DEPARTMENT OF SCIENCE AND TECHNOLOGY
PHILIPPINE COUNCIL
FOR INDUSTRY, ENERGY
AND EMERGING TECHNOLOGY
RESEARCH AND DEVELOPMENT
(DOST-PCIEERD)

DOST PCIEERD ETDD: Formulation of Roadmap and Sectoral Plan for Five Emerging Technologies

Convergence of Emerging Technologies for Industry 4.0

Final Report

SGV
Building a better working world

FOREWORD

Steering the country towards inclusive digital transformation, the Department of Science and Technology – Philippine Council for Industry, Energy and Emerging Technology Research and Development (DOST-PCIEERD) offers its latest Roadmap and Sectoral Plan for convergence of emerging technologies for industry 4.0.

This roadmap is a comprehensive effort by a team of experts from the academe, government, private sector, research community, and other relevant institutions to help stakeholders and the public understand the Council's plans and adoption timelines in achieving the sustainable development goals (SDGs). With this Roadmap in place, our researchers, scientists, and entrepreneurs can now craft priority research programs in a manner that is consistent, harmonized and complimentary – all whichare geared towards bringing about value and benefits to the whole society.

Industry 4.0 centralizes on the concepts and technologies that drives smart factories and processes such as intelligent machines, and big data analytics. To maximize the potential of this field, it is important to have a clear and shared vision of the future Industry 4.0, and develop a strategic action plan that creates and sustains momentum toward progress and prosperity for all.

Our main goal is to bring science closer to society and enable each one of us to use Filipino-made breakthroughs and innovations more efficiently to increase our productivity and drive prosperity. Thus, the council will remain committed in making science work to deliver timely as well as relevant cutting-edge innovations for all Filipinos.

By working with us, we can truly make innovation work for the people.

DR. ENRICO C. PARINGIT
PCIEERD Executive Director

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Executive Summary

Increasingly sophisticated technologies have changed the ways in which the manufacturing sector operates, creating more efficient supply chains, integrated systems and improved production and quality. The Fourth Industrial Revolution, also known as Industry 4.0 (I4.0), introduces revolutionary methods to enhance manufacturing. Through cyber-physical systems, human-machine interaction, and advanced analytics with the use of disruptive technologies such as artificial intelligence, big data and Internet of Things (IoT), markets will be able to boost labor and asset productivity. Supply, manufacturing, maintenance, delivery and customer service will be highly integrated. Equipment and machines, production resources and warehousing systems will achieve autonomy and independently exchange information.

To help the Philippines towards the Fourth Industrial Revolution, this study gives a review on the current state of Industry 4.0 globally and locally. Being a new entrant in the Industry 4.0 space, emphasis is given to how other countries implemented smart manufacturing in their own countries and how the Philippines can learn from them given its current capabilities, efforts, and initiatives.

The strategy outlined in this paper is focused on building the proper foundations to ensure that future collaborations will be conducted in an organized and integrated manner. These foundations are on building the cooperation framework through harmonization with the RAMI 4.0 framework, building the infrastructure needed to support the gradual adoption of I4.0 technologies and processes, and building the community through mission-driven programs. In laying these foundations, the hope is to create and foster a flourishing innovation ecosystem for Industry 4.0 in the country.

With the many existing barriers to adoption, the country still has a long way to go in terms of actually implementing and realizing the value from the Fourth Industrial Revolution. However, the hope remains that with enough people envisioning a smarter Philippines, in whatever form, the journey to it may be difficult, but definitely not impossible.

Introduction

Given the Philippines' economic growth has been increasingly dependent on manufacturing in various sectors, it is critical that it also adapts to the changing environment in which it operates to improve its systems and processes. Technologies in Industry 4.0 will be valuable in enabling the growth of the manufacturing sector in terms of more efficient processes, increased foreign investments, and widening human capital potential. This study aims to provide guidelines that the Philippines can apply towards its move to the Fourth Industrial Revolution.

Currently, the Philippines is still in its planning stages for Industry 4.0. Most of the progress that has been done by the public and private sector involves the creation of roadmaps, discussions during conferences and adoption of technologies in a few industries. Academic institutions have also started offering programs that are necessary to develop highly skilled manpower for the operationalization of these technologies.

A lot of technologies each have the potential to transform how things work in the industry, but it is only through convergence of such that we can fully realize the gains from smarter infrastructure. Similar to the importance of collaborations between people, technologies must also be adaptable enough to integrate with each other and make advanced manufacturing possible.

To set a framework and guideline, this study focuses on how to apply Industry 4.0 technologies for four main sectors which are automotive, aerospace, semiconductor and IT/BPO. The Department of Trade and Industry created a framework called I3S that introduces the goal of improving the manufacturing sector through advanced technologies which includes sectors mentioned, roadblocks that the country faces for Industry 4.0 and programs that are currently being done. However, the Philippines still lacks necessary infrastructure, effective institutional frameworks and enough adopters in the private sector of manufacturing to maximize the benefits of Industry 4.0.

Current State Review

The estimated value that will be created by Industry 4.0 technologies and processes for manufacturers and suppliers is $3.7 Trillion by 2025. However, even with this high value potential, only about 30 percent of companies are taking advantage of this value from Industry 4.0 solutions today.

Global Perspective

Industry 4.0, also known as the Fourth Industrial Revolution, refers to the digitization and advancement of the manufacturing industry through disruptive technologies. Initially an initiative by Germany presented in the Hannover Fair in 2011, Industry 4.0 was a means to improve the country's current manufacturing industry through increasing connectivity between the physical and digital worlds. Within the shift to Industry 4.0, factories will use revolutionary technologies such as the Industrial Internet of Things, Artificial Intelligence, Blockchain, Big Data and Analytics, Autonomous Robots, Simulation, Horizontal and Vertical Integration, Additive Manufacturing (3-D Printing), Cloud, Augmented Reality, and Cyber Security. There are common principles governing the implementation of Industry 4.0. These are outlined in the bullets below:

- **Interoperability**: Cyber-physical systems that allow humans and smart factories to communicate with each other
- **Virtualization**: A virtual copy of the smart factor is created by linking sensor data with virtual plant models and simulation models
- **Decentralization**: Cyber-physical systems make decisions of their own and produce locally through the use of three-dimensional technology
- **Real-time capability**: Enabling the collection and analysis of data and providing the derived insights immediately
- **Service orientation**: Enable new business models in which services can be leveraged via the Internet of Services
- **Modularity**: The flexible adaptation of smart factories to changing requirements by replacing or expanding individual modules
- **Convergence**: Ubiquity of data will break down barriers converging industries, disciplines, and the biological, physical, and virtual worlds
- **Cost reduction and efficiency**: Reduce wasted time, manpower, and resources through instant analysis of processes and operations
- **Mass customization**: Allow products to be accurately designed to the specific needs of each individual consumer, and with the consumer being part of the design process

A core technology in smart manufacturing is the concept of having a digital twin. Following the principle of virtualization, a digital twin serves like a bridge between the physical and virtual world. This allows for data analysis and systems monitoring to resolve problems before they occur, prevent possible system downtimes, develop innovative opportunities, and plan for the future without the need to worry about negatively affecting the actual physical object.

Other countries have started to adapt the Fourth Industrial Revolution. They are distinct in terms of their focus areas. Germany focuses on integrating data, communication and technologies in smart factories. China and the United States on the other hand create new business models that utilize smart products and internet platforms. Examples of efforts that are being done include China's Made in 2025, France's Nouvelle France Industrielle, Sweden's Produktion 2030, Italy's Fabbrica Intelligente, or Belgium's Made Different.

However, the move towards Industry 4.0 is just in its initial phases, globally. According to a Global Expert Survey conducted by Mckinsey (2016), only 30 percent of technology suppliers and 16 percent of manufacturers have an Industry 4.0 strategy. Only four out of ten companies around the world have made significant achievements which are mainly in United States, Germany and Japan. A readiness assessment suggests that the Fourth Industrial revolution will be polarized, favoring those countries that have most of the Manufacturing Value Added (MVA) and the advantage in acquiring necessary technologies. Only 25 countries in Europe, North America, and East Asia are in the most optimal standpoint to move towards Industry 4.0. These countries all have high-income except for China and Malaysia. 90% of countries in Latin America, Middle East, Africa and Eurasia are classified as least ready for Industry 4.0 given their limited production base.

According to a study by Acatech in 2018, the diagram on the right summarizes perceived benefits by stakeholder from adapting technologies related to the Fourth Industrial Revolution:

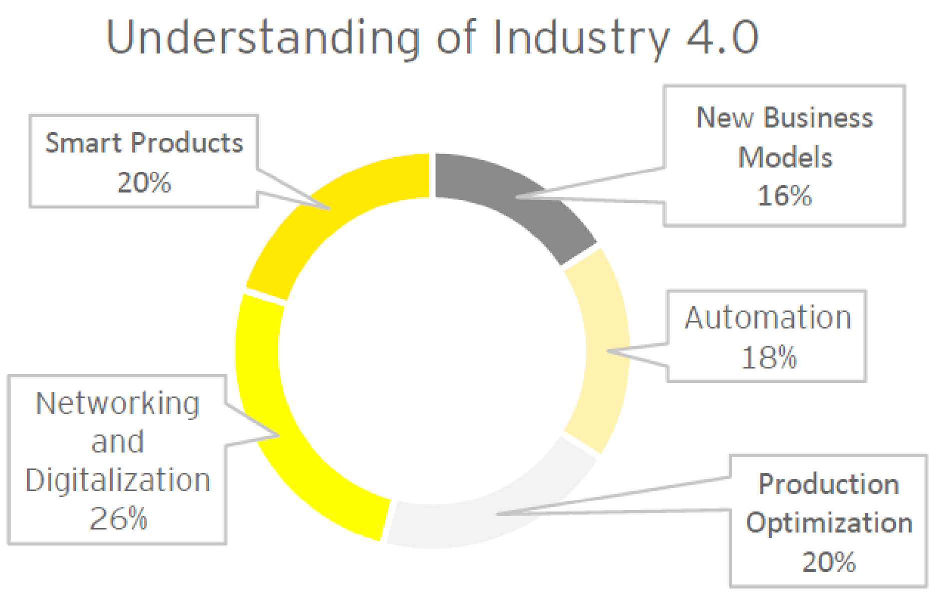


Figure 1. Benefits of Industry 4.0

The critical areas determined as roadblocks for the Fourth Industrial revolution include coordination between organizational units, maintaining cybersecurity standards, determining data ownership when working with third-party providers, lack of skilled human capital and gaining receptivity and support. As Industry 4.0 cuts across different sectors of the manufacturing industries, here are some breakthroughs achieved in this aspect across different countries:

Country	Manufacturing Sector	Details
Netherlands	Logistics	From the usage of a crane to lift shipping containers housing different products to transferring other shipping containers via an autonomous vehicle with a platform to a designated area for collection. The port aims to have automated ships functional by 2030
United States	Construction	The Self-Automated Mason or SAM works on laying down at least 3,000 bricks per day, at least 3 more times than the most efficient mason who can only do 1,000 bricks per day. SAM is created by Construction Robotics to make the construction process easier
United Kingdom	Public Transportation	In the Docklands Light Railway in East London, trains don't require drivers but operate autonomously. Wires that act as sensors built into the tracks track the location of these trains and forward the information to a control center
United States	Food Production	An autonomous tractor made by Case IH in partnership with Bolthouse farms has been pilot tested in 2017 to better understand the uses and improve their current design for the unmanned vehicle

International Highlights

Germany

At the forefront of Germany's move towards the Fourth Industrial Revolution are the Federal Ministry for Education and Research (BMBF) and the Federal Ministry for Economic Affairs and Energy (BMWI). The BMBF and BMWI supports innovative projects and ideas in research through targeted funding programs. They have given €120m for research activities and calls for proposals targeting areas of IT systems for CPS, IoTS and Industry 4.0.

Platform Industrie 4.0 is the central network tasked to advance digital transformation in manufacturing. It is composed of 300 stakeholders from public and private sectors including government, companies, trade unions, and academic institutions. They aim to create standardization, security, and legal framework for the Fourth Industrial Revolution.

The objective of the *Industrie 4.0* is to position Germany's manufacturing industry, with political support, as the world's leading user and provider of digitalized production technologies. The opportunities of digitalization can be focused on four dimensions:

- Production process - efficient production processes and cost savings
- Logistics - more efficient flows of goods and information, lower stocks and plant efficiency, new business opportunities
- Customer retention - closer customer ties
- Hybrid products and the associated smart services - expands Germany as high-qualit production country when it comes to industrial products.

Four key economic, social and societal fields on which German digitalization focuses:

- Productivity and competitiveness - digitalization has already contributed to increase value added in Germany's manufacturing industry
- Employment Development - polarization of labor market, shifts between businesses and sectors and job rotation generation
- Qualification - comply with the requirements of the Industry 4.0 logic
- Big data - data security - intensive performance, conduct checks and comprehensive monitoring

The main industries adapting Industry 4.0 initiatives are automotive, mechanical and plant engineering, and electronics sectors. More than 65% of German companies have been applying these technologies in their processes. Two-thirds of companies in the country already have predictive maintenance while three in four companies have cloud computing solutions. Different research laboratories and institutions exist for different manufacturing sectors. For instance, in the automotive field, focus is given on enhancing the entire value chain in terms of process, product and functional upgrading. Core research areas include intelligent light-weight design with functional integration, and new materials and processes. The electronics sector focuses on leveraging Germany in four areas which are silicon-based technologies, compound semiconductors and special substrates, hetero-integration, and design, testing and reliability.

Launched in 2011, Industrie 4.0 has been successful in its mission of effectively translating research into practice. It especially put emphasis on the role of SMEs in becoming "temporary production networks precise estimates on their contributions" It has supported testbeds that encouraged innovation and used a reference architecture, the RAMI 4.0, as guidance for its decisions and actions. BMWi has funded ten (10) Industry 4.0 competence centres as of January 2017, with five more to come.

Germany also saw a need to break down the complex concepts surrounding Industry 4.0 into distinct and manageable dimensions and components. The RAMI 4.0, or the Reference Architecture Model Industrie 4.0, was developed by the German Electrical and Electronic Manufacturers' Association as a firm and structured support and guidance to Industry 4.0 initiatives. It is essentially a three-dimensional map that shows the most important aspects of Industry 4.0, "ensuring that all participants involved share a common perspective and develop a common understanding." The framework is illustrated on the figure at the right.

The second dimension, shown in multicolored layers, follow basic questions on the business idea. Business refers to the organization and its business processes, Functions refer to the functions of the asset, Information to necessary data, Communication to access to this information, Integration to the connection of the physical assets to the virtual world, and lastly, Asset to refer to the physical object itself. The third dimension tackles where the subject is in the factory hierarchy. The subject can be classified as a product, field device, control device, station, work center, enterprise, or as part of the connected world.

The RAMI 4.0 framework has moved towards becoming a global standard, and is used in international manufacturing powerhouses like the USA, China, Japan, France, and Italy. Each country harmonized the RAMI 4.0 with their own nationally developed reference architectures.

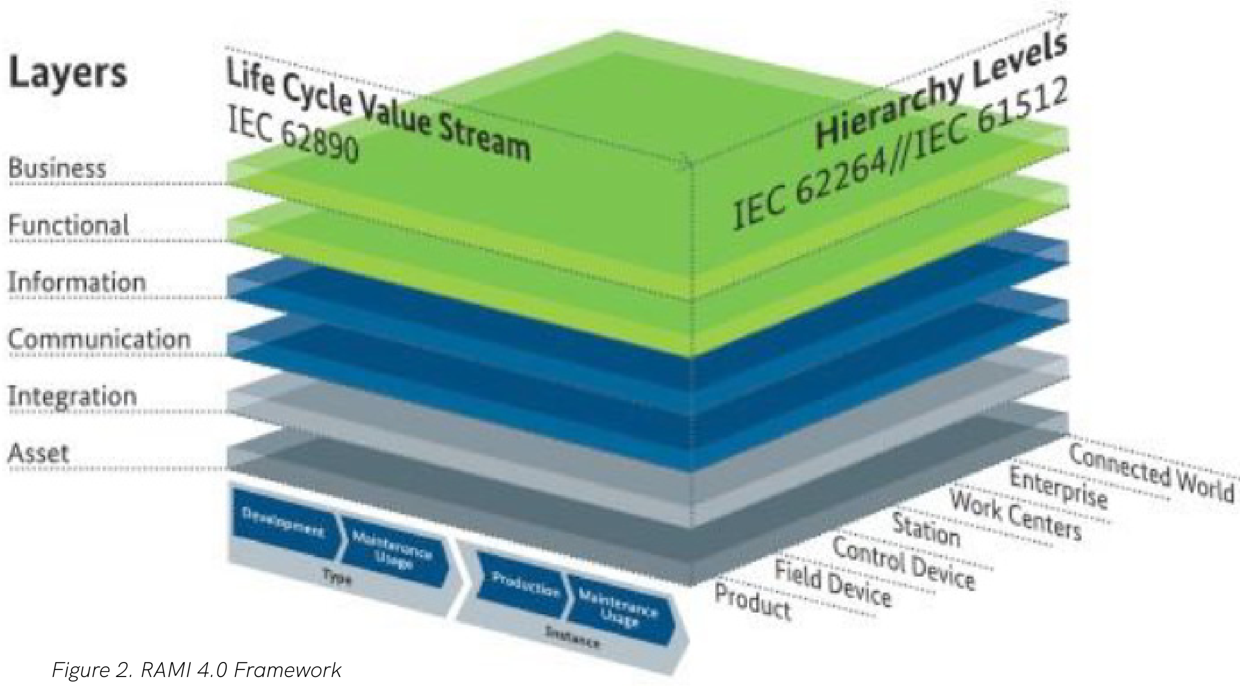


Figure 2. RAMI 4.0 Framework
Source: Platform Industrie 4.0

Singapore

Manufacturing plays a major role in supporting the Singaporean economy, accounting for 20-25% of the country's GDP. However, the local industry faces challenges coming from its competitors from neighboring countries, current restructuring being done in the local landscape, and increasing operational costs. These encouraged Singapore to recognize how much the emerging technologies surrounding Industry 4.0 can impact their manufacturing process, thereby investing time, talent, and resources into the integration of the concept into their systems.

In order to set the direction towards the Fourth Industrial Revolution, the government developed the Singapore Smart Readiness Index. It provides a common framework in understanding the current capabilities of companies, how Industry 4.0 can increase their growth and what steps they can take in order to achieve this. Its three core blocks are Technology, Process and Organization. Under these are 8 pillars which represent critical aspects that companies must focus on to become future ready organizations. Lastly, there are 16 dimensions belonging to these pillars to evaluate the capacity and readiness of facilities. These are illustrated in the diagram to the left.

For instance, the core block of technology deals with three pillars which are automation, connectivity and intelligence. Automation of processes focuses on the flexible execution, control and production of goods and services. Connectivity measures how linked computer systems are to machines and equipment to enable communication and gather data across assets.

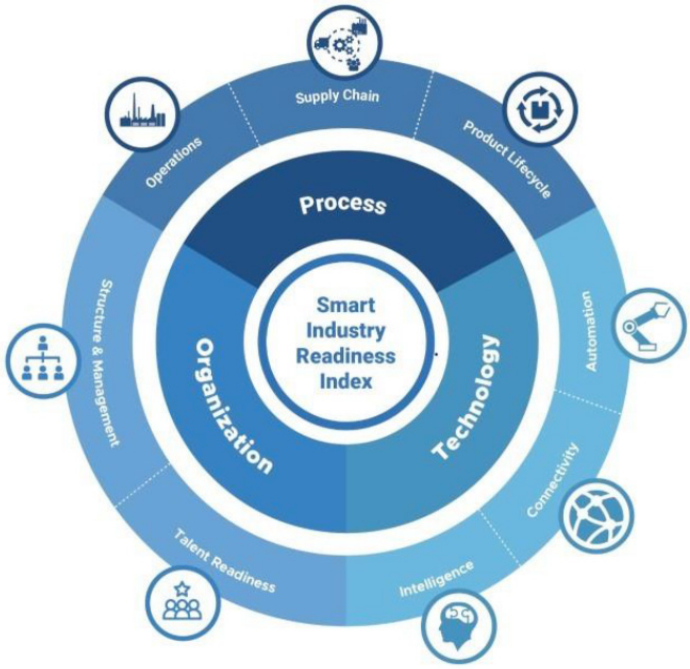


Figure 3. Singapore Smart Readiness Index Components
Source: Singapore EDB

For instance, the core block of technology deals with three pillars which are automation, connectivity and intelligence. Automation of processes focuses on the flexible execution, control and production of goods and services. Connectivity measures how linked computer systems are to machines and equipment to enable communication and gather data across assets. Advancements in cloud computing and wireless infrastructure allow data to be centrally managed. Lastly, Intelligence deals with the ability of these technologies and systems to diagnose problems and create solutions optimally. This involves helping the workforce foresee equipment failures and changes in demand patterns.

The government efforts of Industry 4.0 have been centralized to be led by the Singapore Economic Development Board. Various academic institutions such as the National University of Singapore and the Nanyang Technological State University also play crucial roles in the development of technology and human capital towards the Fourth Industrial revolution.

Nanyang Technological University, HP and National Research Foundation Singapore have launched the HP-NTU Digital Manufacturing Corporate Lab. This is HP's largest research collaboration worldwide and HP's first university partnership in Asia, this lab will spearhead innovation, technology, skills, and economic development critical for Industry 4.0. This is an 84 million USD lab and will push industry transformation towards digital manufacturing and 3D printing technologies. It will focus on new materials and applications such as advanced polymers for manufacturing applications and development of bioprinting models; artificial intelligence and machine learning; and cybersecurity.

Precision engineering company Feinmetall Singapore constructed a $4.5 million digital manufacturing facility for their processes which features advanced manufacturing technologies that allow the company to analyse machine data, develop measures to minimize stoppage, and plan machine maintenance schedules effectively10. OMRON, an automation solution provider, has opened a $10 million Automation center in Singapore to help its local clients deploy their automation solutions.

The power and automation technology group, ABB, opened its Regional Robotics Packaging Application Hub in Singapore in 2014. This facility aims to be a live learning and collaborative environment that will allow end customers, channel partners and ABB to run trials with actual products, assemble robotics systems and conduct factory acceptance tests before delivery. This is envisioned to be an important boost to the further advancement of smart manufacturing in the region.

Singapore is one of the 25 countries identified by the World Economic Forum (WEF) to best benefit from the technologies of advanced manufacturing and smart factories. Given that manufacturing has been a key industry for the country, their National Research Foundation has identified Advanced Manufacturing and Engineering as one of its main domains in the Research Innovation Enterprise 2020 Plan. Eight key industry verticals have been identified for RIE 2020 – Aerospace, Electronics, Chemicals, Machinery & Systems, Marine & Offshore Precision Modules & Components, Biologics & Pharmaceutical Manufacturing, and Medical Technology Manufacturing.

The private sector also has efforts towards the Fourth Industrial Revolution to transform their internal processes. Infineon Technologies, a German semiconductor company is investing $105 million in their existing production site in Singapore to test their technologies and transform into a smart factory. The company expects to cut cycle times in half, increase productivity by 10 percent and save $1 million a year in energy costs through the initiative12. Start-ups have also been emerging in Singapore such as Nugit, a data-analysis platform in Singapore that raised $5.2 million in seed funding from venture-capital funds; Ebizu, a digital advertising facilitator in Malaysia that raised $3.0 million in Series A funding; and Apvera, a security and risk firm in Singapore that raised $1.2 million in venture-capital funding.

Hong Kong

In February 2016, Hong Kong launched a feasibility study on developing the district of Kowloon East into a Smart City. It aims to create a framework for smart city development in the district by identifying challenges, constraints, and opportunities within the district and developing strategies and priorities in response thereof.

The main components of the Smart City Framework for Kowloon East are Information and Communications Technology, Innovationoriented Platform, Mobility & Walkability, Resources Management & Urban Environment, and Governance & Socioeconomic Vibrancy (see diagram). The first two provide the necessary infrastructure and platform needed by the Smart City to enable seamless data sharing and open collaboration. Information and Communications Technology covers WiFi infrastructure, Internet of Things, Open Data, and a centralized digital infrastructure. The Innovation-oriented Platform serves to collect views from the public and collaborate with the academe and the industry. The last three components are the strategic aspects of the project, guiding programs on what specific problem they should aim to solve. Mobility & Walkability considers the efficiencies and sustainability of both the transport of vehicles and of people, including road traffic, pedestrian connectivity, and a green transport network. Resources Management & Urban Environment is comprised of a resource efficient & blue-green infrastructure, built environment, and a healthy and sustainable neighborhood. Governance & Socio-economic Vibrancy focuses on city resilience, implementation models, social inclusion, and asset management.

Figure 4. Kowloon East Smart City Framework
Source: Energizing Kowloon East Office

The study's main foundation is open collaboration and public engagement. Bearing in mind that smart city development is a public service in the first place, the project must be true to the needs of the people and should be able to find solutions to effectively and efficiently solve their problems. The study engaged in two public engagements as of February 2019, with both keen on generating public views and ideas for further development of the smart city proposal and its framework

Smart Factory Capability Build: Siemens and Swinburne

Swinburne University of Technology awards a Diploma of Applied Technologies to students finishing a 2-year program on essential digital professional and technical skills for Industry 4.0. Core subjects include smart product design and cyber physical system integration. The program has three options for specialization: Advanced Manufacturing, Building Information Modelling, and Cloud Technology. More importantly, the program includes a paid employment at Siemens.

More than the paid employment, Siemens contributed $135 Million to the University in order to digitalize the latter's Factory of the Future, which is Australia's first fully immersed facility for Industry 4.0. Siemens' automation technology and digitalization software and hardware have been actively used internationally in transforming the manufacturing sector, and having a guaranteed access to the same equipment used by global companies, students and researchers are able to hone their skills and realize their full potential in the advanced manufacturing space.

The TestLab highlights core technologies and has five studios focusing on the different aspects of smart manufacturing (see diagram). The 3-D Visualization and Design Studio makes use of advanced visualization tool that enable intuitive realtime interaction with realistic 3-D imagery. The Rapid Manufacturing Studio translates digital concepts to metal, plastic, or ceramic prototypes using additive manufacturing tools. The Advanced Inspection and Machining Studio combines machining capability and state-of-the-art inspection equipment to create high quality components.

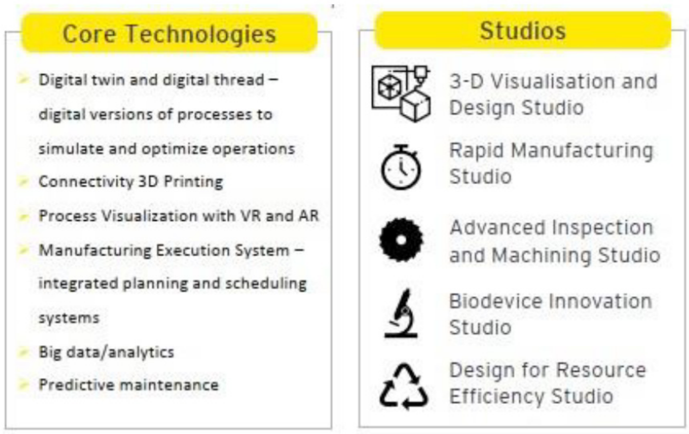


Figure 5. Swinburne Factory of the Future Features

The Biodevice Innovation Studio brings together electronics, optics, chemistry, and biomaterials-handling with rapid prototyping in the production of new medical devices. Finally, the Design for Resource Efficiency Studio focuses on the design, development, and assessment of recycling and manufacturing processes to make sure that resources are used efficiently. This engagement shows how far collaboration between academe and industry can go to develop and further capability building. In such an arrangement, not only do the academe get the training and development of its people and the industry ensures highly skilled future talent, but the entire nation also gains increased capability in participating in the emerging global innovation economy.

Current Local Capacity

The efforts of the Philippines towards the Fourth Industrial Revolution can be encapsulated in the Inclusive Innovation Industrial Strategy or the I3S. This initiative aims at growing innovative and globally competitive manufacturing, agriculture and services while strengthening their linkages into domestic and global value chains. The focus will be among 12 major industries namely automotive, electronics and electrical, aerospace parts, chemicals, iron and steel and tool and die, garments, textiles, and furniture, shipbuilding, tourism, IT-business process management particularly knowledge process outsourcing and E-commerce, agribusiness, construction, and infrastructure and logistics. In line with this are five major strategies in the I3S are:

- Building new industries, clusters and agglomeration
- Capacity building and human resource development
- Medium and Small to Medium Enterprise growth and development
- Innovation and Entrepreneurship
- Ease of doing business and investment environment

The readiness assessment by the WEF in 2018 already mentioned concluded that while the Philippines has a strong production base it suffers mainly in three areas that are crucial to drive growth for Industry 4.0. These are a weak institutional framework, lack of human capital and insufficient technology platforms.

This study highlights four sectors to benefit from Industry 4.0 which are aerospace, automotive, semiconductor and IT/BPO. These are also part of the main focus of I3S. The following discussion describes the existing value chain of these four sectors in the country.

Aerospace

The Philippines is a developing player in the global aerospace industry value chain. The country's industry has capabilities in manufacturing aerospace parts and offering Maintenance, Repair and Overhaul services (MRO). According to the Department of Trade and Industry of the Philippines (DTI), the domestic aerospace industry of the Philippines contributes approximately 0.15 percent of 2013 GDP. This percentage is projected to increase to 0.57 percent by 2022. The industry contributes to 2,200 in direct-employment in 2013, which generated an estimated $10mn as salaries for direct and allied workers in the Philippines.

The country is concentrated in the manufacturing and assembly of a small number of components and subassemblies in the interiors and flight control systems. Most firms sell directly into the primary manufacturing sector i.e. plane assembly. Most firms only carry out machining and finishing operations, with only one reported to conduct direct exports. Firms are located dispersedly across Export Processing Zones (EPZs) in Luzon, Baguio, Clark, Subic and the Batangas.

Automotive

The contribution of the Philippines in automotive manufacturing is mainly in wiring, electronic and aluminum components. Sample of these would be the ignition, chassis, electronics, drive trains, wheel and tire assemblies, vibration controls and front and rear end modules. Electronic components consist of semiconductors, starter, alternator, battery, electronic brake systems, interior electronics and sensor clusters. The country manufactures and assembles parts for common car brands.

Semiconductor

The country primarily contributes in the component part of the value chain. It accounts for 2.8% of global IC exports in 2014. The primary area is assembly and test activities for analog semiconductors and integrated circuits for electronic components. The biggest final product category is storage devices and office equipment and in electrical equipment, transformers and switchgear are the main products. This accounts for $7 billion with 55 firms. Integrated circuits in the component part of the value chain account for $12 billion with 51 firms present in the country.

Raw materials and supplies are imported and in 2017, this reached $23.331 billion16. This comprises 80% of companies' costs where imports are mainly coming from China, Hongkong, Japan, and Singapore. Power is also a high contributor of operational costs in the electronics industry. Electronics and water account for 2% of costs in the electronics industry, however electronics industry accounts for 18% of manufacturing costs in this category. There has been limited expansion in looking into the latest products in the industry.

Majority of the exports are in old technologies such as computer-related office equipment and hard disk drives instead of more innovative products such as smartphones and tablets which have recently been the faster growing markets17. The Philippines must participate in end markets in order to capture significant global share. Lastly, the country also faces competition from abroad. For instance, the country's labor costs are higher by 30-40% compared to Vietnam. Experts in the field such as engineers are moving abroad for higher wages and value adding activities.

BPO/IT

The service sector of the local IT industry is undeniably the largest sector. It is one of the largest contributors to the Philippine economy at 7% of GDP in 2017. With a forecasted P146bn in sales for 2019, the Philippines proves to be capable of consistently providing profitable IT services18. Among the Philippines' main services include outsourcing, data processing and cloud computing. Outsourcing, however, makes up for a bulk of the industry. BPO's, like Convergys, are considered to be a lower-end service on the value chain of the IT service industry. The software sector of the local IT industry is the smallest out of the three. With a forecasted P36bn in sales for 2019, the Philippines has not found success in this industry like that of its Asian neighbors. According to Fitch Solutions' Philippine IT report for 2019, these low figures are caused by the wide-ranging occurrence of piracy in the country. Multiple software developing startups, like Senti, have been surfacing in recent years and have led forecasters to predict an average annual growth rate of 18% for the next five years. The hardware sector is another driver of the local IT industry.

With a forecasted P101bn in sales for 2019, the hardware manufacturing industry is almost comparable to the service sector18. However, forecasters predict that the growth in the hardware sector will slow down to an annual average of 5.8% for the next five years. This is mainly caused by the shift of the tech market from personal computers to smartphones. As the Philippines largely manufactures PC parts, printers and copiers, and server equipment, the growing market for smartphones negatively affects the local hardware industry.

The Department of Science and Technology (DOST) has since been supportive of research and development projects that are in the smart city space. They recently launched a call for proposal entitled the Convergence of Philippine Technologies for Smarter City Development last June 2019, which chose the cities of Cauayan, Iloilo, and Butuan as its pilot cities of implementation. The call highlighted the importance of both the city's economic and industrial growth and the enthusiasm and support of the local government in ushering innovation in order to actualize the city's potential to be a smart city, and serve as a good model to other cities in the country.

The program outline follows a common approach for smart cities, putting value in collaboration, transferability, and integration. Collaborations between the researchers, government through PCIEERD, and the LGUs can advance concepts and generate ideas that can help the city move forward faster.

When technologies are developed in a way that is standardized and can be easily shared, they can be replicable to other cities which also need the same things with less investments in time, money, and effort. Lastly, the project can also make use of the existing technologies that both the DOST and the LGU already use to identify the priority sectors for a specific city, as every city possesses different strengths and capabilities that it can capitalize on for it to progress. Below is a visualization of the process at work:

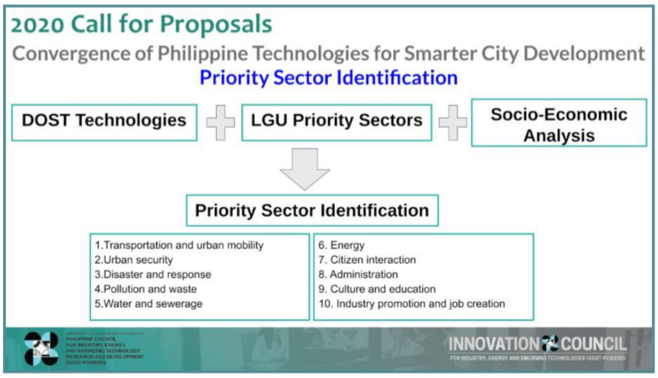
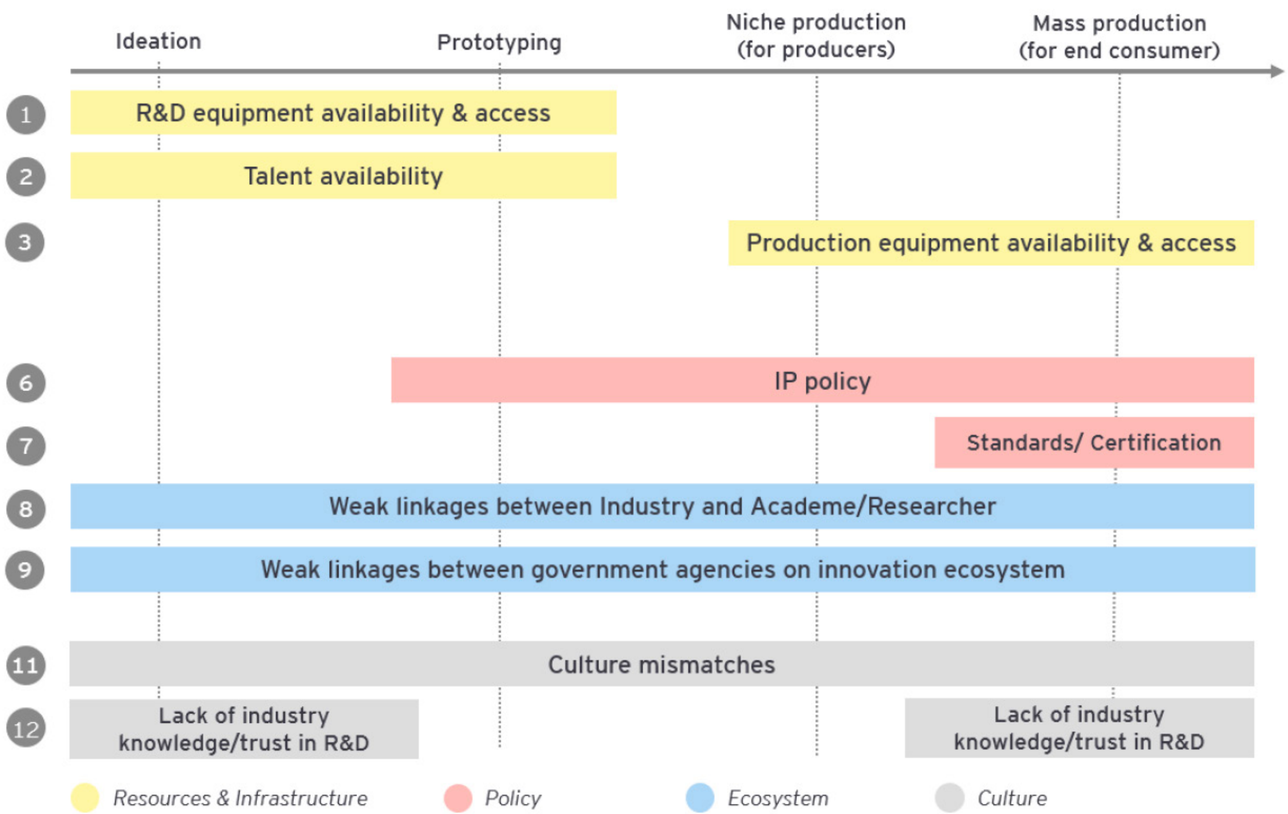


Figure 6. DOST Call for Proposal for Smarter City Development Framework for Priority Identification
Source: DOST PCIEERD

Although a number of proposals were received in this call, the collaboration factor remained to be low, as relevant parties still experienced difficulty connecting the different stakeholders and converging their efforts into a single project.

Barriers to Development



The above have been identified as challenges in the development of Industry 4.0 in the country. The figure outlines the challenges according to the specific phase in research and development where they are observed to be found, and according to their nature as either resource and infrastructure, policy, ecosystem, or culture.

Resources & Infrastructure

R&D equipment availability & access: Especially important in the early stages of development, the inadequate access and availability to R&D equipment limits the capability of researchers to easily proceed with their work. For Industry 4.0, the limited access to prototyping equipment for certain types of manufacturing, including but not limited to electronics & semiconductors, hinder the potential for innovation.

The equipment necessary for R&D in some fields is either unavailable in the Philippines, prohibitively expensive, or of subpar quality compared to what can be ordered from China, Taiwan, or Thailand. As such, researchers prefer to take the latter route for their purposes, resulting in significant lead time in conducting experiments, and also forgoing exposure and experience in that aspect of production.

Talent availability: There is limited talent capability on the side of both the academe and industry in tackling Industry 4.0 in a way that can benefit them both. On the academe side, there is a lack of industry involvement in the training of students for advanced manufacturing techniques and concepts On the industry side, there is not enough exposure to and trust in smart manufacturing and capturing the technologies thereof to easily implement in their factories.

Production equipment availability & access: A feat as big as transitioning to smart technologies is a challenge especially for SMEs who lack the capability for small-scale fabrication. They do not have the facilities to adopt the technologies developed. As for bigger companies, the limitation is on access to small-scale production equipment that will allow them to test the new tools while maintaining their normal production.

Policy

IP Policy: Technology development with the goal of smart manufacturing requires a credible intellectual property policy that can govern all stakeholders involved. On the one end, researchers are not knowledgeable enough about business and law so are afraid of being taken advantage of by industry. On the other end, industry wants as much control and monetization rights over technology rights as possible, so there are many stages of negotiation. The tedious process for compliance discourages collaboration and hampers the potential for innovation. Standards/Certification: This is one of the main points of concern for the advancement of Industry 4.0 in the country. Users and mass producers are apprehensive about adopting new technology without safety standards/certification that give some assurance that the population and potential users are not at risk. Moreover, in a connected world, the misuse of data is a high degree of concern that hinders further research and development into Industry 4.0 and its potential value to the society.

Ecosystem

Weak linkages between Industry and Academe/Researcher: Currently, collaborations between academe and industry only arise from informal channels such as personal networks, chance meetings during conferences, and the like. There is no direct connection between the stakeholders where each can rely on if ever they need support from the other. Moreover, the secrecy of processes happening in the industry makes collaboration difficult. R&D and skill development are performed independent of industry input, so there is low adoption and skill mismatch. Weak linkages between government agencies on innovation ecosystem: Although there is clear support coming from the government for innovation, there is no active channel to the research and industry ecosystem for the latter to gain tangible support for their needs. There isn’t enough collaboration between different government agencies for R&D and innovation needs of researchers and private/public adopters. The innovation ecosystem needs to have a system they can rely on for their R&D needs (e.g. funding, connections, etc.)

Culture

Culture mismatches: The difference in cultures of the industry players and those from the academe make it difficult for both parties to converge on agreement. Leading on different needs and timelines, it is difficult for both parties to compromise and find a common ground. Lack of industry knowledge/trust in R&D: There is lack of awareness on the side of industry on the benefits of the technologies that are being developed by the researchers. This lack of awareness stems toward their apprehensiveness and hesitation to eventually adopt and/or invest in these technologies since they have limited knowledge on their potential and whether they have been tried and tested. With these barriers and without a strong and encouraging force to push the efforts of the Philippines towards Industry 4.0, the country still has a long way to go in terms of actually implementing and realizing the value from it. However, the hope remains that with enough people envisioning a smarter Philippines, in whatever form, the journey to it may be difficult, but definitely not impossible.

Strategy

Among the many barriers discussed above, the most crippling in the context of Industry 4.0 adoption is the weak linkage between Industry, Academe, and Researcher. One of the central tenets of Industry 4.0 being convergence, the biggest hurdle that must be addressed in order to further innovation is the invisible walls between these stakeholders.

The main thrust for the strategy for Industry 4.0 is convergence – of technologies, of initiatives, and of people. A lot of technologies each have the potential to transform how things work in the industry, but it is only through convergence of such that we can fully realize the gains from smarter infrastructure. Similar to the importance of collaborations between people, technologies must also be adaptable enough to integrate with each other and make advanced manufacturing possible.

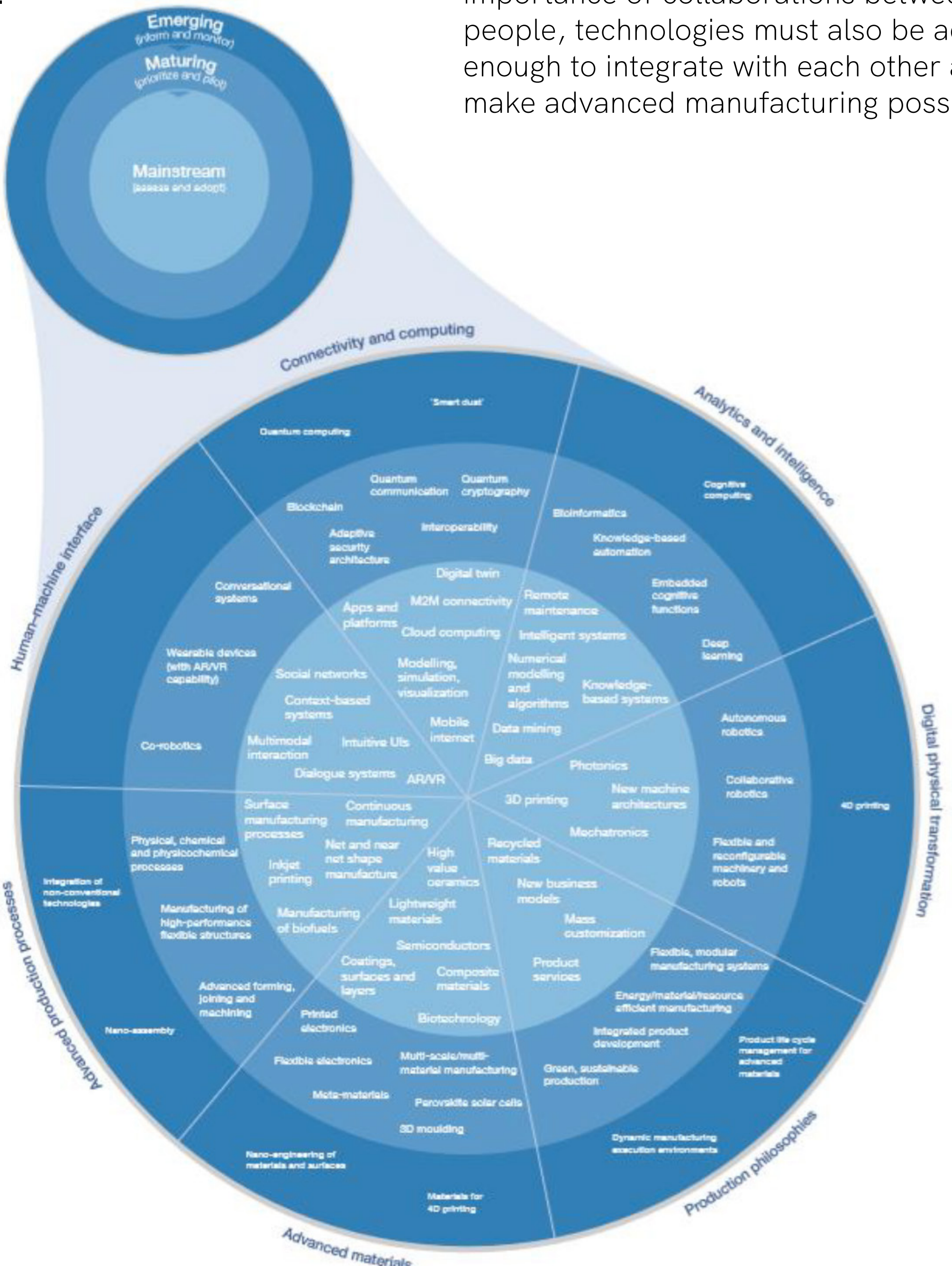


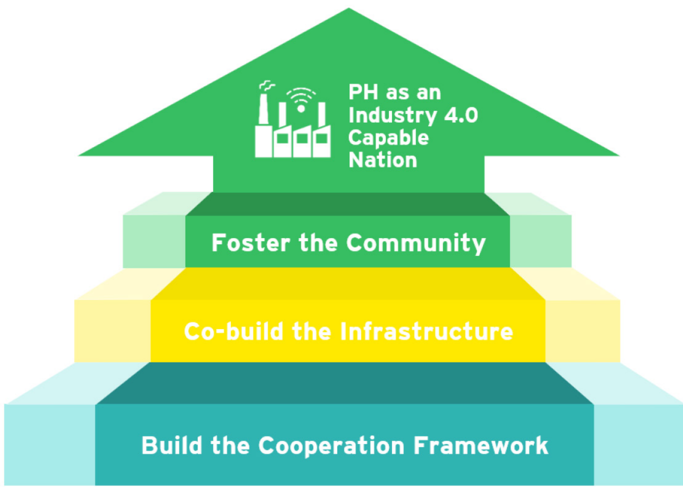
Figure 7. Technology Radar of Global Production Systems
Source: World Economic Forum

The diagram above provides a visualization of the many technologies involved in global production systems, organized in terms of maturity: emerging, maturing, and mainstream. As we can see, most of the technologies are already mainstream and beyond research, with fewer technologies on the emerging and maturing spaces. This means that as Industry 4.0 technologies have become widely practiced in many areas of the world, they have since evolved from basic research into something that is usable and commercializable in the factories. The connections between these technologies also show that the strategy towards advanced manufacturing does not necessarily involve creating new things, but rather putting existing research and development together to make things possible and more efficient.

Our strategy highlights three main Industry 4.0 principles: Connectivity, Interoperability, and Convergence. These are discussed as follows:

- Connectivity: Separate and disjoined units of technologies and processes should be able to establish connections between one another (e.g. the outputs of one are the inputs of another). An important feature to be achieved is the interconnectivity of technologies supporting the smart factory infrastructure. Different technologies would play into the system, each with different functionalities that satisfy certain needs, and it is only when these would be integrated with each other that the full potential of the smart factory can be realized.
- Interoperability: The smart manufacturing system should be able to allow both human and smart factories to communicate with each other easily. Disparate policies should be resolved through a common standard that will govern all communication and allow different stakeholders to achieve mutual understanding.
- Convergence: The ubiquity of data will break down preexisting barriers between the stakeholders and their own processes. This will allow the convergence of different industries, disciplines, and people into the common goal of digitalizing traditional methods in a way that will be favorable to all.

However, for collaboration to be actualized and realize its full potential, the proper foundations must be laid down to ensure that subsequent engagements will be conducted in an organized and integrated manner. Our proposed strategy focuses on building these foundations and addressing the barriers identified in the previous section to create a flourishing innovation ecosystem for Industry 4.0 in the country.



Build the Cooperation Framework

In an industrial ecosystem that is interdisciplinary in nature, the need for a common language among all stakeholders involved in Industry 4.0 is vital in facilitating seamless communication and understanding. This is the first step in the strategy in becoming an Industry 4.0 - capable nation. Scaling up the benefits of Industry 4.0 involves applying the innovations and best practices in one type of manufacturing to another. However, since industries and the processes they operate within each are naturally different, it will be difficult to diffuse innovation widely if each does not understand what the other can do and offer. There needs to be a consistent and credible set of definitions and standards to govern the data, technologies, and relationships in the ecosystem in order to build trust and foster innovation.

The RAMI 4.0, with its purpose of classifying unique products into standard categories, fills this need for a standardized approach to Industry 4.0 (*see diagram on the right for reference)*. Aside from its place of creation in Germany, the standard has also been used in many other countries all over the world, including Italy, Japan, USA, and China. The existence of common standards for everycompany, industry, and country to follow means that techniques, processes, and products can be transferred seamlessly to speed up innovation. It also provides a sense of security that parties follow the same set of standards in designing, producing, and evaluating processes.

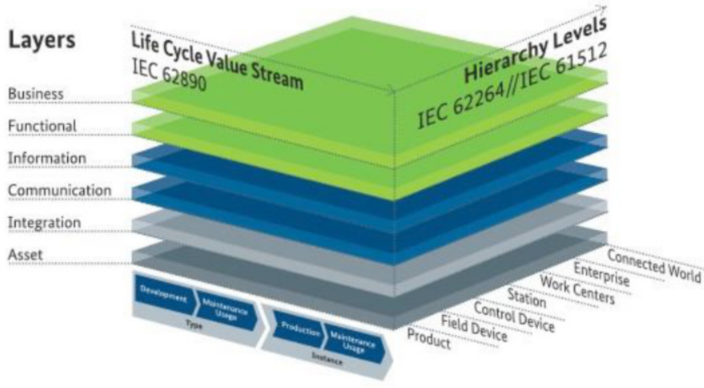


Figure 7. RAMI 4.0 Framework
Source: Platform Industrie 4.0

Applying the RAMI 4.0 in the local setting is a good starting point for addressing the issues present in academe-industry collaborations for advanced manufacturing - regulatory guidance, stakeholder cooperation, and capacity building.

Regulatory Guidance

With the development of localized RAMI 4.0 standards, researchers and industry players will have a single point of reference that they can rely on and refer to when working on complex advanced manufacturing endeavors. The further creation and implementation of localized standards and regulations will be easier if the individual components for each relevant party are properly identified through the common lens provided by RAMI framework, as well as other international frameworks under development or promulgation.

Having R&D and industry experience, DOST will take an active role in helping create the localized standards for the Philippines. The Agency should assist and support the players of the innovation ecosystem in the academe and the industry in the classification of the elements of their research and their business processes into the discrete units outlined in the RAMI framework.

The localized standards will provide more structure to the oversight done by different regulatory agencies which monitor and assess the performance of the stakeholders involved herein. This includes the Department of Science and Technology, Department of Trade and Industry, Securities and Exchange Commission, and other agencies or industry associations. With this, these groups will have a guide in their assessments which will make them understand and assess their stakeholders better.

Being able to organize their perspective into understandable units will also improve governance of the companies in their respective businesses. When you know what you are governing and can visualize this in a straightforward context, oversight becomes easier.

Stakeholder Cooperation

Once both the academe and the industry understand the elements of their work in the context of the RAMI units, it will be easier for everyone to understand the general elements of their peers when put in the same context. Having a common language is one of the keys for successful collaboration.

For R&D

Researchers can study the identifiable units of the RAMI framework in order to understand not just the capability that each stakeholder possesses, but more importantly the element/s (if any) that each needs. As the RAMI breaks down complex processes into easily understandable packages, researchers can view manufacturing processes not in terms of the totality, which can overshadow important features, but in terms of each process' elements. This allows the neutral parties to easily pinpoint the capability and need of each stakeholder and be able to connect one party to another based on this assessment.

For Industry

The use of this common standard will enable interoperability between the companies. Being able to view their peers through a standard framework like RAMI gives players in different fields a frame for comparison, allowing each to check for compatibility with their own systems, fostering cooperation if appropriate. Given an organized perspective on complex processes, companies are given more options to mix and match based on what they need and what other companies have.

For example, if Company A identified a desired process improvement in the production part of the life cycle *(first dimension)*, in the layer of integration *(second dimension)*, and classified as part of the work center *(third dimension)*, Company A can easily communicate this need to stakeholders from unrelated industries who may have expertise on it. On the other end, Company B who possesses expertise in the same area plotted in the RAMI framework can connect with Company A who needs Company B's expertise. If it were not for the framework, Company A might not have reached out to other companies and may not have communicated its need in a clear and understandable manner. Limited by the culture of secrecy of business processes, both companies might even be hesitant in sharing their resources if the processes are not seen from the lens of a standardized Industry 4.0 framework. This process can also be visualized in the same way for researchers-industry collaborations.

Capacity Building

Viewing the elements based on their placement on the map and with respect to the whole, it will be easier to identify the gaps, understand them, and fill them in appropriately. This is especially helpful for talent and capability gaps.

In the same way that DOST should be able to identify the needs of the companies in terms of their business processes, they will be able to do the same in terms of the need for capability building. Armed with better understanding of the needs, the upskilling of existing talent and the acquisition of new ones will be easier and more systematic. A clear standard that defines such needs eliminates subjectivity and will allow for impartial evaluations and clearer directions for capacity building.

This increased capability to identify the demand for skill and talent will also benefit researchers and educational institutions in crafting and adjusting their plans and strategies to fulfill the demand characterized. Once the demand is set and structured according to the components of the RAMI 4.0 framework, schools can respond to them accordingly and in a more specific way. This facilitates better matching of demand and supply between industry and academe.

Even with the straightforward nature of the RAMI 4.0 framework, localizing implementation in the Philippines will be challenging. First and foremost, unifying different stakeholders who come from different contexts will require a rigorous study of the framework and how its dimensions will apply to the stakeholders' backgrounds. DOST must have the ability to bridge the thinking across different industries, with the scientific considerations that may apply in each area.

The logistics of sharing the framework and its implementation guidelines should be properly conducted. The government should be able to communicate the policies to everyone concerned and make it clear that the policies should be the standard to be followed. It is also important to seek the assistance of RAMI 4.0 experts from Germany to ensure clear understanding and communication thereof.

The existence and local application of the RAMI 4.0 framework to the Philippines will serve to align the varying perspectives and disciplines into common and understandable units, as well as reduce the possibility for misinterpretations. Through the framework, even completely different players can find common ground for collaboration once the elements of their work are visualized in distinct units. This will benefit domestic projects, but also open the doors for international collaboration with stakeholders where the framework has already been adopted.

As these standards are in support of the country's I3S strategy, the collaboration of DOST and DTI is warranted. DTI's responsibility will be in coordinating for inputs from, and supporting the framework adoption by, Industry. DOST's responsibility will be in dissecting the framework from an R&D lens, applying its concepts and schema on the direction laid out for local R&D and capability building.

Digital Twin Technology

One of the most powerful technologies used in the manufacturing sectors is digital twin technology. By having an identical digital version of processes and equipment, one can do whatever they want with it without having to worry about possible repercussions if simulations were made in the physical world.

This technology makes the following possible with substantially less difficulty:

Monitoring: Having a digital twin will allow multiple people to monitor the subject remotely. By having a digital version that people can easily access through their computers, monitoring is possible even without the need for investments in effort and resources to physically go to manufacturing plants.

Prototyping: Simulations cannot be easily done on physical subjects due to the risk of failure especially on high-value investments. However, with a digital twin, new components, tools, or techniques can be created and tested within the virtual version first where there is no tangible area to be affected. Having this safe space for growth and innovation will help companies develop new opportunities and enhance planning for the future.

Repair and Maintenance: Digital twins of physical components can be subjected to computer simulations to predict problems and anticipate catastrophic failures based on actual daily performance. This will allow companies to take immediate corrective action or provision for maintenance. Another common problem experienced by manufacturers, especially the traditional ones, is the discontinuation of production of necessary parts for their equipment. They usually complain about the part no longer being produced or they couldn't find other manufacturers who produce the same part that they use for their business processes. With a digital version in place, the ability to service the needs of the company can be distributed across a broader network.

Sharing: The nature of the digital twin allows it to be easily shared and accessed by authorized individuals, fostering alignment and fruitful collaborations with the people companies want to reach.

Implementing the use of digital twin technology in the local manufacturing landscape broadens the opportunities available to Filipino manufacturers by allowing them to monitor, control, and simulate their processes and equipment without having to worry about physical and financial repercussions.

Co-build the Infrastructure

Some of the key enabling technologies of the Fourth Industrial revolution are big data, robotics and Industrial Internet of Things (IoT). In the field of artificial intelligence, companies such as Wave Computing already exist to develop technologies related to this field in order to help various institutions in the Philippines. However, the most recent Asia Pacific AI readiness Index showed that the Philippines ranked 6th out of 7 countries within ASEAN, noting that AI development is still fragmented and uneven in the country. To adopt the Industrial Internet of Things and Big Data technology, a strong telecommunications base is critical. In this area the Philippines ranked 99th and 88th worldwide in terms of mobile and fixed broadband internet speed, respectively. Its average speed is only at around 8Mbps. One of the roots of this issue is the lack of government support in this area as most support for the telecommunications industry is from the private sector. Public funding support for strong infrastructure is a necessity to push forth Industry 4.0 in the country.

The move to the transformation of local manufacturing into smarter and more advanced processes is difficult in the country. The risk of possibly low returns after a huge investment makes businesses hesitant to invest resources into making their factories smart, thus forcing them to play safe amidst the opportunities of growth and expansion. This particular need of a safe space where they can test prototypes and pilot innovative production practices is one of the things that innovation facilities are intended to solve.

There is already a network of innovation centers located in every region of the Philippines, but these have varying levels of experience and have different expertise, and therefore are not standardized. With the standards and regulations in place from the previous section, existing innovation labs can locate themselves on the map and improve where needed. New laboratories can also be set up if the need arises.

These innovation facilities would function as operating sandbox environments for technologies developed that apply the concepts of Internet of Things, Artificial Intelligence, Robotics, and the like. They will also house prototyping equipment for use by the researchers and industries for the mean time that users cannot afford their own equipment due to the high investment required. The objectives of the facility are focused on three key areas, namely, Flexibility, Interconnectivity, and Quality & Safety.

Flexibility

The usual production setup for companies is catered for bulk production sizes, simply because this is more practical and would allow for more time and cost savings. One of the things hindering companies from trying out new products and technologies to integrate in their processes is the risk of possible losses from testing. The innovation facility aims to address this issue and make "Batch Size 1" possible. Batch Size 1 is a concept in smart manufacturing where machines become adaptable depending on product specifications made by either the company or the customer. More than supporting testing, it would encourage businesses to be more innovative without having to sacrifice significant investments in the new processes that they want to try.

Interconnectivity

An important feature to be achieved for this facility is the interconnectivity of technologies supporting the smart factory infrastructure. Different technologies would play into thesystem, each with different functionalities that satisfy certain needs, and it is only when these would be integrated with each other that the full potential of the smart factory can be realized. To visualize, the concept of Just-in-Time manufacturing is not possible without all production aspects knowing and understanding the complexities of each aspect. Production must be aware of what and when orders come into the system in order for it to accurately predict when it should begin production and vice versa.

Quality & Safety

One of the main objectives of this facility is the improvement of production quality and safety. With greater computer support and less human intervention on the processes, there is less probability for human errors to take place and affect production cycles. This will improve the quality of products being developed and allow for fewer mishaps and wastage in production.

This project will begin with the acquisition of commercially available smart factory technologies that have already been proven effective in use. The equipment and components within are those certain to work based on previous use cases. These will be aggregated in a pilot facility that would function as a hub for testing of production runs using the smart equipment acquired. The facility will also function as a testing ground and benchmark for the technologies of DOST that have been and will be developed in connection with the smart factory for their further development and improvement.

There is a need to ensure that DOST and researchers are able to observe the construction of this pilot facility by the private entities, so that the knowhow and experience gained can be applied in future iterations to be constructed, which may utilize not just commercially-developed technology, but also DOST-developed innovations.

Collaboration is a strong and important input to this project. It is envisioned to be a platform for the academe, industry, and government to explore on innovation and gain insights from other players. This facility would function as a safe space for both the academe and companies alike who would want to expand their learning and test the effectivity of their prototypes with less monetary investments and risk of processing wastes. Through this, members of the academe will have a testbed for research and development of other evolving technologies. Private companies and emerging entrepreneurs can rent the facility as a pilot location for their novel procedures and new product lines, with the ultimate goal of being able to develop their own smart factories in their own businesses.

Moreover, the government will not just be providing financial support to the facility, but it will also be utilizing it in the creation of standards to provide guidance and limitations in tech development and testing. This will be the main avenue for government to test the technologies for compliance to international standards, including relevant safety and quality regulations imposed by organizations such as the International Organization for Standardization (ISO) and the like. Not only will the technologies be regulated, but this would also be a means for government to monitor and keep track of whether the technologies nurtured in the facility is at par with its counterparts in the global landscape.

Foster the Community

Aligning with the strategy for Artificial Intelligence and Information Communications Technology, the strategy for building the community for the Convergence of Emerging Technologies for Industry 4.0 is focused on the creation of mission-driven programs. These programs will serve as long-term channels to sustainably develop capability for smart manufacturing all throughout the country. Unlike DOST projects that have relatively short durations, these will not have specifically identified durationsas these should evolve together with changing circumstances in both the industries and society in general.

Each mission can only be accomplished through collaboration between the adopter (Industry or Government), the researchers, and academe.

The **adopter** will provide the context for the research and refinement for eventual use, as well as partial funding and other resources, as they will eventually be the beneficiary of the research and development. This is mostly expected to be Industry, as smart manufacturing mainly aims to cater to the industrial economy. However, Government itself can also be a consumer of Industry 4.0 technologies for programs involving public service delivery and smart city development.

The **researchers** will inject the knowhow and will facilitate the development to the adopter's specifications.

The **academe** will provide the manpower and retain the knowledge gained for use and dissemination in other projects.

These programs will be serve as important support in driving the development of Industry 4.0 in the Philippines with applied and basic research on Industry 4.0 aligned to the respective missions of the programs. For each mission, infrastructure, talent, and partnerships will be established to see the project through to a defined outcome. The resources for each project can be centralized into the different innovation facilities discussed in the previous section that is dedicated for the accomplishment of the mission. As these facilities are established in different parts of the country in different educational institutions most suited to the purpose, it is ensured that talent development isspread throughout the Philippines.

Mission programs can be established for key industries such as ICT/Semicon and Aerospace, as well as Government Service Delivery and Smart City Development. Although Government Service Delivery and Smart City Development are not manufacturing-oriented, the Industry 4.0 principles make a good foundation for developments in these areas.

Business Cases

I. TestLabs and FabLabs Collaborations

To facilitate the development of Industry 4.0, TestLabs should be developed as a common platform for academe, research, and industry to develop and test products and processes. This will allow greater involvement and collaboration between the different sectors.

It is worth noting that there are similar facilities that currently exist - Fabrication Laboratories (FabLabs) are operated and funded by DOST and DTI. These FabLabs are equipped with Industry 4.0 level technologies such as 3D printers that allow individuals and smaller companies to develop and test innovations. However, researchers want greater and more consistent access, more advanced equipment, and more open collaboration than what is currently the norm at the FabLabs.

The TestLabs and upgraded FabLabs will grant researchers more access to test and experiment with new technologies and products, students and academic the chance to experience 4.0 technologies and equipment and allow industries to showcase their technologies, prototype newer ones, and produce small batches for commercial distribution just to get their business started.

High-Tech Industry

Existing large manufacturing and technology companies such as Beta Nanocoating, Texas Instruments, and TMX have expressed interest in hosting TestLabs within their facilities, provided that the government is willing to help fund and provide the necessary technologies. These companies will also form partnerships with universities and apprenticeships which will allow students to undergo hands-on training in 4.0 technologies in the TestLabs, achieve the necessary level of exposure and job readiness, and find employment with partner industries. An example of this is the partnership between Siemens and Swinburne University in the development of a Testlab and a 2-year apprenticeship degree.

To put private industry R&D into context, we can look into a large national enterprise such as IMI in the semiconductor industry. Cumulatively, IMI spent PHP 855 million for R&D in 2017-2019. This internal investment made by IMI represents the value the company is willing to put into innovation as long as there is a direct benefit to their portfolio. Public investments made by DOSTPCIEERD for advanced materials included some that could have benefited SME electronics and semiconductor companies. These grants for advanced materials and nanotechnology amounted to nearly PHP 1.9 billion from 2011 to 2019. Such a partnership would be highly beneficial in terms of tech adoption, training, and long-term synergies created. DOST could be the early stage investor in many projects, while IMI can be the late stage investor in the strategic partnership.

Food Industry

Big players in the local scene like Jollibee and IMI spend a considerable amount of investment on research and development. Jollibee spends around 2% of its annual revenue on R&D. Although Jollibee uses large suppliers for sourcing its ingredients, it started a program for direct sourcing from farmers. The program is named Farmer Entrepreneurship Program (FEP). Under the program, Jollibee sources ingredients for its menu items directly from farmers in Ilocos Sur, Nueva Ecija, Quezon and Pangasinan. FEP is supported by National Livelihood Development Corporation, a government financing agency. This is an example of large corporations beingwilling participants in applied R&D, and having a large network of SMEs in their value chain who can be tapped as part of the innovation and adoption ecosystem. Large corporations on their own may be wary of adopting R&D, and SMEs on their own are the same, but a large ecosystem will have more room for seizing opportunities in applied R&D.

In these cases, it is worth noting that big companies see the value to research and development. The big players have their own R&D departments and controlled by its head office and key offices. As of this time, the Philippines is not an R&D hub for these big players. Hence, a Filipino owned large company is the best option for long term strategic partnership for R&D and industry development. Looking through the industry value chains, a strategic partnership can be formed to maximize the probability of success of the public investments on R&D. Both large corporates and the government funding agencies can work together to serve the SMEs and further the entire innovation landscape in the country.

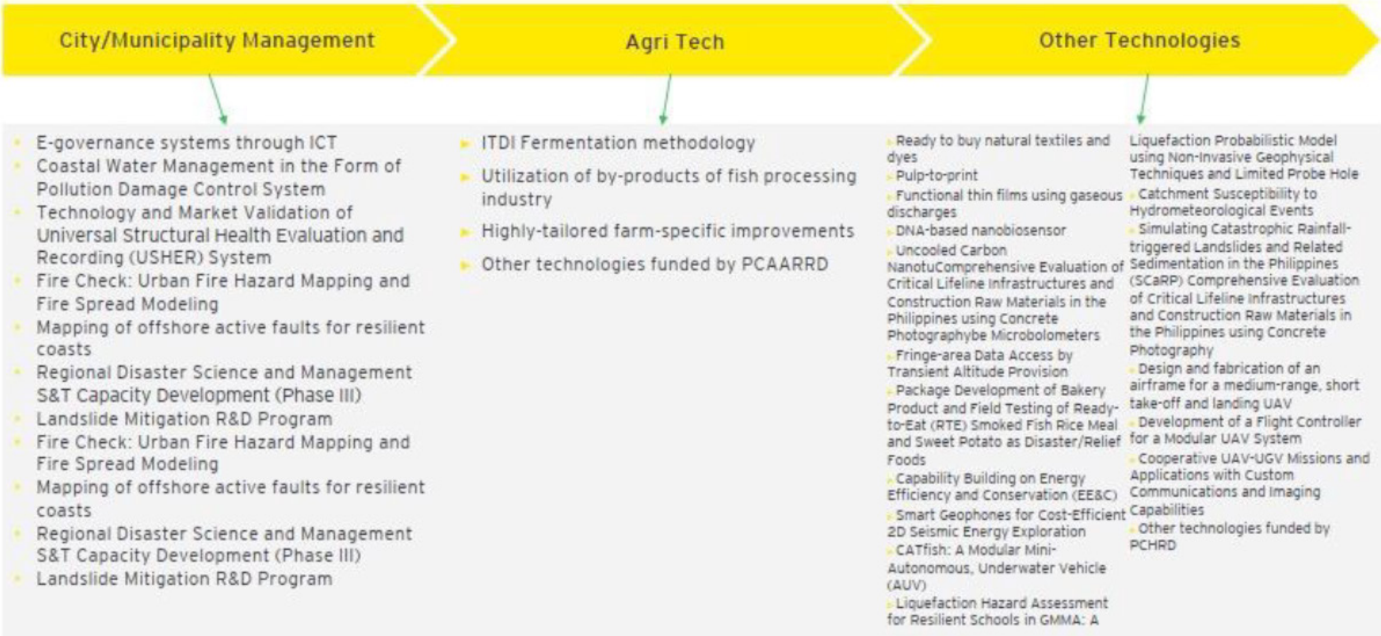
In the development of these facilities and these partnerships, it is important not to repeat the mistakes of those shared that came before it (e.g. ADMATEL, EPDC), which fell short of serving as a platform for achieving true synergy between industry, research, and academe, and managed to become more of a service facility only for one or two of these. There is an element of cultural shift necessary to achieve productive synergy and realize maximum returns from the collaboration of different sectors, and these shared spaces can be designed to influence that from the beginning. Already, we have seen companies willing to exchange between non-competitors, ideas on I4.0 best practices they have adopted in their factories. Formal and informal associations can be built around these TestLabs and FabLabs to realize more returns from shared and collaborative development.

II. Smart Cities

Globally, the concept of smart cities has been widely associated with the latest advanced technologies – autonomous vehicles, self-sustaining households, and the maximization of renewable energy utilization. However, this definition, though it seems ideal, does not entirely capture the essential idea of a smart city, and cannot be necessarily applied to any city uniformly. This is why there is a need to further refine and in this case, redefine, what it means to be a smart city. Putting the Philippines in context, every city possesses different strengths and capabilities that it can capitalize on in order to progress; and with this comes varying levels of readiness of the city infrastructure and its people to support development. The issues including electricity shortage, high electricity costs, and lack of basic infrastructure hinder PH cities from efficiency of everyday decisions.

However, irrespective of these differences, each city must first ensure the following aspects that are crucial for future and much bigger improvements: mobility of its individuals, basic waste management, and the availability of open public spaces. Localizing smart city development is an opportunity for DOST to use the technologies developed under its supervision in supporting the initiatives for smart cities in the country. Using the database of research and development conducted over the years in different sectors like agriculture, health, or emerging technologies, the Agency can match these technologies to address the needs of each LGU. An example is shown in the diagram below:

The Department of Science and Technology have also had multiple efforts in the fields of data science and processing through the Advanced Science and Technology Institute (ASTI). From our working sessions with the team, we have identified some satellite data application prototypes that can directly be applied to the key aspects of City Development: Land Use Mapping, Sustainability & Resilience, and Property Valuation. It is worth noting that the technologies identified for city development in this section follow the same principles for advanced manufacturing; the relationship thereof to be further discussed in each of the succeeding sections.



Land Use Mapping

ASTI Prototypes: Using Night Lights for Disaster Impact Assessments, Road Network Identification using AI

As a primary aspect of the city development strategy, land use mapping must not only be able to identify locations per their ideal usage, but also do it in an efficient way. ASTI's geospatial techniques on nightlights and road networks provide a good support for this purpose. As a visualization, the data on nightlights can identify which areas are bustling with economic activity during the day, and which in turn serve as the residence of people during nighttime. By then, you would already have information as to particular areas of activity that can be used in city planning.

The identification of road networks will also be crucial in the classification of lands according to usage. By having satellite information on the network of roads surrounding plots of land, the mobility of both cargo and individuals can be easily assessed and deducted. Furthermore, the development of farm-to-market roads as well as arterial & main roads can be planned and executed better with data coming from the road network identification, which further ensures the connectivity of people to products and basic services.

Combining these information, particular areas for commercial or residential development are distinguished and consequent planning & review of transport infrastructure can be done effectively.

The ability to collect and analyze these kinds of data and be able to derive insights from it in realtime will allow decisions to be decentralized and curated according to the resources and capabilities of the area.

These principles will also be essential in the context of advancing manufacturing capability, where all sorts of data on production statistics and operational circumstances can provide strong foundation to upgrading the traditional manufacturing process.

Sustainability & Resilience

ASTI Prototypes: Flood Mapping using AI, Heat Indexation

One of the key concepts behind a smart city is sustainability. ASTI's technologies on flood mapping and heat indexation can identify areas that are prone to flood and where heat is more intense compared to other areas. With these information, infrastructure placements can be planned and physical limits/flood control mechanisms can be put in place where they are needed.
These are crucial to ensure that life will not be endangered and economic activity will still continue even in the onset of flood or other natural causes.

Natural and man-made hazards like flood, fire, or drought are not strangers to manufacturers. These are things that companies consistently monitor and aim to prevent before they actually happen. Technologies that can identify high-risk areas are extremely helpful to businesses as these increase their chances of mitigating the risk. This will require interoperability between the cyber and physical systems, where the technologies will monitor, assess, and communicate the results to the people who are in charge of preparing their companies in case of unforeseen and unfortunate circumstances.

Virtualization of the physical factories also enhances sustainability and resilience of the companies as the technology will provide them with strong decision support in crafting business continuity plans through simulations.

Property Valuation

ASTI Prototypes: Object Classification and Detection (useful for resettlements, complements real estate property valuation)

The prime source of local government revenue is the collection of real property taxes. The successful collection of real property taxes rests upon an effective valuation of real estate properties. Lands and properties must be accurately identified to avoid potential lost revenue resulting from misclassifications. Combining with the output coming from land use mapping, technologies on object classification and detection will be useful in improving the accuracy of real estate valuation.

Being able to detect, identify, and classify objects through the use of smart technology enables the modularization of a complex process. Organizing business processes into manageable modules allows a company to be adaptable to changing circumstances by adjusting affected individual modules to suit the current situation.

Moreover, this object identification will pave the way for parts and components to be specifically designed and customized based on the needs of
each customer, giving the customer more power in the design process.

These three essentially comprise the strategy for city development. Although primarily referring to smart city development, the technologies used to further each aspect when envisioned in the context of the principles of Industry 4.0 places them in the same lens. The flexibility of smart technologies to be applied and adapted by different stakeholders, no matter the difference innature, ensures the sustainability and continuous improvement of not just the technologies themselves, but the stakeholders using them.

Other Roles

Industry and LGUs

Large companies need to be open to tapping the potential that academe and researchers have, even outside their own company. In order to take advantage of the opportunities academe and researchers can provide in terms of talent and innovation, companies need to dialogue with them, allow some level of access and exposure to their operations, and where feasible, share facilities with those who can improve on them. A common observation by those in academe and research about industry is that they are so apprehensive about collaborating because of the risk of opening up to the competition. However, if safeguards are put in place, the benefits of collaboration may still outweigh the risks. SMEs also have a role to play, as their agility and flexibility allow for emerging innovations to be more easily integrated into their operations.

Lastly, LGU participation will be invaluable in furthering use cases in Smart Cities, which will help disseminate and laymanize the principles of Industry 4.0 through a government adopter, with whom collaborations with DOST, academe, and researchers may be less complicated to obtain.

Academe (Business)

In order to cultivate a stronger SME and startup culture for more rapid innovation in industry, there is a need to introduce the concepts of startup development, especially in business schools. While the researchers have frequently cited their difficulty in transitioning from research into the rigors of business development, some also suggested that they would benefit greatly from assistance from those in the business track.

Department of Trade and Industry (DTI)

Because this approach aims to involve the industry at a larger scale, the DTI must play an active role in managing relationships with the industry – from large corporates to SMEs.

DTI's responsibility in the development of Industry 4.0 standards such as RAMI 4.0 will be in coordinating for inputs from, and supporting the framework adoption by, Industry. DTI will also primarily assist in industry policy formulations and provision of support services for industry players who want to connect to the innovation landscape. DTI and DOST must maintain a close relationship to cultivate an R&D culture in Philippine industry.

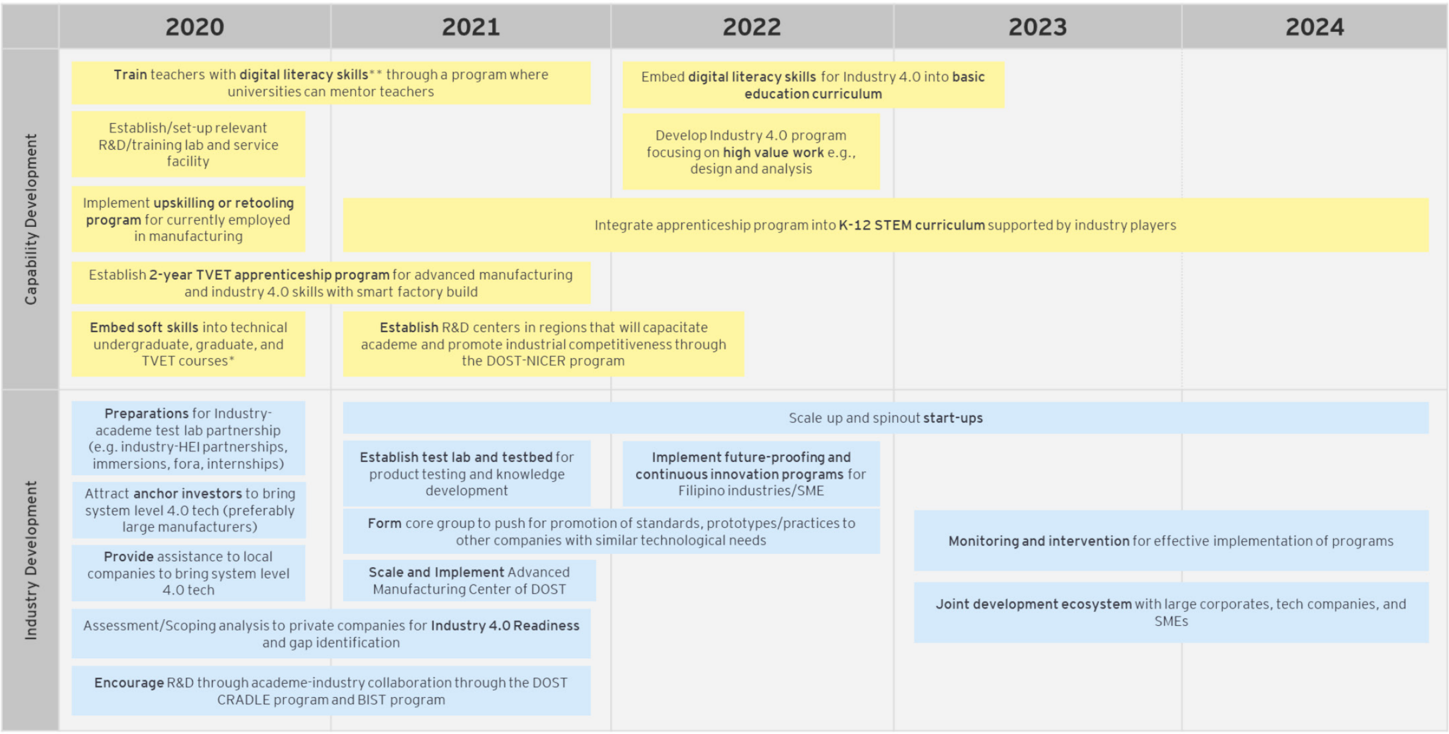
Moreover, DTI will be instrumental in building up the middle-of-the-value chain manufacturing ecosystem that is the gap between researchers' bench-scale production and large corporates' mass production. They must establish facilities and implement the programs according to the recommendations above.

Department of Finance (DOF)

To encourage companies to engage in innovative endeavors, new laws make incentives available in the form of tax credits or deductions. In line with this, the DOF must consider the direction of DOST and DTI in promoting R&D and small-scale industries, and monitor the granting of innovation incentives. These should also be reviewed regularly to assess if they are still effective and justifiablen to support innovation and the expansion of the manufacturing base.

Roadmap

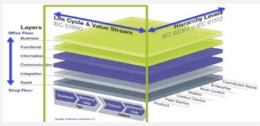
a. Program Roadmap



	2020	2021	2022	2023	2024

Policy, Government & Public Sector

- Expand current **Data Privacy Laws** to include data security, ethics, and protection
- Amend current **IP Laws** to include protection of Industry 4.0 technologies
- Operationalize data-sharing between relevant stakeholders
- Form **technical committee** for implementation of international standards
- Orient and Equip stakeholders for international standards then apply **international standards** (i.e. RAMI 4.0)
- **Provide rewards and incentives** for industries that adopt digital technology
- Develop policies to ease procurement of specialized equipment for research, academe, and industry use
- **Digitalization of government processes** for manufacturing such as licensing and certification
- Properly identify smart machines and Implement **liability laws** regarding their use
- **Establish online platform** consolidating incentives and programs for businesses
- **Establish network** linking all government processes



Infrastructure

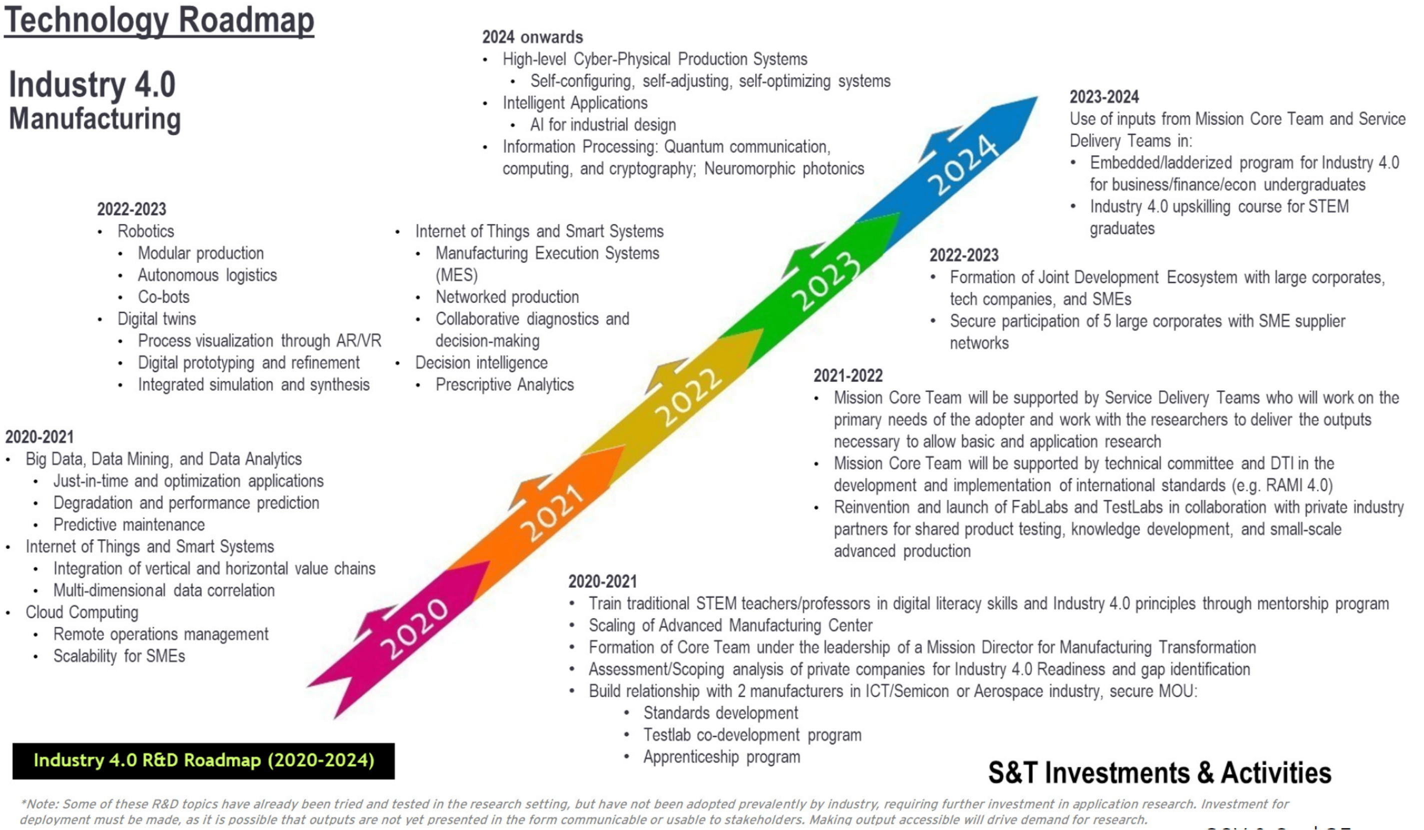
- Complete roll-out of **National Broadband Plan, National Cybersecurity Plan, and other connectivity initiatives**
- Perform feasibility study for **smart grid infrastructure** for energy
- Identify **pilot areas** in urban and rural cities in Luzon, Visayas, and Mindanao
- **Expand** internet access and speed (possibly with 5G)
- Consider the concept of having **Universal Service Obligation** for application in the Philippines
- Deploy **IoT sensors and devices** for public applications with local communities providing security
- **Facilitate Data Trusts** between government and industry to meet the needs of the parties involved and allow data transactions to proceed with confidence and trust
- **Explore** use of tech that allows **sharing of computer resources** (Bayanihan grid computing concept)
- Develop and deploy **smart grid infrastructure** for energy
- **Deploy** smart infrastructure and platforms

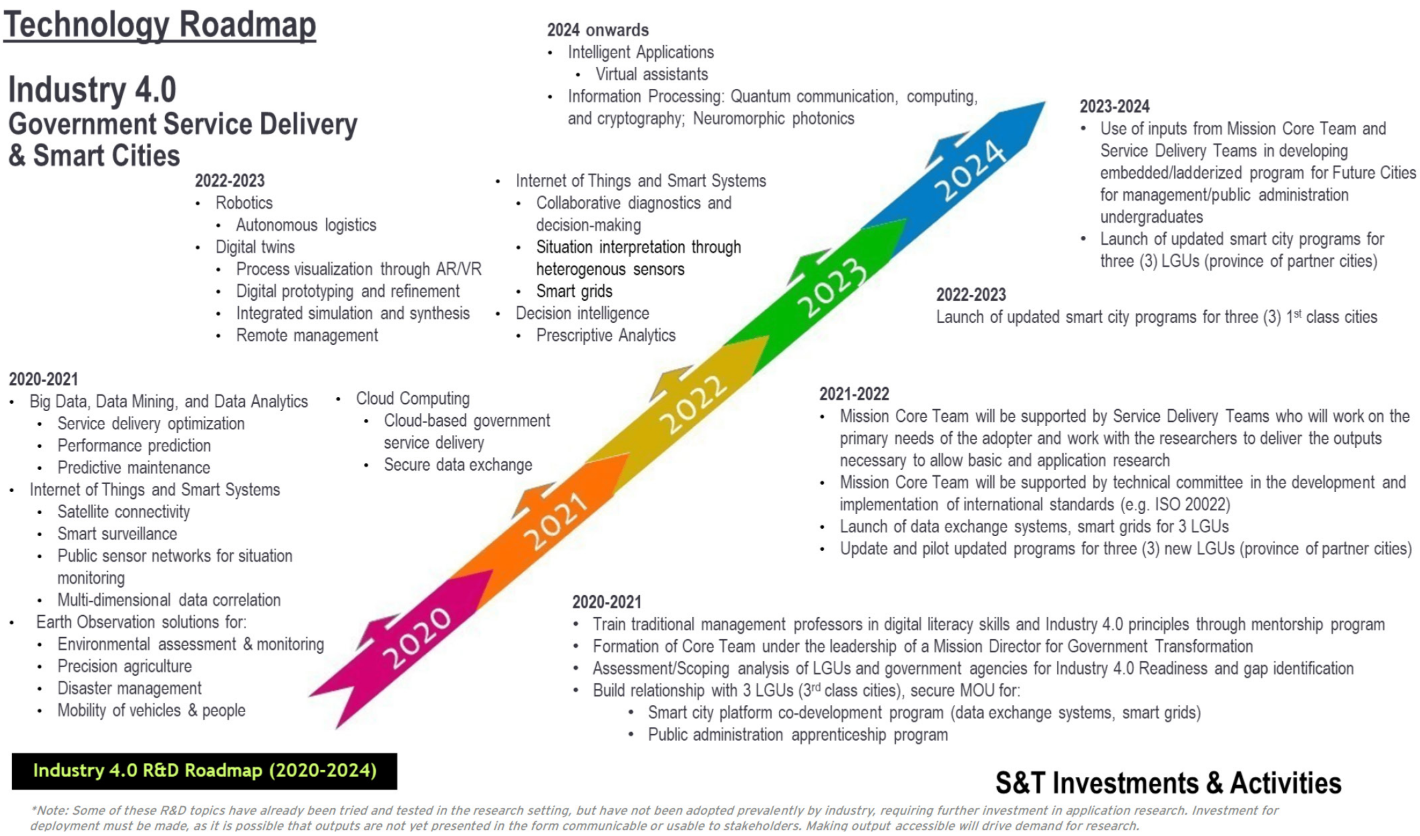
	2020	2021	2022	2023	2024

Technologies Application

- Consider **community participation** for smart city adoption
- **Develop** criteria and assessment for technologies before adoption
- Launch **updated smart city/municipality program providing facilities and people** for first **3 cities**
  - Primary candidates are 3rd class cities and municipality cities
  - Secondary candidates are 1st class cities who want lower cost smart city implementation
- Launch updated smart city/municipality program **for 3 new cities targeting primary candidates**
- Zero launch of updated smart city/municipality programs due to election year
- Launch updated smart city/municipality program for **6 primary and secondary candidates**
- Launch updated smart city/municipality program for **10 cities.**

b. Technology Roadmap





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