. universities and technology consulting. Ravi earned his master's degree in economic policy from the University of Chicago. In addition, he has an MBA in finance with doctoral level coursework in economics and a bachelor's degree in chemical engineering.



Shirley Santoso Partner and President Director, A.T. Kearney Inc.

Shirley Santoso is a Partner in A.T. Kearney's Jakarta office and Asia Pacific Lead for

the firm's Leadership, Change and Organization Practice. A seasoned transformation expert across Asian countries and industries, her experience includes work with Asia Pacific's most dynamic telecom operators, health care providers, large retailers, financial institutions, infrastructure players and family-owned businesses. Ms. Santoso's current focus is in the areas of strategy and organization transformation, where she has led many successful strategy, organizational effectiveness, turnaround and large-scale transformation engagements for Indonesian and Southeast Asian clients. These include organization and operating model redesign, alignment of key stakeholders and leadership teams, governance setup and change management.



Jouke Verlinden Representative of Delft University of Technology, Netherlands

Jouke Verlinden (1969) received his MSc in computer science (1993)

and has a background in interactive computer graphics and virtual reality. He worked in industry as interaction designer and project manager for seven years before returning to academia. Since 2000 he has been an Associate Professor of Augmented Reality and Digital Fabrication at Delft University of Technology (TU Delft). He is editor of the AR{t} Journal and the International Journal of Interactive Design, Engineering and Manufacturing. Together with graduate students and staff, Jouke is working on "augmented matter in context" to enable embodied dialogues by bridging physical and digital boundaries. His research interests include interaction design and novel design support systems, augmented reality, 3D printing, factory in a day, sail simulator and kinetic mirror.



Nikolai Dobberstein Partner, A.T. Kearney

Nikolai Dobberstein is a Partner in A.T. Kearney's Mumbai office with a focus on telecoms, technology, media

and information technology and business process outsourcing. He has broad experience in working with telecoms, tower companies and information technology and business process outsourcing service providers in India, Southeast Asia and the Middle East. He has worked on engagements ranging from growth and technology strategy, digital services and media strategy, network rollouts and sharing to large-scale transformation programmes and major cost and operational frontline improvements. He has lived in Asia since 1993 and has served in various leadership roles as a management consultant, board member and business head. Before joining A.T. Kearney in 2011, he was ExCo member for New Businesses and Strategy at Maxis Malaysia, responsible for all mobile data and Internet businesses and propelling Maxis into a global top 15 mobile data player. He has a PhD in technology and innovation management from the University of Kiel, Germany.



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