SMART INDUSTRY READINESS INDEX

THE SMART INDUSTRY READINESS INDEX

Catalysing the transformation of manufacturing

EDB singapore

At a Glance

Singapore Economic Development Board (EDB), a government agency under the Ministry of Trade and Industry, is responsible for strategies that enhance Singapore's position as a global centre for business, innovation, and talent. We undertake investment promotion and industry development, and work with international businesses, both foreign and local, by providing information, connection to partners and access to government incentives for their investments. Our mission is to create sustainable economic growth, with vibrant business and good job opportunities for Singapore.

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Foreword

Big data, robotics, and additive manufacturing are some of the technologies that are driving the convergence of digital and physical in every industrial sector, from production to logistics, from aerospace to utilities. This convergence, commonly referred to as Industry 4.0, holds immense opportunities for Singapore. It will redefine the nature of manufacturing. Instead of standalone factories, Industry 4.0 will create dense and interconnected networks of facilities, suppliers, partners, and customers. It will create new jobs of tomorrow, where man and machine work together to manage smart facilities and global supply chains.

While companies recognise the opportunities, many do not know where and how to start. The pace of transformation is also uneven across industries. The Smart Industry Readiness Index seeks to provide a common framework for all companies to participate in, and benefit from, this transformation. Developed by EDB in partnership with TÜV SÜD and validated by an advisory panel of experts, the Smart Industry Readiness Index will help companies determine where to start and how to scale and sustain their Industry 4.0 efforts.

More importantly, we hope that the Smart Industry Readiness Index will be a catalyst for companies, industries, workers, and the Government to come together to prepare for and create Singapore's future in this new era of Advanced Manufacturing.

Dr Beh Swan Gin
Chairman
Singapore Economic Development Board

Executive Summary

Manufacturing is on the brink of a new age — arising from the convergence of the physical and digital worlds. This new paradigm, commonly referred to as Industry 4.0, has the power to transform how products are created, how supply chains are managed, and how value chains are defined. For companies around the world, Industry 4.0 presents an opportunity to gain new competitive advantages through greater productivity, agility, and speed. For Singapore in particular, Industry 4.0 creates a window of opportunity to cement its role as a global manufacturing hub and to transform its manufacturing base.

The Smart Industry Readiness Index

Industry 4.0 is now gathering momentum globally. According to the 2016 Industry 4.0 global survey conducted by PwC, nearly three-quarters of respondents foresaw a high level of digitalisation in their companies over the next five years. However, in McKinsey's 2017 digital manufacturing global expert survey, companies also pointed out that the lack of a clear vision, strategy, and a systematic roadmap were the biggest challenges hindering Industry 4.0 adoption.

The Smart Industry Readiness Index (SIRI) is a deliberate attempt to address these challenges. Created in partnership with global testing, inspection, and certification company TÜV SÜD and validated by an advisory panel of industry and academic experts, SIRI comprises a suite of frameworks and tools to help manufacturers — regardless of size and industry — start, scale, and sustain their manufacturing transformation journeys. This white paper introduces three frameworks and tools: the SIRI Framework, the LEAD Framework, and the Assessment Matrix tool.

The SIRI Framework

The SIRI Framework consists of three layers. The topmost layer is made up of the three fundamental building blocks of Industry 4.0: Process, Technology, and Organisation. Underpinning the building blocks are eight pillars, which represent critical aspects that companies must focus on to become future-ready organisations. The third and final layer comprises 16 dimensions that companies should reference when evaluating the current maturity levels of their facilities.

The Assessment Matrix

Referencing the 16 dimensions in the SIRI Framework, the Assessment Matrix is the world's first Industry 4.0 self-diagnostic tool aimed at helping companies worldwide evaluate the current state of their factories and plants. It is designed to strike a balance between technical rigour and usability.

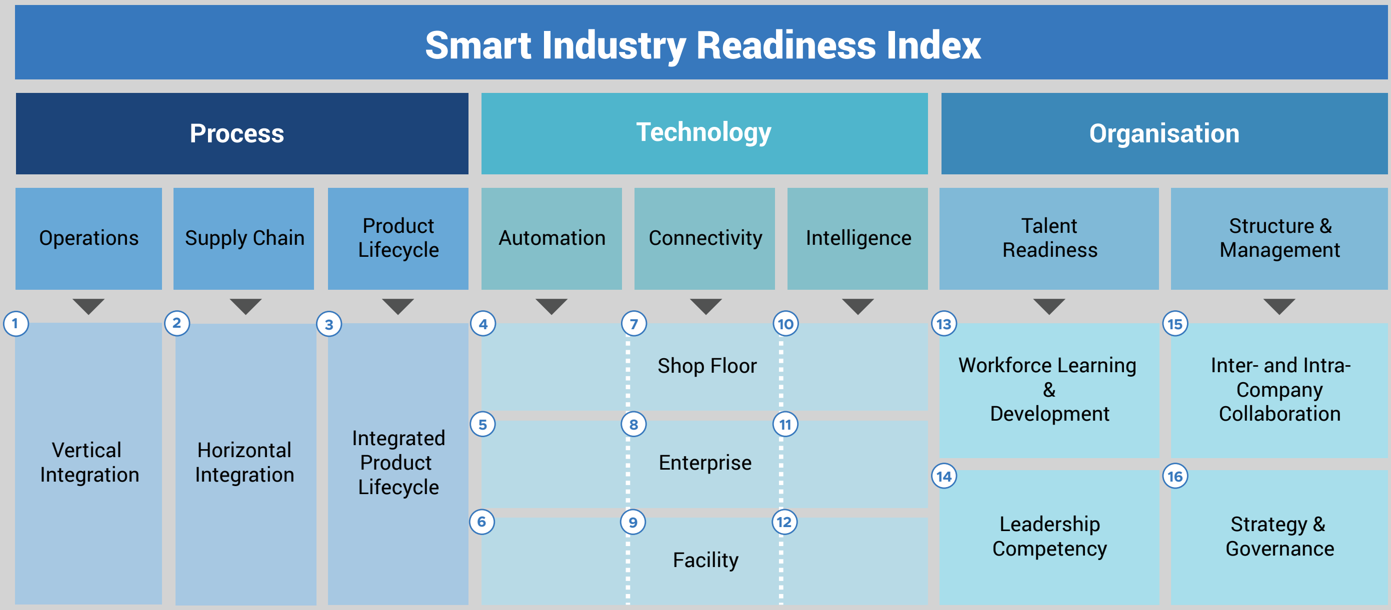

Figure 1: The Smart Industry Readiness Index (SIRI) Framework

The LEAD Framework

Transforming and upgrading a manufacturing facility is not a one-off exercise. Rather, it is a continuous and iterative process. This is encapsulated in the LEAD framework — a circular, continuous four-step process that all manufacturers can adopt in their approach towards Industry 4.0 transformation.

Figure 2: The LEAD Framework

(1) **Learn** the key concepts of Industry 4.0 and build a common language for alignment: SIRI enables this by offering frameworks that help increase the level of understanding of key Industry 4.0 concepts and establishing a common language among individuals, business units, and partners.

(2) **Evaluate** the current Industry 4.0 maturity levels of existing facilities: With a common understanding of Industry 4.0, companies can use the Assessment Matrix to assess the current state of their facilities. Through each dimension, companies can examine their current processes, systems, and structures and place themselves in one of six possible bands. It should be noted that while all dimensions should be taken into account, the relative importance of each one will vary depending on the company's needs and the industry it is operating in.

(3) **Architect** a comprehensive transformation strategy and implementation roadmap: The SIRI framework acts as a checklist to ensure that all the building blocks, pillars, and dimensions are formally considered. Additionally, the Assessment Matrix doubles as a step-by-step improvement guide, with the six bands within each dimension delineating the intermediate steps needed to progress to higher bands. This helps companies to identify high-impact initiatives and structure robust implementation roadmaps with clearly defined phases, targets, and timelines.

(4) **Deliver** impact and sustain transformation initiatives: Once a company has developed its transformation roadmap, SIRI's frameworks and tools also serve as a live blueprint that the company can use to measure and refine its Industry 4.0 initiatives over a multi-year period.

The Way Forward

Companies who seek to embrace Industry 4.0 often have different starting points. Regardless of where they start from or the industry they are in, all companies stand to benefit from Industry 4.0. SIRI offers a suite of practical and usable frameworks and tools for companies to determine where to start, how to scale, and what they could do to sustain growth.

Introduction

Industry 4.0 is transforming manufacturing

The fourth industrial revolution is upon us. Although the first three industrial revolutions of mechanisation, mass production, and computerisation have come to define the world we live in today, the fourth industrial revolution will usher in a new age of innovation and transformation. This is characterised by the advent of cyber-physical systems, arising from the convergence of the digital and physical worlds.

This new age, commonly known as Industry 4.0, represents a paradigm shift for manufacturing on multiple fronts. Once solely focused on the execution of pre-programmed logic, machines and devices are now part of intelligent, autonomous networks capable of communicating and interacting with one another. Processes are no longer static; instead, they are adaptive, self-corrective, and capable of responding to demands in real time. Rigid, centralised factory control systems also give way to decentralised intelligence and decision-making, reshaping the basis of competition from scale to flexible production. With product life cycles and supply chains digitalised across the value chain, companies can move beyond the mere provision of products and equipment to offer new, disruptive services and business models. Production, too, can transcend the factory environment, as manufacturing systems are vertically integrated with enterprise processes and horizontally networked across the value chain. This integration allows companies to respond to the needs of customers with greater efficiency, flexibility, and speed.

Collectively, these shifts will have a profound impact on companies and economies around the world. In the future, Industry 4.0 will create a world where processes are increasingly digitalised and integrated; where devices, machines, and systems can autonomously optimise processes and manage operations; and where humans and machines work together to create smart facilities that are efficient, flexible, and adaptive.

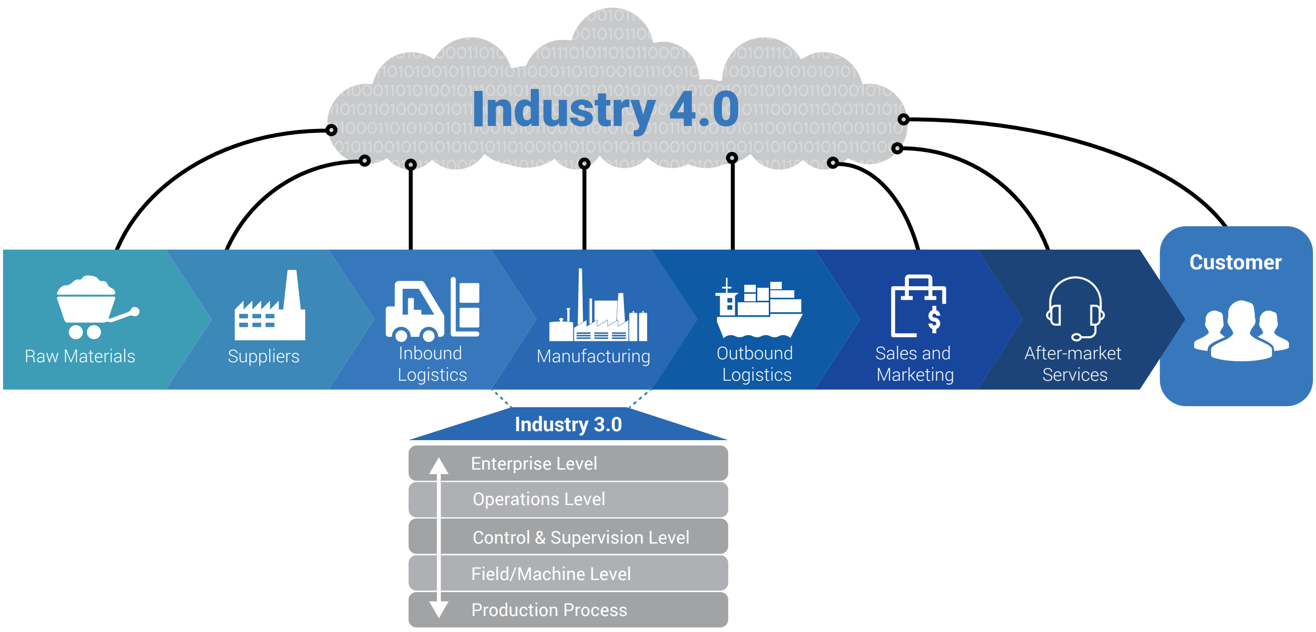

Figure 3: From Industry 3.0 to Industry 4.0

> *The Smart Industry Readiness Index Framework strikes a good balance by offering practical applicability while maintaining both conceptual and technical rigour.*
>
> ***– Prof Dr -Ing Siegfried Russwurm,*** *University of Erlangen-Nürnberg*

Manufacturing: A Key Pillar of Singapore's Economy

A national imperative for growth and transformation

Today, Singapore is recognised as a hub for high-value manufacturing. Singapore has developed a diverse manufacturing industry and occupies a leadership position in sectors such as aerospace, semiconductors, chemicals, and biomedical sciences. For instance, 10 per cent of all the integrated circuit chips in the world are fabricated, assembled, or tested in Singapore. Five of the world's top 10 drugs are manufactured here. And, despite not having any hydrocarbon reserves of its own, Singapore's integrated energy and chemicals complex — Jurong Island — is the world's fifth-largest producer of refined oil and ranks among the top 10 globally in terms of chemicals exports by volume.

With its deep engineering and innovation capabilities, Singapore has been ranked fifth in the world under the manufacturing value-added category in the 2017 Bloomberg Innovation Index. It is also the fourth-largest exporter of high-tech goods in the world, after China, the US, and Germany.

According to a study by the Boston Consulting Group, Industry 4.0 could add S$36 billion in total manufacturing output, boost labour productivity by 30 per cent, and create 22,000 new jobs in Singapore by 2024. Industry 4.0 therefore presents an opportunity for Singapore to cement its position as a global manufacturing hub. With shifting factors of production now favouring innovation-intensive economies, Singapore's skilled workforce and strengths in innovation position the country well to be amongst the top locations for companies to design and execute their Industry 4.0 strategies.

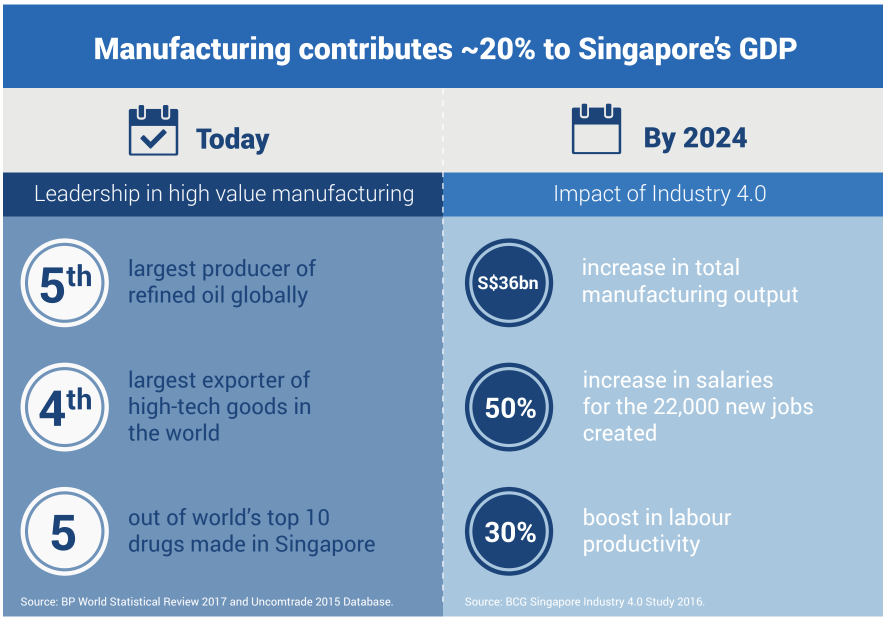

Figure 4: The impact of Industry 4.0 on Singapore's manufacturing industry

> *Singapore's ambition is to be the global hub for manufacturing and one of the best places globally for high-tech innovation. What makes Singapore unique is the strong partnership between industry, the ecosystem of partners, and the government. This allows companies to translate Industry 4.0 concepts and technologies into new value, for Singapore and for the markets around us.*
>
> *– **Mr Lim Kok Kiang,** Assistant Managing Director, EDB*

The Smart Industry Readiness Index

Catalysing the transformation of manufacturing

Objectives and intent

Industry 4.0 is gathering momentum. Based on a 2017 study conducted in partnership with Accenture, seven out of 10 manufacturers from the energy, chemicals, and utilities sectors in Singapore plan to deploy Industry 4.0 solutions by 2020. Companies also regard Industry 4.0 as a lever to boost both organisational efficiency and business productivity.

However, the pace of Industry 4.0 adoption is uneven across different industries and companies. Companies both globally and locally are grappling with the concept of Industry 4.0 and the value it could bring. For these companies, questions such as *What is Industry 4.0, and how can it benefit my company? Where should I start? What are my gaps today and where are the opportunities tomorrow?* remain unanswered.

The Smart Industry Readiness Index (SIRI) Framework and an accompanying Assessment Matrix tool were therefore developed to address these challenges. The SIRI Framework covers the 3 core building blocks (Process, Technology, and Organisation) critical to achieving future-ready facilities, and the Assessment Matrix tool is designed to strike a balance between technical rigour and practical applicability.

The Assessment Matrix also defines the end states and the intermediate steps needed for continual improvement. Collectively, the SIRI Framework and Assessment Matrix tool aim to equip companies with practical knowledge about:

- What Industry 4.0 is and the tangible benefits it could yield;
- The maturity levels of their organisations and facilities; and
- How they can improve in a targeted and incremental manner.

Created in partnership with global testing, inspection, and certification company TÜV SÜD, and validated by an advisory panel of academic and industry experts, SIRI's frameworks and tools are designed to help all companies globally — regardless of size, profile, and level of maturity — to determine where to start, how to scale, and what they can do to sustain growth.

> *With rapid advancements in digital technologies and the push for process integration, the time for Industry 4.0 is now. For companies globally, disruptive technologies of Industry 4.0 hold the promise of creating smart facilities that are highly efficient and digitally integrated. It is an opportunity to take the lead in shaping one of the most significant shifts in manufacturing that we have ever seen.*
>
> ***Mr Raimund Klein,** Executive Vice President, Digital Factory & Process Industries & Drives, Siemens*

Development Process

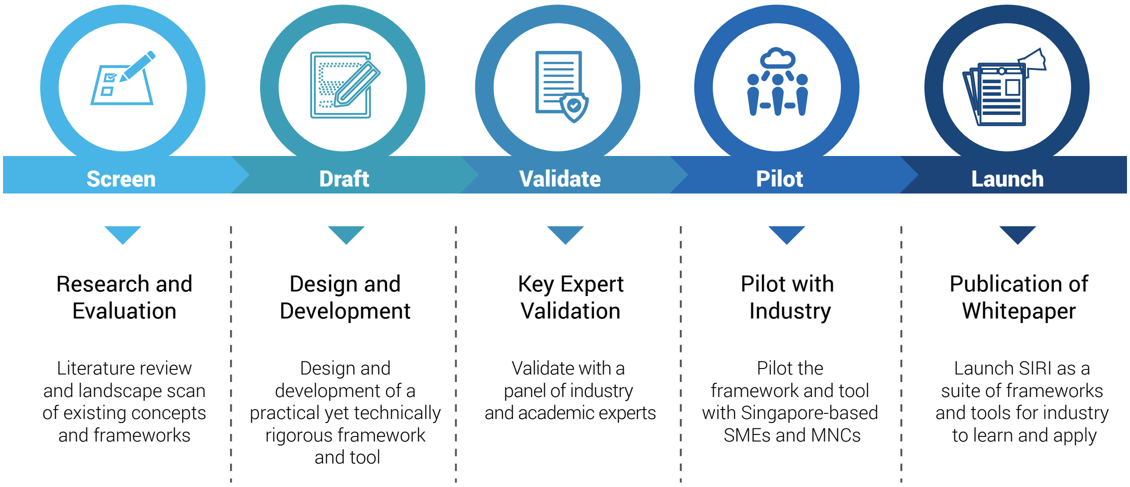

Figure 5: The five stages of the development process

The development process commenced with a literature review of a wide range of Industry 4.0 related concepts and frameworks. These included industry reports, landscape studies, business surveys, and models produced by leading associations and industry players. At its core, the SIRI Framework and Assessment Matrix draws on the Reference Architectural Model for Industry 4.0 ("RAMI 4.0") developed by *Plattform Industrie 4.0*, one of the largest Industry 4.0 networks in the world. Today, RAMI 4.0 has been formally acknowledged by key experts and respected associations to be *the* reference architecture model which best embodies the key concepts and ethos of Industry 4.0. Beyond RAMI 4.0, other reference materials included (but were not limited to) the Industrie 4.0 Maturity Index developed by the German Academy of Science and Engineering (acatech) and the Bersin model for human capital development by Deloitte.

To ensure the technical robustness and usability of the Assessment Matrix, an advisory panel of experts from industry and academia was also consulted. The panel's input was then used to further improve the Assessment Matrix. Thereafter, the Assessment Matrix was piloted with a group of Singapore-based industrial companies. Participating companies ranged from small and medium-sized enterprises (SMEs) to multinational corporations (MNCs), including both discrete and process manufacturing facilities. Each pilot was conducted through a workshop involving the company's senior management and engineering and operations teams, alongside the core SIRI development team. The insights, suggestions, and feedback gained from each pilot were then taken into account when refining the Assessment Matrix.

> *The Smart Industry Readiness Index gives clear orientation to manufacturers on what Industry 4.0 means and how they can initiate their transformation journey. The Assessment Matrix is a world's first Industry 4.0 tool that is developed by the government for nation-wide transformation of industrial sectors. Strongly aligned with Industry 4.0 and other global manufacturing initiatives, the SIRI Framework and Assessment Matrix have the potential to be the global standard for the future of manufacturing.*
>
> ***– Prof Dr -Ing Axel Stepken,*** *Chairman of the Board of Management, TÜV SÜD*

The SIRI Framework

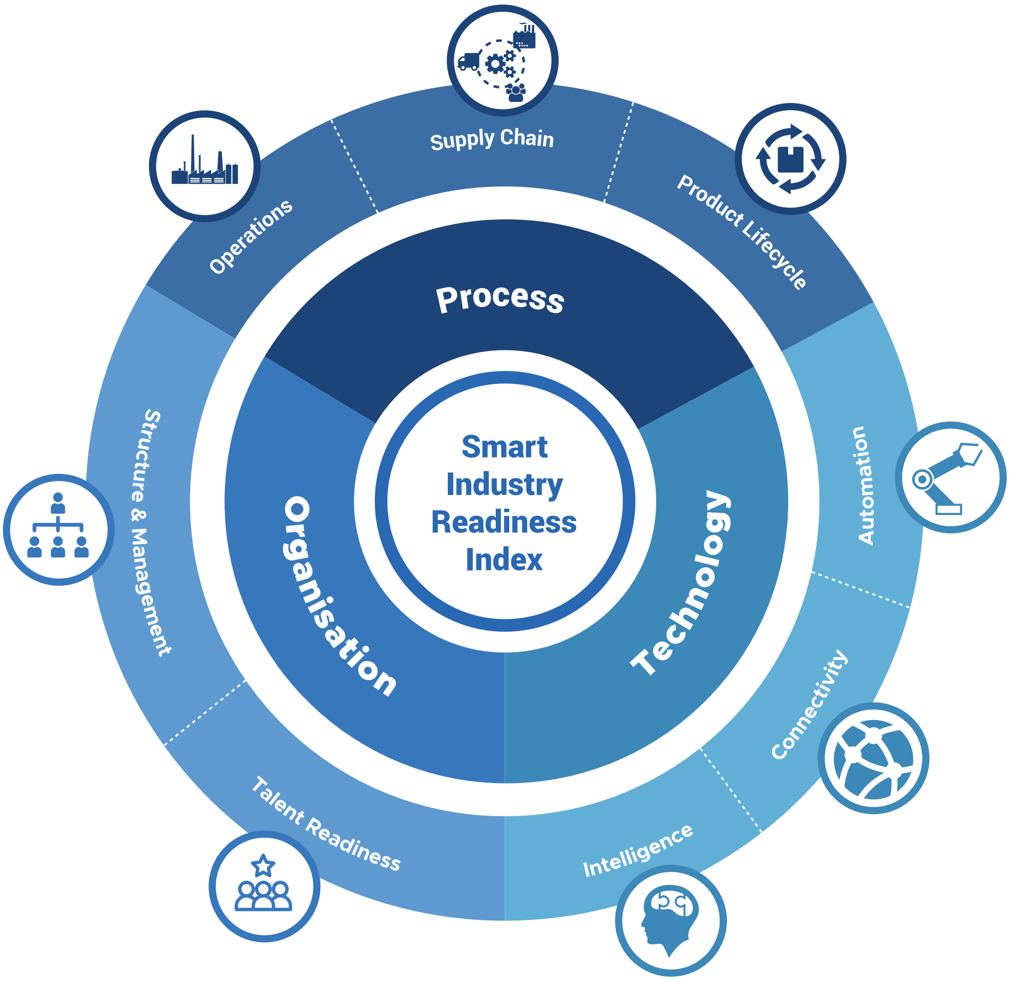

Figure 6: The 3 building blocks and the 8 pillars

The 3 Building Blocks and the 8 Pillars

The SIRI Framework identifies the 3 fundamental building blocks — Technology, Process, and Organisation — that must be considered for any factory or plant to transform into a factory/plant-of-the-future. All 3 building blocks must be considered in order to harness the full potential of Industry 4.0. Underpinning the 3 building blocks are 8 key pillars, which represent critical areas that companies must focus on to become future-ready organisations under the Industry 4.0 reference model.

The Technology Building Block

Technological advancement has been the cornerstone of the last three major industrial revolutions. The discovery of steam power enabled the first industrial revolution, while innovations in electric power catalysed the second. In a similar manner, Industry 3.0 was powered by the advent of electronics and Information Technology (IT) systems, which allowed companies to achieve an unrivalled degree of precision and efficiency through automation.

Technology remains critical under Industry 4.0. New digital technologies, such as cloud computing, machine learning, and the Internet of Things (IoT) are creating a hyper-connected industrial landscape where physical assets and equipment are integrated with enterprise systems to enable the constant and dynamic exchange and analysis of data. These cyber-physical systems in turn make companies more agile and nimble.

For companies to realise their Industry 4.0 ambitions, a high degree of automation, ubiquitous connectivity, and intelligent systems are necessary. To reflect this, the *Technology* building block has been segmented into the 3 pillars of *Automation*, *Connectivity*, and *Intelligence*.

> *One of the key disruptive forces of Industry 4.0 is the ever-increasing volume, velocity and value of data. Looking ahead, traditional manufacturing companies need to change their perception of data, not just as numbers on a screen, but as a strategic asset that can unlock revenue growth and deliver cost savings. Companies who embrace this shift will start building the infrastructure for connectivity and intelligence right away.*
>
> ***– Ms Vidya Ramnath,** Vice President, Global Plantweb Solutions & Services, Emerson Automation Solutions*

The Automation Pillar

Automation — the application of technology to monitor, control, and execute the production and delivery of products and services — was the hallmark of Industry 3.0. It not only freed workers from mundane and repetitive tasks, but also enhanced the speed, quality, and consistency of execution.

While *Automation* has been and will continue to be a key enabler for companies, the role of automation is changing. To cope with rising demand for smaller batches and on-demand production, it is no longer sufficient to simply maximise efficiency. To adapt quickly to changing market needs, *Automation* needs to be flexible instead of fixed. As automation systems become flexible, they will generate a larger range of products in smaller batches, without needing to invest in significant capital or time to overhaul or redesign processes. This puts manufacturers in a more competitive position, helping them to pursue a large variety of global business opportunities and adapt to rapidly changing customer needs.

The Connectivity Pillar

Connectivity measures the state of interconnectedness between equipment, machines, and computer-based systems to enable communication and data exchange across assets. Like *Automation*, the concept of *Connectivity* has taken on a new meaning under Industry 4.0. Every day, more and more devices and systems are being converted from wired and analogue formats to wireless and digital ones. Such IoT-enabled devices are also increasing in both quality and quantity, generating enormous amounts of data as a result. Technological advancements in cloud computing and wireless infrastructure also make it possible for data to be centrally collected and managed. Likewise, systems that were once independent or isolated can now be integrated, unifying the various shop floor, facility, and enterprise systems through connected organisation-wide networks. Interoperability — the ability to access data across assets and systems with ease — is key to achieving this. Companies need to standardise or make use of complementary communication technologies and protocols to establish more open, inclusive, and transparent communications networks.

Such deeply interconnected systems also make cyber-physical security an integral aspect of *Connectivity*. Hyper-connected manufacturing operations can increase the number of vulnerable points in a system, which could give cyber-attacks a far more extensive impact than before. To mitigate this risk, secure and resilient cyber-physical security architectures will need to be established.

The Intelligence Pillar

While *Automation* provides the muscle for Industry 4.0 and *Connectivity* acts as its central nervous system, *Intelligence* is the brain powering this new age. *Automation* and *Connectivity* focus on establishing linkages between equipment, machines, and computer-based systems for the collection and integration of data. *Intelligence* is about the processing and analysis of that data. This is important as modern manufacturing is no longer just about finding ways to operate faster while reducing expenses; it is also about doing so in a data-driven and intelligent way. The benefits to be derived from the *Intelligence* pillar are significant and far-reaching. With technologies such as cloud and data analytics, the vast quantities of data generated can be processed and translated into actionable insights to diagnose problems and identify opportunities for improvement. With machine learning, highly intelligent systems can assist the workforce in predicting equipment failures and changes in demand patterns. At their best, these intelligent systems can also autonomously make decisions and respond to changing internal and external business needs.

The Process Building Block

To maximise value, *Technology* must always be applied in tandem with effective, well-designed *Processes*. After all, using technology to digitalise a poorly-designed process will only result in a poorly-designed digital process. Conversely, applying technology to a well-developed process will enhance its efficiency and enable the creation of new value.

From the beginnings of modern manufacturing, companies have used process improvements to lower costs and shorten their time-to-market. Previously, companies centred their efforts on improving the efficiency of individual processes. Under Industry 4.0, the concept of process improvements has expanded to focus on the integration of processes within a firm's *Operations*, *Supply Chain*, and *Product Lifecycle.* This stems from the new ethos of connecting intelligent facilities with every part of the production value chain.

As processes within *Operations*, *Supply Chain*, and *Product Lifecycle* become integrated, they will converge into a single unified system where data is shared, processed, and integrated across the product management, production, and enterprise layers of the organisation. This will then generate the next leap forward in flexibility and efficiency.

The Operations Pillar

The first pillar, *Operations*, encompasses the planning and execution of processes which lead to the production of goods and services. The end goal is to convert raw materials and labour into goods and services at the lowest cost. While this objective does not change in the context of Industry 4.0, companies can now access new technologies and approaches to achieve this goal more rapidly and with better results. For instance, companies can use data analytics to reduce waste by identifying and improving inefficient processes. They can also use wireless communications to connect discrete processes and systems, to enable the remote monitoring and decentralised control of assets.

The Supply Chain Pillar

Supply Chain management encompasses the planning and management of raw materials and inventory of a company's goods and services, all the way from the point of origin to the point of consumption. Under Industry 4.0, traditional supply chain models will become increasingly digital: processes across the supply chain will be connected through a sensor network and managed through a central data hub and analytics engine. The digitalisation of supply chains will also allow decisions about cost, inventory, and operations to be made from an end-to-end perspective rather than in isolation. This evolution benefits all players across the value chain, with greater speed due to reduced lead times; greater flexibility through real-time optimisation for changing needs; greater personalisation; greater efficiency and greater transparency, both internally and for partners.

The Product Lifecycle Pillar

The *Product Lifecycle* refers to the sequence of stages that every product goes through from its initial conceptualisation to its eventual removal from the market. These stages range from design, engineering, and manufacturing to customer use, service, and disposal. A robust product lifecycle management framework has always been integral to manufacturing operations; however, shorter product cycles and a growing demand for personalisation have accentuated the need for greater integration and digitalisation across the different *Product Lifecycle* stages.

Advancements in digital tools have made it easier than ever before to bring together data, processes, business systems, and people to create a single unified information backbone that can be managed digitally. Industry 4.0 also introduces the concept of a "digital twin", which is a virtual representation of the physical assets, processes, and systems involved throughout a product lifecycle. A digital twin offers two key benefits. Firstly, the information generated at each stage can be shared seamlessly, facilitating better decision-making and enabling processes to be dynamically optimised in other stages. This allows companies to shorten their design and engineering cycles and respond to customer demands more quickly. Secondly, a digital twin removes the limitations of working with physical prototypes. By working off the digital twin, multiple prototypes can be created and tested virtually at speed, at scale, and at a much lower cost.

> *Industry 4.0 is driving a paradigm shift — from the optimisation of physical assets and systems to the optimisation of processes, where data is integrated across the operations, enterprise, and product lifecycle layers. This allows for stronger cross-functional integration and closer collaboration not just within the company but also with external stakeholders such as suppliers and customers.*
>
> *– **Dr -Ing Gunther Kegel,** CEO, Pepperl+Fuchs & President of VDE*

The Organisation Building Block

Organisation is the third building block of Industry 4.0. Often under-regarded, *Organisation* plays an equally important role alongside *Technology* and *Processes*. To remain relevant in the face of increasing competition under Industry 4.0, companies must adapt their organisational structures and processes to allow their workforce to keep pace.

Industry 4.0 calls for a greater focus on two key components that can affect an organisation's effectiveness. The first component is the people who make up the organisation – the entire workforce from the top management down to the operational teams. The second component is the institutional systems that govern how the company functions. Both components must be taken into account in order to fully reap the benefits of Industry 4.0. For instance, even a competent leadership team and workforce will be demotivated by rigid structures, inconsistent practices, and siloed processes. Likewise, open channels for collaboration and innovation will not be effective unless employees are informed and incentivised to use them.

As such, the necessary enhancements must be made to people, represented by *Talent Readiness*, and the company, represented by *Structure & Management*, before a company can implement Industry 4.0 strategies effectively.

The Talent Readiness Pillar

For any transformation to deliver value, *Talent Readiness* — the ability of the workforce to drive and deliver Industry 4.0 initiatives — will be a key factor for success. As organisations embrace flatter structures and decentralised decision-making, it becomes critical to build a competent and flexible workforce characterised by continuous learning and development at all levels. Everyone has a role to play. Management must put in place systems or practices that will allow people to constantly stay abreast of the latest developments in Industry 4.0. This will allow them to capture new opportunities to drive improvement. Concurrently, the wider workforce needs to be multi-skilled and adaptable to manage Industry 4.0's dynamic and digitalised operations. This is enabled by formal talent development programmes that are not only aligned with the company's business and human resource objectives but also foster a culture of self-learning and personal development. If successful, a skilled, self-learning workforce and leadership core will be created, one which will be able to maximise the value of any transformation initiative.

The Structure & Management Pillar

An organisation's *Structure* is its system of explicit and implicit rules and policies that outline how roles and responsibilities are assigned, controlled, and coordinated. *Structure* influences how teams act and interact and how initiatives are to be implemented to achieve organisational goals. Just as process design determines how successful production will be, an organisation's *Structure* determines how successful the company will be in achieving its goals. Under Industry 4.0, organisations will see greater decentralisation of decision-making, increased openness in information sharing, and more collaboration among teams both internally and with external partners. In the long run, this will enable companies to make decisions in a more agile manner and to become more responsive to changes.

Meanwhile, *Management* is fundamentally about getting people to work together towards a well-defined common goal. Given the paradigm shifts on multiple fronts, Industry 4.0 is also a change management exercise. Strong leadership, supported by a clear strategy and governance framework, is hence essential for any organisation to successfully navigate this increasingly complex and highly networked world. Robust *Structure & Management* will make an organisation more flexible, collaborative, and empowered to design and implement Industry 4.0 strategies effectively.

> *Companies must embrace Industry 4.0 to prepare the digital foundation needed for a manufacturing future that is like no other — Industry X.0 — which has at its heart highly intelligent, interconnected products and ecosystems that create a fully digital value chain, supplemented by new core innovation competencies and deep cultural change. Therefore, beyond digitalisation, organisational talent, structures and processes will need to be adapted and built across the enterprise to put it on the right trajectory into this future of 'connected everything'.*
>
> *– **Mr Senthil Ramani,** Managing Director, Accenture*

The 16 Dimensions of Assessment

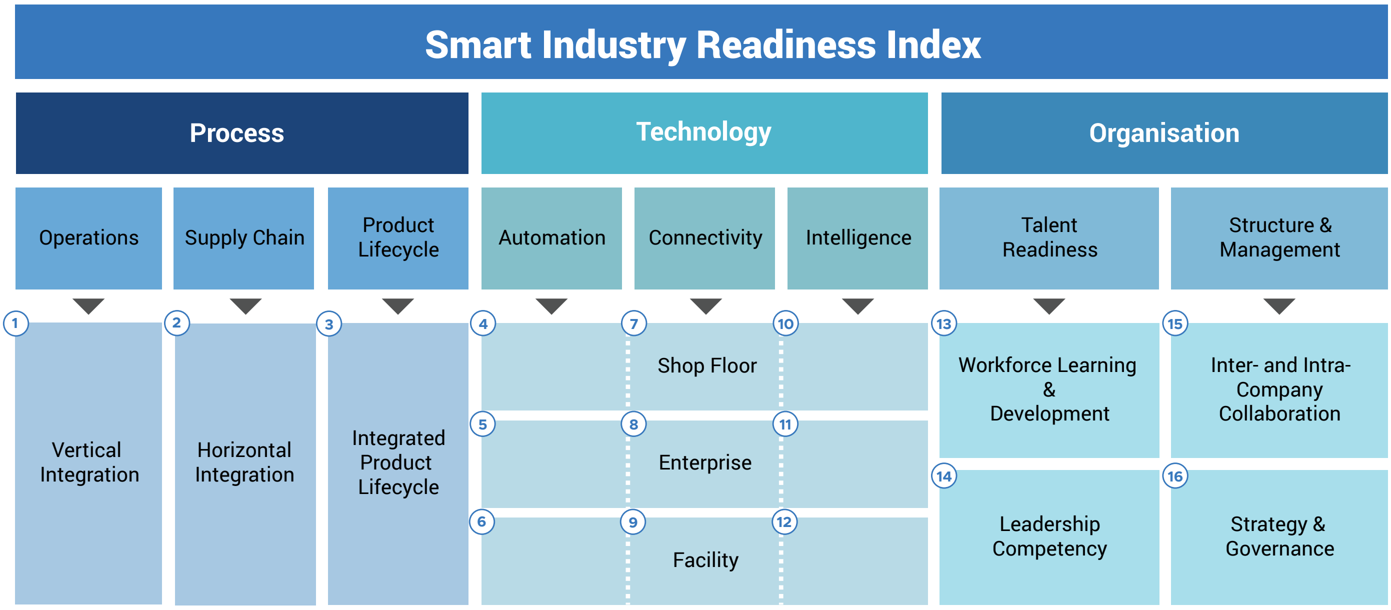

Figure 7: The 16 Dimensions of Assessment

The 3 building blocks and 8 pillars which we have just described map onto 16 dimensions, which are assessment areas, covered in the Assessment Matrix tool, that companies can use to evaluate the current readiness of their facilities. A brief description of each of the 16 dimensions is provided in this section, and the full Assessment Matrix tool can be found on page 22.

Dimension 1: Process — Vertical Integration

Vertical Integration is one of the three key characteristics of a digitalised facility defined under Industry 4.0 by acatech. It can be understood as the integration of processes and systems across all hierarchical levels of the automation pyramid within a facility to establish a connected, end-to-end data thread. This dimension seeks to assess the extent of formal connections and linkages between and across processes and systems, and it also takes into account how data is exchanged and analysed. In its ideal form, the *Vertical Integration* dimension defines a state where all OT and IT systems across the production and enterprise levels are integrated into automated, interoperable, and flexible networks that will permit seamless data exchange, analysis, and decision-making. This will in turn allow better communication, flexibility, and operational efficiency, and will also enable faster and more concerted responses to any changes in resource availability, operational demands, or product types.

Dimension 2: Process — Horizontal Integration

Horizontal Integration, the second key characteristic of Industry 4.0, refers to the integration of enterprise processes across the organisation and with other stakeholders along the value chain. Enterprise processes include demand planning, procurement, logistics, and after-market services, while stakeholders include suppliers, business partners, and customers. Much like *Vertical Integration*, *Horizontal Integration* evaluates the presence of formal channels that enable information sharing as well as how data is exchanged and analysed. As processes and systems become ever more defined and digital, the *Horizontal Integration* dimension describes an end state where a company's internal processes converge with those of its suppliers and partners. This creates an interoperable and transparent network, within which all stakeholders are able to coordinate and optimise their processes, tasks, and decisions across the entire value chain. Besides enabling higher productivity and shorter lead times, such an integrated value chain can also facilitate the creation of new business and operating models.

Dimension 3: Process — Integrated Product Lifecycle

Integrated Product Lifecycle integrates people, processes, and systems along the entire product lifecycle, and also examines how data is collected, managed, and analysed across the different stages of the product lifecycle. These stages include design and development, engineering, production, customer use, service and disposal.

To build an *Integrated Product Lifecycle*, companies will need to use digital tools and systems to create a production information backbone that can be accessed by employees and their extended enterprise networks. At the most advanced stage, companies may create "digital twins" of processes and assets. By removing physical constraints through these digital twins, companies can shorten development cycles, improve existing systems, and launch new processes and products swiftly and at scale.

For Dimensions 4–12

Under the Technology building block, the SIRI Framework and Assessment Matrix segments the areas of assessment into three layers: the Shop Floor, where the production and management of goods are carried out; the Enterprise, where administrative tasks are carried out; and the Facility, which is the physical building or premises where production takes place.

Dimensions 4–6: Automation – Shop Floor, Enterprise, and Facility

Across the Shop Floor, Enterprise, and Facility layers, the *Automation* dimensions evaluate the degree and flexibility of automation, as well as the extent of its integration across multiple systems. The lower bands assess the overall automation levels of both production and support processes. Flexibility is then introduced in a higher band, as flexible automation will allow processes to be reconfigured and machines to be re-tasked. This allows companies to manufacture a greater variety of products with shorter turnaround times. At its most advanced stage, automation systems across all three layers will converge and interact dynamically with one another as a single integrated whole.

Dimensions 7–9: Connectivity – Shop Floor, Enterprise, and Facility

The *Connectivity* dimensions evaluate the level of interconnectedness between the equipment, machines, and systems that reside within the Shop Floor, Enterprise, and Facility layers. Once formal connections have been established across assets and systems, the higher bands measure the interoperability, security, speed, and agility of the network as a whole. These qualities allow interconnected systems to communicate with one another seamlessly, and allow them to be reconfigured dynamically in response to changing needs.

Dimensions 10–12: Intelligence – Shop Floor, Enterprise, and Facility

The *Intelligence* dimensions evaluate the ability of IT and OT systems at the Shop Floor, Enterprise and Facility layers to identify and diagnose any deviations and adapt to changing needs. At the lower bands, basic intelligence is derived by processing large quantities of data and detecting any deviations from predefined parameters. As more advanced algorithms and models are introduced, computer systems will be able to detect deviations, identify likely causes, and even predict potential failures ahead of time. Ultimately, IT and OT systems will autonomously learn and adapt to new needs while making decisions on their own to optimise processes, assets and resources.

Dimension 13: Organisation – Workforce Learning and Development

A Workforce Learning and Development ("L&D") strategy aims to develop the workforce's capabilities, skills and competencies to achieve organisational excellence. In the context of Industry 4.0, this is especially critical as new technologies and processes will fundamentally alter the nature of work and the types of skills required. Traditional engineering capabilities will need to be augmented with new digital skills, such as data analytics, systems integration, and software development.

In the long term, the entire workforce needs to have digital confidence, which may include skills such as data interpretation and automation management. Employees will also need to adapt to new types of interactions between people and machines, where humans manage operations alongside intelligent machines and systems.

As a proxy to workforce readiness, the *Workforce Learning and Development* dimension measures the quality of a company's L&D programmes. To start with, L&D programmes should be structured and implemented on an ongoing basis; this will provide employees with opportunities for continuous learning, helping them to acquire new skills and enhance existing ones. This is important as occupational needs and job roles evolve with time.

To achieve a high level of workforce readiness, L&D programmes must be aligned with business needs and integrated with other key human resource functions like talent attraction and career development. They must also be dynamically updated based on the feedback and insights provided by employees and business teams, and should proactively position the workforce for future skills. Integrated and forward-looking L&D programmes allow companies to build a high-performing and future-ready workforce capable of managing and sustaining Industry 4.0 initiatives.

Dimension 14: Organisation — Leadership Competency

Leadership Competency refers to the readiness of the management core to leverage the latest concepts and technologies for the company's continued relevance and competitiveness. As transformation is a multi-year journey that will evolve and adapt over time, it must be led from the front by a strong leadership core with commitment, a clear vision, and the right capabilities and knowledge. To unlock their full potential, companies may adopt flatter organisational structures and enable decentralised decision-making. At the lower bands, this dimension examines the management team's familiarity with the latest concepts and technologies, and the ways by which such knowledge is acquired. Companies should establish processes and systems for the acquisition of information on the latest trends, concepts, and technologies. As a company progresses, this dimension will then measure the leadership team's ability to independently design, execute, and adapt transformation strategies to ensure the company's relevance in the long term.

Dimension 15: Organisation — Inter- and Intra- Company Collaboration

Inter- and Intra- Company Collaboration refers to the process of working together, both internally and with external partners, to achieve a shared vision and purpose. Industry 4.0 has created a connected network of systems and technologies which reduce the cost of collaboration. It has also redefined the basis of competition while increasing the pace of change; in such a highly networked environment, companies must be able to collaborate effectively and adapt swiftly.

However, the biggest barriers to collaboration are often not technical, but cultural and institutional in nature. As such, the *Inter- and Intra- Company Collaboration* dimension assesses the formal channels that enable employees to share information and work together, as well as the institutional structures and systems that allow collaborative behaviours and initiatives to flourish. Flatter organisational structures enable faster decision-making, and the alignment of incentives can empower the workforce to collaborate more effectively.

At its highest form, cross-functional teams can be dynamically formed across internal departments and even include partners and customers, with shared goals, resources, and joint key performance indicators (KPIs).

The benefits of a high level of collaboration run deep. Through effective and open inter- and intra-collaboration, companies can tap into a wider degree of expertise and resources to address complex, multi-stakeholder challenges. In the long term, this will shift the company from a culture of internal competition to a culture of shared goals, accountability, and rewards.

Dimension 16: Organisation — Strategy and Governance

Strategy and Governance relate to the design and execution of a plan of action to achieve a set of long-term goals. It includes identifying priorities, formulating a roadmap, and developing a system of rules, practices and processes to translate a vision into real business value.

This dimension examines how well an organisation has developed and implemented its strategy, and a robust governance model. Both factors are critical and must exist in tandem to manage the complexity that comes with the increasing interconnectedness of processes, systems, and people.

To navigate change and mitigate risk, companies will need to define their vision and end-outcomes while establishing consistent guiding principles and supporting structures. This will guide decision-making and help determine the approaches needed to achieve the company's desired outcomes. The different bands map the natural progression that a company will take, from the identification of Industry 4.0 as a strategic focus to the development, implementation, scaling, and continual enhancement of the strategy and governance model.

> *Industry 4.0 is a global leadership topic that should be on top of any CXO's agenda. Strong leadership competency is an imperative to drive enterprise transformation, to shift the focus from today's operational needs to readiness for tomorrow's opportunities.*
>
> ***– Mr Amos Leong,** CEO, Univac*

The LEAD Framework

Mapping the Industry 4.0 Transformation Journey

> *The SIRI Framework and the Assessment Matrix allow our manufacturing teams to take stock of what we are doing well and where we can do better. This forms a good basis to build a shared Industry 4.0 vision and strategy, enabling us to take decisive action in initiating a multi-year transformation journey.*
>
> ***– Mr Hashim Baba,*** *Plant Manager, Becton Dickinson Singapore*

To help manufacturers characterise their transformation journeys, we present a circular, continuous four-step process that all manufacturers can adopt in their approach towards Industry 4.0 transformation. These steps, encapsulated in the LEAD framework, will help companies determine where to start, how to scale, and what they should do to sustain growth in a world powered by Industry 4.0.

1. **Learn** key concepts and build a common language for alignment
2. **Evaluate** the current Industry 4.0 maturity levels of existing facilities
3. **Architect** a comprehensive transformation strategy and implementation roadmap
4. **Deliver** impact and sustain transformation initiatives

Figure 8: The LEAD framework

> *While the term Industry 4.0 was created several years ago, many manufacturing companies, particularly SMEs, remain unfamiliar with it. The SIRI Framework is an intuitive and realistic reference framework that is useful for all industrial companies, both big and small, to not only learn these new concepts but also to apply them to our facilities.*
>
> ***– Mr Desmond Goh,*** *Director, People Bee Hoon Factory*

LEARN key concepts and build a common language for alignment

A thorough understanding of key Industry 4.0 concepts will provide companies with a firm foundation for transformation. However, according to McKinsey's 2016 and 2017 Industry 4.0 Global Expert Surveys, there is a high level of uncertainty among manufacturers about what is required for the implementation of Industry 4.0. As a consequence, many are still struggling to get started, and fewer than half the participants in the surveys considered their companies to be well-prepared for Industry 4.0. They highlighted their lack of familiarity with key concepts, combined with the absence of a clear strategy and roadmap, as some of the biggest challenges hindering Industry 4.0 adoption.

Even when companies have started their Industry 4.0 transformation journeys, knowledge generally remains confined to the corporate management level or to a few in-house experts. However, real transformation requires the wider workforce within each company to be exposed to Industry 4.0 and to have a sound understanding of how this new paradigm can make a positive impact on their daily work.

SIRI aims to help companies in this critical first step by strengthening their institutional knowledge about Industry 4.0 in two ways. First, by examining the three building blocks, eight pillars, and 16 dimensions presented by the SIRI Framework, companies can be more informed and educated about the core concepts and fundamental principles of Industry 4.0.

This ensures that companies will be equipped with the following knowledge:

- An understanding of the key principles, concepts and technologies under Industry 4.0;
- An overview of the tangible benefits and business value that Industry 4.0 can yield; and
- A guide to illustrate how companies can achieve their ideal end states in a practical, stepwise fashion

Second, SIRI aims to establish a common language among the various stakeholders necessary for Industry 4.0 transformation. The new technical terms and jargon arising from Industry 4.0 can be confusing and counterproductive for companies. By providing companies with an intuitive and standardised set of terms and definitions, SIRI can establish a common understanding among companies and the workforce. This will facilitate more effective communication within the organisation and with external partners and customers. A common language also allows technology providers to have more effective and productive conversations with manufacturers, helping them to identify gaps, define priorities, and structure comprehensive transformation roadmaps.

> *Within many organisations, the level of familiarity towards Industry 4.0 concepts can vary significantly across the different technology and operations teams. Even for companies with considerable expertise, knowledge often resides in specific individuals or teams, rather than being uniformly understood across the entire organisation. The SIRI Framework and Assessment Matrix tool form a good basis to drive alignment towards a common understanding and vision.*
>
> *– **Mr Allan Ferrie,** Assembly and Test Director, Rolls-Royce Singapore*

EVALUATE the current Industry 4.0 maturity levels of existing facilities

Learning the key concepts is an essential first step. However, that alone will not help companies to devise effective transformation strategies. Companies must understand where they currently are before they can identify what and how to improve. Thus, to help companies conduct comprehensive assessments of their factories or plants, this whitepaper includes an Assessment Matrix tool incorporating all 16 dimensions. This Assessment Matrix tool can be found in the next section of this paper and should take no more than one or two days to complete.

Before undertaking the assessment, however, companies should go through the following thought process to ensure that the assessment exercise will produce meaningful results. Companies need to identify three things:

- ***What to evaluate.*** Companies need to define the scope of their assessment, and can choose to evaluate either an entire manufacturing facility or break it down to examine each product group independently. The latter is especially relevant for companies that own multiple product groups, each of which may be at a different stage of maturity or have its own distinct processes. Ultimately, however, companies should seek to evaluate their facilities in their entirety.

- ***Who to evaluate.*** After defining the scope of the assessment, companies should identify the key stakeholders who will participate in this exercise. Due to the comprehensive nature of the Assessment Matrix, the assessment exercise should ideally involve a cross-functional team including key stakeholders like the general manager and senior leaders from the operations, IT facility, and human resource departments.

- ***How to evaluate.*** Due to the mix of legacy and new systems within every brownfield facility, companies will find that, for certain dimensions, the state of their facilities may not be fully represented in one single band. For example, under the facility automation dimension, heating, ventilation and air-conditioning (HVAC) systems might be fully automated, which would place them under Band 3. However, lighting systems might still require manual operation, which is more accurately represented in Band 2. In such cases, it is up to the companies' discretion to opt for either banding.

Conducting a SIRI Assessment, or evaluating the current state of a factory or plant using the Assessment Matrix, must also be based on the five fundamental principles listed in Figure 9. Principle 3 is especially important and must be emphasised: while all 16 dimensions should be formally considered, this does not mean that every dimension is of equal importance. Instead, the importance and relevance each dimension will vary depending on each company's needs and cost profile.

For example, if utilities constitute a greater component of overall operating expenses, facility-related dimensions will be of higher priority to that company. Conversely, if labour costs make up a large portion of overall operating expenses, shop floor automation may warrant more attention.

In the same vein, the relative importance of each dimension also varies across industries. For example, approximately 70% of manufacturing costs in the energy and chemicals industry are attributable to raw materials. It is therefore natural for companies in this industry to focus on horizontal integration in order to reduce inefficiencies across their supply chains. Similarly, facility automation will be an important dimension for the semiconductor industry as cold rooms — needed for the management of ambient temperature and humidity — require significant amounts of electricity, and efficient facility automation could translate into significant cost savings.

The 5 Principles of Assessment

1. The SIRI Assessment provides a snapshot of a facility's current state but not its future potential.

2. The SIRI Assessment uses Industry 4.0 concepts as the reference points. Future manufacturing and industrial concepts, as well as technologies, should also be taken into consideration, if relevant.

3. All dimensions should be considered, though the importance and relevance of each will vary depending on the nature of the industry and the company's current and future needs.

4. Companies should not feel compelled to achieve Band 5 across all dimensions. Instead, they should strive towards higher bandings based on specific business needs and aspirations.

5. The SIRI Assessment is more than a one-off exercise — it should be used on an ongoing basis.

Figure 9: The 5 Principles of Assessment

Once these considerations have been taken into account, companies can begin the assessment. Through open discussions, companies should measure their existing processes, systems, and structures. They should then score themselves in one of six bands for each of the 16 dimensions. The Assessment Matrix tool deliberately uses bands instead of scores, each of which represents a distinct stage of the Industry 4.0 transformation journey. This is because, in reality, each stage is better represented by a range rather than by a discrete point.

> *As part of our Smart Enterprise program, we have been investing in many initiatives to achieve significant improvements in speed, productivity, and quality. Here, we see this Assessment Matrix as a useful tool to help us to unlock maximum value by not only pushing us to investigate new dimensions that were not considered previously, but also allowing us to pursue our Industry 4.0 strategy in a more targeted fashion.*
>
> ***– Mr Laurent Filipozzi,** Site Head, Infineon Plant, Singapore*

ARCHITECT a comprehensive transformation strategy and implementation roadmap

According to PwC's 2016 Global Industry 4.0 survey, global industrial companies plan to invest US$907 billion (S$1260 billion) per year globally in Industry 4.0 over the next five years. With a growing number of companies looking to initiate or scale up their transformation initiatives, the SIRI Framework and Assessment Matrix serve as a timely guide to help them design a comprehensive strategy and roadmap for Industry 4.0 transformation — to ensure that they start out on the right footing.

In this third step, companies can use the SIRI Framework and Assessment Matrix in two tangible ways. First, the SIRI Framework serves as a checklist for companies, helping them to ensure that all the building blocks, pillars, and dimensions are formally considered. While the relative importance of each dimension may vary, companies must consider all the dimensions to ensure that all the ground is covered. Even if they ultimately decide to deprioritise specific dimensions and focus on others, it is important that these decisions be informed choices made after careful consideration.

Also, many industrial companies often fail to include improvements in complementary or adjacent domains that might yield additional benefits. This happens for two reasons. One, many companies tend to focus only on the domain directly related to the issue at hand: for instance, if a company employs too many low-skilled workers engaged in repetitive tasks, that company will tend to focus on increasing shop floor automation. Two, teams and companies tend to focus more on areas they are already familiar with: for example, a warehouse management team will naturally tend to focus on supply chain initiatives. Thus, the SIRI Framework serves as a checklist to provide companies with a systematic way to broaden the scope of their existing or future transformation initiatives.

Secondly, the Assessment Matrix doubles as a step-by-step improvement guide, breaking down and laying out the intermediate steps of the long-term Industry 4.0 transformation journey. These intermediate phases are necessary because even though there are many frameworks articulating the ideal Industry 4.0 end-state, few provide practical guidance on how to get there. Without proper guidance, many companies will struggle to develop a way to bridge the gap between their current "as-is" state and their "to-be" vision. This issue is often amplified for brownfield facilities, where limitations and considerations such as operational continuity, fragmented systems, and legacy infrastructure often dictate and limit the scale and feasibility of transformation initiatives. By providing clear definitions and descriptions for all bands across the 16 dimensions, the Assessment Matrix aims to address this challenge. It will enable companies to systematically identify high-impact initiatives and structure effective implementation plans with clearly defined phases, timelines, and targets.

> *Often, companies tend to focus excessively on shop floor automation and under-invest in equally important areas such as process design and workforce competency. The SIRI Framework serves as a useful counter-check to ensure that no dimensions are overlooked, in order to capture maximum value from any Industry 4.0 initiatives.*
>
> ***– Mr Yeoh Pit Wee,** Director for Manufacturing Operations, Rockwell Automation*

> *There are many grand Industry 4.0 visions and plenty of innovative solutions to achieve these visions. However, it is difficult to translate this into tangible steps that deliver real value to the business. A well-defined roadmap will be a big help in identifying the most appropriate technologies to apply and an execution plan, to achieve both short- and long-term goals.*
>
> ***– Mr Lim Hock Heng,*** *Site Director, GSK Singapore*

DELIVER impact and sustain transformation initiatives

As with all transformation initiatives, a well-designed strategy is only as good as its execution. Once a company has come up with its transformation roadmap, the next step is to put the right infrastructure, systems, and processes in place. Companies will need to determine the optimal approach to achieve their outcomes across the various phases and initiatives.

To ensure sustained impact, SIRI serves as a blueprint for companies to measure and refine their initiatives over a multi-year period. Transformation should not be short-lived but should instead be a long-term endeavour. Even as companies kick-start their transformation through quick wins, the right systems should be put in place to sustain these gains. Transformation strategies must also adapt and evolve continually, and companies should therefore consider establishing central, cross-functional teams to execute initiatives, monitor progress, assess impact, and identify future opportunities for improvement.

> *Like us, many companies have already started their transformation journey. Beyond addressing the operational concerns today, SIRI offers a useful framework to also guide our future decisions to deliver sustained impact. It also ensures that we're always moving in the right direction and focusing on the things that matter.*
>
> ***– Mr Goh Koon Eng,*** *General Manager, Chevron Oronite*

The Way Forward

Businesses must start taking decisive action today

Companies seeking to embrace Industry 4.0 often come from very different starting points, with different capabilities and varying levels of ambition. Some will require a comprehensive transformation of their operations, processes, and business models. Others may need to expand their focus and explore adjacent areas. That said, regardless of the starting point or the nature of the industry, companies of all sizes will benefit from Industry 4.0.

Collectively, SIRI's frameworks and tools offer a systematic approach for companies to start, scale, and sustain their transformation initiatives. Although the relative significance of the 3 building blocks, 8 pillars, and 16 dimensions will vary across different industries, the concepts within SIRI attempt to provide companies with a common language to boost internal alignment and co-innovation with external partners. With the SIRI Framework and the Assessment Matrix, companies have the opportunity to take decisive action today by following the four steps in the LEAD Framework — to set themselves on the right trajectory for transformation and growth.

Assessment Matrix: The 16 Dimensions

Process Building Block | Operations Pillar | Vertical Integration Dimension			
Vertical Integration is the integration of processes and systems across all hierarchical levels of the automation pyramid within a facility to establish a connected, end-to-end data thread.			
Band		**Definition**	**Description**
0	**Undefined**	Vertical processes are not explicitly defined.	Resource planning and technical production processes are managed and executed in silos, based on informal or ad-hoc methods.
1	**Defined**	Vertical processes are defined and executed by humans, with the support of analogue tools.[1]	Resource planning and technical production processes are managed and executed in silos, based on a set of formally defined instructions.
2	**Digital**	Defined vertical processes are completed by humans with the support of digital tools.	Resource planning and technical production processes are managed and executed in silos, by Operations Technology (OT) and Information Technology (IT) systems.
3	**Integrated**	Digitised vertical processes and systems are securely integrated across all hierarchical levels of the automation pyramid.[2]	OT and IT systems managing resource planning and technical production processes are formally linked; however, the exchange of data and information across different functions is predominantly managed by humans.
4	**Automated**	Integrated vertical processes and systems are automated, with limited human intervention.	OT and IT systems managing the resource planning and technical production processes are formally linked, with the exchange of data and information across different functions predominantly executed by equipment, machinery and computer-based systems.
5	**Intelligent**	Automated vertical processes and systems are actively analysing and reacting to data.	OT and IT systems are integrated from end to end, with processes being optimised through insights generated from analysis of data.

[1] Analogue refers to pre-digital methods of collecting, storing and sharing information (e.g. paper-based tracking systems).
[2] The industrial automation pyramid distributes systems in five levels: the field level, control level, production level, operations level, and enterprise planning level. Please refer to the definition of the automation pyramid in the Glossary for details.

Process Building Block | Supply Chain Pillar | Horizontal Integration Dimension			
Horizontal Integration is the integration of enterprise processes across the organisation and with stakeholders along the value chain.			
Band		**Definition**	**Description**
0	**Undefined**	Supply chain processes[3] are not explicitly defined.	Enterprise processes are managed and executed in silos, based on informal or ad-hoc methods.
1	**Defined**	Supply chain processes are defined and executed by humans, with the support of analogue tools.	Enterprise processes are managed and executed in silos, based on a set of formally defined instructions.
2	**Digital**	Defined supply chain processes are completed by humans with the support of digital tools.	Enterprise processes are managed and executed in silos by IT systems.
3	**Integrated**	Digitised supply chain processes and systems are securely integrated across business partners and clients along the value chain.	IT systems managing enterprise processes are formally linked; however, the exchange of data and information across different functions is predominantly managed by humans.
4	**Automated**	Integrated supply chain processes and systems are automated, with limited human intervention.	IT systems managing enterprise processes are formally linked, with the exchange of data and information across different functions being predominantly executed by computer-based systems.
5	**Intelligent**	Automated supply chain processes and systems are actively analysing and reacting to data.	IT systems are integrated from end to end, with processes being optimised through insights generated from analysis of data.

[3] Supply chain processes refer to the processes responsible for the flow and management of raw materials, inventory, goods, and services from the point of origin to the point of consumption.

Process Building Block | Product Lifecycle Pillar | Integrated Product Lifecycle Dimension			
Integrated Product Cycle is the integration of people, processes and systems along the entire product lifecycle, encompassing the stages of design and development, engineering, production, customer use, service, and disposal.			
Band		**Definition**	**Description**
0	**Undefined**	Product lifecycle[4] processes are not explicitly defined.	Processes along the product lifecycle are managed and executed in silos, based on informal or ad-hoc methods.
1	**Defined**	Product lifecycle processes are defined and executed by humans, with the support of analogue tools.	Processes along the product lifecycle are managed and executed in silos, based on a set of formally defined instructions.
2	**Digital**	Defined product lifecycle processes are completed by humans, with the support of digital tools.	Processes along the product lifecycle are managed and executed in silos, by digital tools.
3	**Integrated**	Digitised product lifecycle processes and systems are securely integrated across all stages of the product lifecycle.	Digital tools and systems that manage the product lifecycle are formally linked with each other; however, the exchange of information along the product lifecycle is predominantly managed by humans.
4	**Automated**	Integrated product lifecycle processes are automated, with limited human intervention.	Digital tools and systems that manage the product lifecycle are formally linked with each other, and the exchange of information along the product lifecycle is predominantly executed by computer-based systems.
5	**Intelligent**	Automated product lifecycle processes are actively analysing and reacting to data.	Digital tools and systems deployed for the management of the product lifecycle are integrated from end to end, with the processes being optimised through insights generated from analysis of data.

[4] The product lifecycle process refers to the process that every product goes through, from its initial conceptualisation to its eventual removal from the market. The stages include design, engineering, manufacturing, customer use, service, and disposal.

Technology Building Block | Automation Pillar | Shop Floor Automation Dimension			
Shop Floor Automation is the application of technology to monitor, control and execute the production and delivery of products and services, within the location where the production and management of goods is carried out.			
Band		**Definition**	**Description**
0	**None**	Repetitive production[5] and support processes[6] are not automated.	Production processes are executed by humans.
1	**Basic**	Repetitive production processes are partially automated, with significant human intervention. Repetitive support processes are not automated.	Production processes are executed by humans with the assistance of equipment, machinery and computer-based systems.
2	**Advanced**	Repetitive production processes are automated, with minimal human intervention. Repetitive support processes are not automated.	Production processes are predominantly executed by equipment, machinery and computer-based systems. Human intervention is required to initiate and conclude each process.
3	**Full**	Repetitive production processes are fully automated, with no human intervention. Repetitive support processes are partially automated, with limited human intervention.	Production processes are fully automated through the use of equipment, machinery and computer-based systems. Human intervention is required for unplanned events.
4	**Flexible**	Automated production processes are reconfigurable through plug-and-play automation. Repetitive support processes are partially automated, with limited human intervention.	Equipment, machinery and computer-based systems can be modified, reconfigured, and re-tasked quickly and easily when needed. Limited human intervention is required for unplanned events.
5	**Converged**	Flexible production and support processes are converged with enterprise and facility automation platforms to form highly autonomous networks.	Equipment, machinery, and computer-based systems are flexible and formally integrated with enterprise and facility systems, to allow for dynamic, cross-domain interactions.

[4] Production processes refer to standardised series of actions that directly result in the production of intermediate or finished goods.
[5] Support processes refer to standardised series of actions which exchange materials or data, but do not directly result in the production of intermediate or finished goods.

Technology Building Block | Automation Pillar | Enterprise Automation Dimension			
Enterprise Automation is the application of technology to monitor, control and execute processes, within the location where the administrative work is carried out. These processes include, but are not limited to, sales and marketing, demand planning, procurement, and human resource management and planning.			
Band		**Definition**	**Description**
0	**None**	Enterprise processes are not automated.	Enterprise processes are executed by humans.
1	**Basic**	Enterprise processes are partially automated, with significant human intervention.	Enterprise processes are executed by humans with the assistance of computer-based systems.
2	**Advanced**	Enterprise processes are automated, with minimal human intervention.	Enterprise processes are predominantly executed by computer-based systems. Human intervention is required to initiate and conclude each process.
3	**Full**	Enterprise processes are fully automated, with no human intervention.	Enterprise processes are fully automated through the use of computer-based systems. Human intervention is required for unplanned events.
4	**Flexible**	Automated enterprise processes are adaptable.	Computer-based systems can be modified, reconfigured, and re-tasked quickly and easily when needed. Limited human intervention is required for unplanned events.
5	**Converged**	Flexible enterprise processes are converged with shop floor and facility automation platforms to form highly autonomous networks.	Computer-based systems are flexible and formally integrated with those of shop floor and facility systems to allow for dynamic, cross-domain interactions.

Technology Building Block | Automation Pillar | Facility Automation Dimension			
Facility Automation is the application of technology to monitor, control and execute processes within the physical building and/or premises where the production area is located. These processes include but are not limited to the management of HVAC, chiller, security, and lighting systems.			
Band		**Definition**	**Description**
0	**None**	Facility processes are not automated.	Facility processes are executed by humans.
1	**Basic**	Facility processes are partially automated, with significant human intervention.	Facility processes are executed by humans, with the assistance of equipment, machinery and computer-based systems.
2	**Advanced**	Facility processes are automated, with minimal human intervention.	Facility processes are predominantly executed by equipment, machinery and computer-based systems. Human intervention is required to initiate and conclude each process.
3	**Full**	Facility processes are fully automated, with no human intervention.	Facility processes are fully automated through the utilisation of equipment, machinery and computer-based systems. Human intervention is required for unplanned events.
4	**Flexible**	Automated facility processes are adaptable.	Equipment, machinery and computer-based systems can be modified, reconfigured, and re-tasked quickly and easily when needed. Limited human intervention is required for unplanned events.
5	**Converged**	Flexible facility processes are converged with shop floor and enterprise automation platforms to form highly autonomous networks.	Equipment, machinery and computer-based systems are flexible and formally integrated with those of shop floor and enterprise systems to allow for dynamic, cross-domain interactions.

Technology Building Block | Connectivity Pillar | Shop Floor Connectivity Dimension			
Shop Floor connectivity is the interconnection of equipment, machines and computer-based systems, to enable communication and seamless data exchange, within the location where the production and management of goods is carried out.			
Band		**Definition**	**Description**
0	**None**	Production assets and systems are not connected.	Equipment, machinery and computer-based systems are not able to interact or exchange information.
1	**Connected**	Production assets and systems are connected via multiple communication technologies and protocols.	There are formal network links that will enable equipment, machinery and computer-based systems to interact or exchange information.
2	**Interoperable**	Connected production assets and systems are interoperable across multiple communication technologies and protocols.	Equipment, machinery and computer-based systems are able to interact and exchange information without significant restrictions.
3	**Interoperable And Secure**	Interoperable production assets and systems are secure.	There is a vigilant and resilient security framework to protect the network of interoperable equipment, machinery, and computer-based systems from undesired access and/or disruption.
4	**Real-Time**	Interoperable production assets and systems are secure and capable of real-time communication.	Interoperable and secure network links across different equipment, machinery and computer-based systems are able to interact or exchange information as the information is generated without delay.
5	**Scalable**	Interoperable production assets and systems are secure, capable of real-time communication, and scalable.	Existing networks can be configured quickly and easily to accommodate any modifications made to the existing composition of equipment, machinery and computer-based systems.

Technology Building Block | Connectivity Pillar | Enterprise Connectivity Dimension			
Enterprise Connectivity is the interconnection of equipment, machines and computer-based systems, to enable communication and seamless data exchange, within the location where the administrative work is carried out.			
Band		**Definition**	**Description**
0	**None**	Enterprise IT systems are not connected.	Computer-based systems are not able to interact or exchange information.
1	**Connected**	Enterprise IT systems are connected via multiple communication technologies and protocols.	There are formal network links that will enable computer-based systems to interact or exchange information.
2	**Interoperable**	Enterprise IT systems are interoperable across multiple communication technologies and protocols.	Computer-based systems are able to interact and exchange information without significant restriction.
3	**Interoperable And Secure**	Interoperable Enterprise IT systems are secure.	There is a vigilant and resilient security framework to protect the network of interoperable computer-based systems from undesired access and/or disruption.
4	**Real-Time**	Interoperable Enterprise IT systems are secure and capable of real-time communication.	Interoperable and secure network links across the different computer-based systems are able to interact or exchange information as the information is generated, without delay.
5	**Scalable**	Interoperable Enterprise IT systems are secure, capable of real-time communication, and scalable.	Existing networks can be configured quickly and easily to accommodate any modifications made to the existing composition of computer-based systems.

Technology Building Block | Connectivity Pillar | Facility Connectivity Dimension			
Facility Connectivity is the interconnection of equipment, machines and computer-based systems, to enable communication and seamless data exchange, within the physical building and/or land plot where the production area is located.			
Band		**Definition**	**Description**
0	**None**	Facility assets and systems are not connected.	Equipment, machinery and systems are not able to interact or exchange information.
1	**Connected**	Facility assets and systems are connected via multiple communication technologies and protocols.	There are formal network links that will enable equipment, machinery and computer-based systems to interact or exchange information.
2	**Interoperable**	Facility assets and systems are interoperable across multiple communication technologies and protocols.	Equipment, machinery and computer-based systems are able to interact and exchange information without significant restrictions.
3	**Interoperable And Secure**	Interoperable facility assets and systems are secure.	There is a vigilant and resilient security framework to protect the network of interoperable equipment, machinery, and computer-based systems from undesired access and/or disruption.
4	**Real-Time**	Interoperable facility assets and systems are secure and capable of real-time communication.	Interoperable and secure network links across different equipment, machinery and computer-based systems are able to interact or exchange information as the information is generated with delay.
5	**Scalable**	Interoperable facility assets and systems are secure, capable of real-time communication, and scalable.	Existing networks can be configured quickly and easily to accommodate any modifications made to the existing composition of equipment, machinery and computer-based systems.

Technology Building Block | Intelligence Pillar | Shop Floor Intelligence Dimension			
Shop Floor Intelligence is the processing and analysis of data to optimise existing processes and create new applications, products, and services, within the location where the production and management of goods is carried out.			
Band		**Definition**	**Description**
0	**None**	OT and IT systems are not in use.	No electronic or digital devices are used.
1	**Computerised**	OT and IT systems execute pre-programmed tasks and processes.	Equipment, machinery and computer-based systems are able to perform tasks based on pre-programmed logic.
2	**Visible**	Computerised OT and IT systems are able to identify deviations.	Equipment, machinery and computer-based systems are able to notify operators of deviations from predefined parameters.
3	**Diagnostic**	Computerised OT and IT systems are able to identify deviations and diagnose potential causes.	Equipment, machinery and computer-based systems are able to notify operators of deviations, and provide information on the possible causes.
4	**Predictive**	Computerised OT and IT systems are able to diagnose problems and predict future states of assets and systems.	Equipment, machinery and computer-based systems are able to predict and notify operators of potential deviations, and provide information on the possible causes.
5	**Adaptive**	Computerised OT and IT systems are able to diagnose problems, predict future states and autonomously execute decisions to adapt to changes.	Equipment, machinery and computer-based systems are able to predict and diagnose potential deviations, and independently execute decisions to optimise performance and resource efficiency.

Technology Building Block | Intelligence Pillar | Enterprise Intelligence Dimension			
Enterprise Intelligence is the processing and analysis of data to optimise existing administrative processes and create new applications, products and services.			
Band		**Definition**	**Description**
0	**None**	Enterprise systems are not in use.	No electronic or digital devices are used.
1	**Computerised**	Enterprise IT systems execute pre-programmed tasks and processes.	Enterprise computer-based systems perform tasks based on pre-programmed logic.
2	**Visible**	Enterprise IT systems are able to identify deviations.	Enterprise computer-based systems are able to notify relevant personnel of deviations from predefined parameters.
3	**Diagnostic**	Enterprise IT systems are able to identify deviations and diagnose potential causes.	Enterprise computer-based systems are able to notify relevant personnel of deviations, and provide information on the possible causes.
4	**Predictive**	Enterprise IT systems are able to diagnose problems and predict future states of assets and systems.	Enterprise computer-based systems are able to predict and notify relevant personnel of potential deviations, and provide information on the possible causes.
5	**Adaptive**	Enterprise IT systems are able to diagnose problems, predict future states, and autonomously execute decisions to adapt to changes.	Enterprise computer-based systems are able to predict and diagnose potential deviations, and independently execute decisions to optimise performance and resource efficiency.

Technology Building Block | Intelligence Pillar | Facility Intelligence Dimension			
Facility Intelligence is the processing and analysis of data to optimise existing processes and create new applications, products and services, within the physical building and premises where the production area is located.			
Band		**Definition**	**Description**
0	**None**	OT and IT systems are not in use.	No electronic or digital devices are used.
1	**Computerised**	OT and IT systems execute pre-programmed tasks and processes.	Equipment, machinery and computer-based systems perform tasks based on pre-programmed logic.
2	**Visible**	Computerised OT and IT systems are able to identify deviations.	Equipment, machinery and computer-based systems are able to notify relevant personnel of deviations from predefined parameters.
3	**Diagnostic**	Computerised OT and IT systems are able to identify deviations and diagnose potential causes.	Equipment, machinery and computer-based systems are able to notify relevant personnel of deviations, and provide information on possible causes.
4	**Predictive**	Computerised OT and IT systems are able to diagnose problems and predict future states of assets and systems.	Equipment, machinery and computer-based systems are able to predict and notify relevant personnel of potential deviations, and provide information on the possible causes.
5	**Adaptive**	Computerised OT and IT systems are able to diagnose problems, predict future states, and autonomously execute decisions to adapt to changes.	Equipment, machinery and computer-based systems are able to predict and diagnose potential deviations, and independently execute decisions to optimise performance and resource efficiency.

Organisation Building Block | Talent Readiness Pillar | Workforce Learning & Development Dimension			
Workforce Learning & Development ("L&D") is a system of processes and programmes that aims to develop the workforce's capabilities, skills and competencies to achieve organisational excellence.			
Band		**Definition**	**Description**
0	**Informal**	Informal mentorship and apprenticeship are the predominant modes of workforce L&D.	There is no formal L&D curriculum to on-board and train the workforce.
1	**Structured**	Formally designed training curriculum for skills acquisition is the predominant mode of workforce L&D.	There is a formal L&D curriculum with clear commencement and conclusion points. The scope of L&D is limited to skills acquisition.
2	**Continuous**	Structured L&D programmes are designed to run on an ongoing basis, to enable the ongoing enhancement and/or expansion of employees' skillsets.	There is a structured L&D curriculum that adopts an approach of continuous learning, to enable the constant learning, re-learning, and improvement of new and existing skills.
3	**Integrated**	Continuous L&D programmes are formally aligned with the organisation's business needs and human resources (HR) functions.	There is a continuous L&D curriculum that is integrated with organisational objectives, talent attraction, and career development pathways.
4	**Adaptive**	Integrated L&D programmes are actively developed, refreshed and customised based on insights provided by key stakeholders through feedback loops.	Formal feedback channels are in place to allow integrated L&D programmes to be jointly curated and updated by employees, HR, and business teams.
5	**Forward-looking**	Active efforts are made to identify and incorporate innovative L&D practices and training for future skillsets into the adaptive L&D programmes.	There are proactive steps to incorporate requirements for future skillsets and novel L&D methodologies into existing L&D programmes.

Organisation Building Block | Talent Readiness Pillar | Leadership Competency Dimension			
Leadership Competency refers to the readiness of the management core to leverage the latest trends and technologies for the continued relevance and competitiveness of the organisation.			
Band		**Definition**	**Description**
0	**Unfamiliar**	Management is unfamiliar with the most recent trends and technologies.	Management is unacquainted with the latest concepts that can enable the next phase of advancement.
1	**Limited Understanding**	Management has some awareness, through ad hoc channels, of the most recent trends and technologies.	Management is partially familiar with the latest concepts that can enable the next phase of advancement.
2	**Informed**	Management is well-informed, through formal channels and avenues, of the most recent trends and technologies.	Management is fully familiar with the latest concepts that can enable the next phase of advancement.
3	**Semi-dependent**	Management is reliant on external partners to develop initiatives that leverage on the most recent trends and technologies to improve at least one area of the organisation.	With external assistance, management is able to apply the latest concepts to enable improvements in at least one area.
4	**Independent**	Management is able to, with relative independence, develop initiatives that leverage on the latest trends and technology to improve more than one area of the organisation.	Management is able to apply the latest concepts to enable improvements across multiple areas.
5	**Adaptive**	Management is able to independently adapt its organisational transformation framework to changing trends and technologies.	Management is able to augment its improvement initiatives as the latest concepts change or evolve over time.

Organisation Building Block | Structure & Management Pillar | Inter- and Intra- Company Collaboration Dimension			
Inter- and Intra- Company Collaboration is the process of working together, through cross-functional teams and with external partners, to achieve a shared vision and purpose.			
Band		**Definition**	**Description**
0	**Informal**	Communication and information sharing across teams happens on an informal basis.	Teams generally work in silos. Communication and collaborations happen on a casual, ad hoc basis.
1	**Communicating**	Formal channels are established for communication and information sharing across teams.	Teams are provided with formal avenues to exchange information.
2	**Cooperating**	Formal channels are established to allow teams to work together on discrete/one-off tasks and projects.	Teams are provided with formal avenues to interact and work on discrete tasks and projects together.
3	**Coordinating**	Teams are empowered by the organisation to make adjustments that will facilitate cooperation on discrete tasks and projects.	Teams have the mandate to alter or adjust certain obligations and responsibilities, to reduce the barriers for cooperation on joint tasks and projects.
4	**Collaborating**	Teams are empowered by the organisation to share resources on both discrete and longer-term tasks and projects.	Teams have the mandate to commit resources to both discrete and longer-term tasks and projects. Risks, responsibilities, and rewards are partially shared.
5	**Integrated**	Formal channels are established to enable dynamically forming teams to work on cross-functional projects with shared goals, resources and KPIs.	Teams can be formed with flexibility and agility to address problem statements as they arise. Risks, responsibilities, and rewards are predominantly shared.

Organisation Building Block | Structure & Management Pillar | Strategy & Governance Dimension			
Strategy & Governance is the design and execution of a plan of action to achieve a set of long-term goals. It includes identifying priorities, formulating a roadmap, and developing a system of rules, practices and processes to translate a vision into business value.			
Band		**Definition**	**Description**
0	**None**	Transformation towards a Factory/Plant-of-the-Future is not present in any part of the organisation strategy.	Intentions to establish a Factory/Plant-of-the-Future are not identified as a strategic focus in the company's current or future plans.
1	**Formalisation**	Transformation towards a Factory/Plant-of-the-Future has been formally identified as a business strategy at the corporate or business level.	Intentions to establish a Factory/Plant-of-the-Future have been identified as a strategic focus in the company's current or future plans.
2	**Development**	Transformation initiative towards a Factory/Plant-of-the-Future is being developed or has been developed by a dedicated team.	A long-term strategy and governance model to establish a Factory/Plant-of-the-Future is being developed or has been developed.
3	**Implementation**	Transformation initiative towards a Factory/Plant-of-the-Future has been formally implemented in least one functional area.	The long-term strategy and governance model to establish a Factory/Plant-of-the-Future has been put into action.
4	**Scaling**	Transformation initiative towards a Factory/Plant-of-the-Future is expanded to include more than one functional area.	The long-term strategy and governance model to establish a Factory/Plant-of-the-Future is scaled up to include other secondary areas.
5	**Adaptive**	Transformation initiative towards a Factory/Plant-of-the-Future is refreshed and updated dynamically.	The long-term strategy and governance model to establish a Factory/Plant-of-the-Future is constantly reviewed and dynamically refreshed to account for the latest advancements in technology, business philosophy, and practices.

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8. Infineon Technologies Asia Pacific Pte Ltd
9. JEP Precision Engineering Pte Ltd
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11. PBA Systems Pte Ltd
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Glossary

A

Adaptable
Able to adjust to new conditions.

Analogue tools
Tools that are not digital in nature, such as conventional paper-based tracking.

Artificial intelligence
The ability of a machine to mimic cognitive functions that humans associate with other human minds, such as learning and problem solving.

Automation pyramid
The industrial automation pyramid distributes systems in five levels. These levels are:

- **Level 0 (Field level):** Sensors and actuators interface directly with physical production processes.
- **Level 1 (Control level):** Machines and systems are operated and managed. This level includes control systems such as PLCs and SDCDs.
- **Level 2 (Production level):** Product lines are monitored, supervised, and controlled. This level includes supervisory systems such as SCADAs and PIMS.
- **Level 3 (Operations level):** Production planning and quality management are managed by tools like Manufacturing Execution Systems (MES).
- **Level 4 (Enterprise planning level):** Order management and other enterprise-level processes are managed by corporate planning tools. This level includes tools such as ERPs.

Autonomous network
A network that is able to function without human input.

B

Big data
Data set(s) with characteristics (e.g. volume, velocity, variety, variability, veracity, etc.) that cannot be efficiently processed using existing technologies and techniques to extract value for a particular problem domain at a given point in time.

C

Cloud computing
A model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications, and services) that can be rapidly provisioned and realised with minimal management effort or service provider interaction.

Communication protocol
A system of rules that allows two or more entities of a communications system to transmit information via any kind of variation of a physical quantity. The protocol defines the rules syntax, semantics, and synchronisation of communication, as well as possible recovery methods. Protocols may be implemented by hardware, software, or a combination of both.

Communication technology
See “Information Technology”.

Cyber-physical system (CPS)
A system that links physical objects/processes with digital elements/processes via open and constantly interconnected information networks.

D

Data analytics
The process of inspecting, cleansing, transforming and modelling data with the objectives of discovering useful information, suggesting conclusions, and supporting decision-making. Examples of data analytics techniques include data mining, machine learning and business intelligence.

Digital tools
Electronic technology that generates, stores, and processes data that humans can utilise to complete a given task. Such tools include tablets, digital design programmes, etc.

Digital twin
A dynamic digital replica of physical assets, processes and systems. Sensor information and other input data are used to enable the digital twin to mirror and predict the activities or performance over the life of its corresponding physical twin.

Digitalisation
The use of digital technologies to change a business model and provide new revenue and value-producing opportunities. It is the process of moving to a digital business.

Digitisation
The conversion of information (e.g. text, sounds, images, etc.) into a digital format, where information is organised into bits.

Discrete manufacturing
Production process where output is individually identifiable and measurable in distinct units, rather than by weight or volume. Examples include consumer electronics, automobile manufacturing, etc.

Dynamic
Used to describe processes or systems that constantly improve performance by changing system parameters in response to varying operational conditions.

F

Fixed automation
Fixed automation uses specially purposed equipment or systems to automate a particular task. However, it is difficult to alter or change their design.

Flexible automation
An extension of programmed automation, flexible automation refers to equipment which can be easily and rapidly reconfigured to accommodate changes in product design and/or manufacturing processes.

I

Information Technology (IT)
The use of computers, storage, networking and other physical devices, infrastructure, and processes to create, process, store, secure, and exchange all forms of electronic data.

Industrial Internet of Things (IIoT)
The application of the Internet of Things to the manufacturing, logistics, oil and gas, transportation, energy/utilities, mining and metals, aviation, and other industrial sectors.

Industry 4.0
Describes the organisation of production processes based on technology and devices autonomously communicating with each other along the value chain. There are six design principles in Industry 4.0:

- **Interoperability**: The ability of machines, devices, sensors, and people to connect and communicate with each other through the Internet of Things.
- **Virtualisation**: The ability of cyber-physical systems to create and simulate a virtual copy of the physical factory, and monitor the objects in the surrounding environment.
- **Decentralisation**: The ability of cyber-physical systems to make decisions independently and to perform tasks as autonomously as possible. In the case of exceptions or conflicting goals, tasks are automatically delegated to a higher level.
- **Real-Time Capability**: The ability to collect and analyse data on an on-going basis, and to provide up-to-date insights as new information is input into the system.
- **Service Orientation**: The emphasis that production must be customer-oriented, where products are consistently updated to the latest customer specifications through an efficient, digitalised product lifecycle feedback loop.
- **Modularity**: The ability to respond quickly and adapt effectively to dynamic business environments.

Internet of Things (IoT)
The infrastructure of interconnected objects, people, systems, information resources, and intelligent services with the ability to process information from the physical and virtual worlds and react accordingly.

Interoperable
The ability of two or more systems or components to exchange information and to use the information that has been exchanged.

IT/OT convergence
The integration of Information Technology (IT) systems used for data-centric computing with Operational Technology (OT) systems used to monitor and control how physical devices perform. Examples of OT systems include Computer Numerical Control (CNC) systems, Programmable Logic Controllers (PLCs), etc.

O

Operational Technology (OT)
Hardware and software that detects or causes changes in physical processes through the direct monitoring and/or control of physical devices such as valves or pumps.

Organisational governance
System by which organisations are directed and controlled.

P

Plug-and-play
Denotes software or devices that are intended to work perfectly when first used or connected, without the need for physical device reconfiguration or adjustment by the user.

Preprogrammed logic
Predefined sequences written in electronic devices that are designed to control the logical sequence of events in an industrial setting.

Process manufacturing
Production process where output is typically produced in bulk quantities, as opposed to discrete and countable units. Examples include chemicals, gasoline, and pharmaceutical production.

Programmed automation
Programmed automation means that the equipment or machine has the capacity to change the sequence of operations to accommodate different task configurations, usually through adjustment of a coded program or by having changeable parts.

R

Real-time
Used to describe systems where input data is processed within milliseconds, such that it is available almost immediately as feedback to the process from which it is coming.

S

Secure
The activity or process, ability or capability, or state whereby information and communications systems and the information contained therein are protected from and/or defended against damage, unauthorised use or modification, or exploitation.

Smart factory
A facility where the degree of integration across systems is sufficiently high to enable self-organisation and self-optimisation in production processes and all business processes relating to production.

System integration
The process of linking together different computing systems and software applications physically or functionally to act as a coordinated whole.

V

Value chain
Sequence of value-creation processes undertaken by organisations, including but not limited to production, marketing, and the provision of after-sales services.

Value chain networks
Interconnected networks of value chains.

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