

THE PRIORITISATION MATRIX

CATALYSING THE TRANSFORMATION OF MANUFACTURING





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The **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

Since the term *Industrie 4.0* was introduced in 2011, the conversation in the global manufacturing community has evolved from learning about its key concepts and benefits to exploring how to best implement transformation roadmaps.

Today, few companies doubt the benefits of Industry 4.0. Instead, companies are asking a new set of questions around implementation: How can I start? What should I focus on? As companies become more aware about Industry 4.0, it is evident that taking the next step towards implementation is not an easy one.

In 2017, Singapore launched the Smart Industry Readiness Index ("the Index") to help manufacturers learn about the key tenets of Industry 4.0. We also introduced an Assessment Matrix to help manufacturers evaluate the existing state of their facilities and assess their Industry 4.0 readiness levels. The Index was well-received and has helped many companies kick-start their Industry 4.0 journey over the last two years. Looking ahead, we realised that we needed to do more to help companies better design and execute their transformation roadmaps.

Developed with the support of our partners and Industry 4.0 thought leaders – McKinsey & Company, SAP, Siemens, and TÜV SÜD – this new Prioritisation Matrix seeks to guide manufacturers, in Singapore and around the world, identify the areas of focus that will yield the greatest benefit to them. We believe that the ability to prioritise will alleviate the uncertainties that manufacturers face, and be the needle-mover in accelerating the pace of Industry 4.0 transformation.



Dr Beh Swan Gin Chairman Singapore Economic Development Board

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Executive Summary

Over the last few years, many manufacturers' understanding of Industry 4.0 and its potential value has grown steadily. Yet, many have been unable to translate their acquired knowledge to actionable transformation plans. According to a 2018 McKinsey survey of manufacturing companies, while 75 per cent of respondents recognised that Industry 4.0 solutions could improve business performance, only 13 per cent had embarked on Industry 4.0 initiatives. Many manufacturers that completed the Smart Industry Readiness Index Assessment Matrix also reflected the same uncertainty regarding next steps.

This gap between awareness and implementation is usually due to companies lacking an overall Industry 4.0 roadmap.

Prioritisation is a critical exercise for companies that enables them to formulate an effective Industry 4.0 roadmap as it helps them identify focus areas that will generate the greatest value. Having clearly-identified focus areas drives both informed decision-making and effective resource allocation.

Despite the importance of prioritisation, there has been little assistance and guidance available for manufacturers – big and small – that wish to embark on this process in a robust and comprehensive way. This whitepaper is a deliberate attempt to help companies approach prioritisation in a systematic fashion that is both robust and comprehensive.

TIER: A Holistic Framework for Prioritisation

The TIER framework provides a conceptual structure that underscores four key principles companies must consider for a holistic prioritisation.





TODAY'S STATE

Develop an in-depth understanding of the company's current Industry 4.0 maturity level





IMPACT TO BOTTOM LINE

Analyse how distinct
Industry 4.0 areas affect the
company's profits and
identify those that can
generate the greatest
financial return





ESSENTIAL BUSINESS OBJECTIVES

Determine the business objectives that are most critical to the company to guide the selection of relevant Industry 4.0 areas





REFERENCES TO THE BROADER COMMUNITY

Emulate successes and learn from the mistakes of the broader manufacturing community.

The Prioritisation Matrix

To help companies translate the four principles into practice, the Prioritisation Matrix was developed with the support of knowledge partners McKinsey & Company, SAP, Siemens and TÜV SÜD. Designed as a management planning tool, the Prioritisation Matrix brings together four inputs which each reflect a key principle of prioritisation represented in the TIER framework. The goal is to assist companies in quantitatively identifying the high-priority Index Dimensions where improvements will bring the most benefit.

THE PRIORITISATION MATRIX FORMULA



The Way Forward

Together, the TIER framework and Prioritisation Matrix offer a holistic approach to help ensure that companies move in the right direction as they forge ahead with their Industry 4.0 transformations roadmaps.

An application has been developed to automate the calculation of Impact Values, also known as the potential impact of improvements, across all 16 Index Dimensions. Companies interested to use the application may approach the authors or any of the knowledge partners.

Introduction

Industry 4.0 Transformation Journey: The LEAD Framework

Transforming and upgrading a manufacturing facility is not a one-off exercise for companies. Rather, it is a continuous journey and iterative process for companies, and their experience can be encapsulated by the LEAD framework:

- 1 LEARN key concepts and build a common language for alignment;
- 2 EVALUATE the state of existing facilities and the company's readiness level for Industry 4.0;
- 3 ARCHITECT a comprehensive transformation strategy and implementation roadmap; and
- 4 DELIVER impact and sustain transformation initiatives

THE LEAD FRAMEWORK

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LEARN

Learn key concepts and build common language for alignment

EVALUATE

Evaluate the state of existing facilities and the company's readiness level

ARCHITECT

Architect a comprehensive transformation strategy and implementation roadmap

DELIVER

Deliver impact and sustain transformation initiatives

Figure 1: The LEAD Framework

Background: The Smart Industry Readiness Index (2017)

To help manufacturers take the first step on their transformation journey, the Singapore Economic Development Board ("EDB") launched the Smart Industry Readiness Index ("the Index") and its accompanying Assessment Matrix in November 2017.

The Assessment Matrix is the world's first self-diagnostic Industry 4.0 tool aimed at helping companies worldwide – regardless of size, industry, and digital maturity – determine how to start, scale and sustain their Industry 4.0 transformation.

Created in partnership with TÜV SÜD and validated by a global advisory panel of industry experts,

the Index was designed to strike a balance among technical rigour, usability and relevance.

The Index identifies 3 fundamental building blocks of Industry 4.0: Technology, Process, and Organisation. All 3 building blocks must be considered to harness the full potential of Industry 4.0. Underpinning the 3 building blocks are 8 key pillars, which represent critical aspects that companies must focus on to become future-ready organisations. Finally, the 3 building blocks and 8 pillars map onto 16 dimensions, which are areas of assessment that companies can use to evaluate the current Industry 4.0 readiness of their facilities.

PROCESS TECHNOLOGY Organisation Operations Supply Chain Vertical Integration Integration Integration Technology Organisation Talent Readiness Structure & Management Automation Connectivity Intelligence Automation Shopfloor 4. 7. 10. Enterprise Enterprise 5. 8. 11. Facility Facility Competency Strategy & Governance Strategy & Governance Strategy & Governance

Figure 2: The 16 Dimensions of Assessment

A Perennial Challenge: Moving from Awareness to Implementation

Since its launch, the Index has helped many companies better understand Industry 4.0 and its potential value to their manufacturing facilities. Despite the increased knowledge, the majority of

firms remained noncommittal about developing and executing action plans, exposing a significant gap between awareness and implementation of Industry 4.0 solutions.

THE GAP FROM AWARENESS TO IMPLEMENTATION

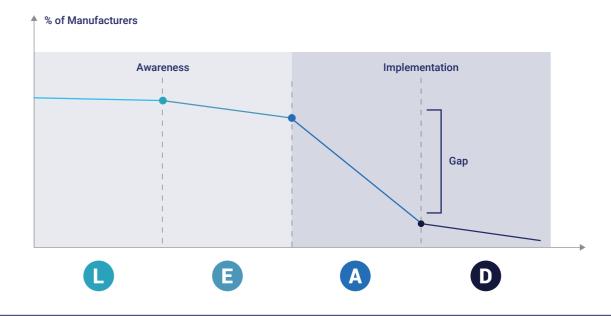


Figure 3: The Gap from Awareness to Implementation

This observation is also echoed by various global consultancy reports and surveys. For example, in a 2018 McKinsey survey of over 200 manufacturing companies across six ASEAN markets, 75 per cent of respondents recognised that Industry 4.0 technologies and concepts could improve business performance, yet only 13 per cent had embarked on Industry 4.0 initiatives.

Referencing the LEAD framework, it is apparent that manufacturers continue to be apprehensive in moving from the Evaluation phase to the Architecting phase of their digital transformation journey.

"The overarching objective of the Index is to help manufacturers leverage Industry 4.0 technologies and concepts to stay relevant and competitive in an increasingly digital age. As more companies develop a better understanding of their manufacturing facilities' Industry 4.0 maturity level, we must work more closely with them to translate their knowledge into action. Prioritisation is an important step to achieve that."

- Mr Lim Kok Kiang, Assistant Managing Director, EDB

Prioritisation: Key to Bridging the Awareness-Implementation Gap

There are many reasons why companies have been slow to adopt Industry 4.0 solutions despite high levels of awareness. One of the most commonly cited barriers is the lack of an effective strategy. In a world of scarce resources, information overload, and pressures to deliver short-term results, a clear Industry 4.0 vision is essential for companies to push beyond small-scale pilots and embrace real transformative projects.

Prioritisation plays an important role in closing the awareness-implementation gap as it is a critical exercise for any company formulating an Industry 4.0 strategy and roadmap. Prioritisation enables companies to identify focus areas that will generate the greatest value, which drives informed decision-making and effective resource allocation.

Despite the importance of prioritisation, there has been little assistance and guidance available for manufacturers – big and small – that wish to embark on this process in a robust and comprehensive way.

This whitepaper thus aims to provide a conceptual framework and an accompanying tool to help the global manufacturing community unlock the power of prioritisation. Adopting the terminology of the LEAD framework, it is an attempt to support companies in Architecting their digital transformation, and progressing toward implementation and Delivery.

"Prioritisation is important for companies to gain clarity on the right Industry 4.0 areas to focus on, but it must be carried out in a rigorous manner to drive the right outcomes. The TIER framework and Prioritisation Matrix is a first-of-its-kind reference to catalyse the digital transformations of manufacturing sectors."

- Mr Raimund Klein, Executive Vice President & Head, Digital Industries, ASEAN, Siemens

TIER: The 4 Principles of Prioritisation

TIER: A Holistic Prioritisation Framework

Companies may find it challenging to prioritise their Industry 4.0 focus areas. One of the most common mistakes is failing to factor in all necessary considerations for a holistic prioritisation, resulting in suboptimal outcomes.

What are the key elements that my company should consider? How might my company conduct the prioritisation exercise in a systematic fashion? These are crucial questions that manufacturers are asking today.

To help them unlock answers, this whitepaper establishes four key principles of prioritisation.

These four principles – collectively known as the TIER framework – will help manufacturers hone in on the Industry 4.0 areas where improvements made will deliver the greatest value. This will enable companies to start, scale and sustain their Industry 4.0 transformation journeys in the right direction.





TODAY'S STATE

Develop an in-depth understanding of the company's current Industry 4.0 maturity level





IMPACT TO BOTTOM LINE

Analyse how distinct Industry 4.0 areas affect the company's profits and identify those that can generate the greatest financial return





ESSENTIAL BUSINESS OBJECTIVES

Determine the business objectives that are most critical to the company to guide the selection of relevant Industry 4.0 areas





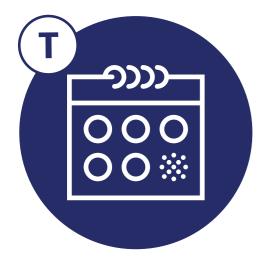
REFERENCES TO THE BROADER COMMUNITY

Emulate successes and learn from the mistakes of the broader manufacturing community.

Figure 4: The TIER Framework

Smart Industry Readiness Index | The Prioritisation Matrix

Catalysing The Transformation Of Manufacturing



TODAY'S STATE

Develop an in-depth understanding of the company's current Industry 4.0 maturity level

Before starting any prioritisation exercise, it is important for companies to be aware of the present state of their factories. This can be achieved by conducting a detailed and ideally independent assessment of their manufacturing facilities. With that knowledge, manufacturers can identify areas of strengths to build on and areas of weaknesses for improvements. It can also empower companies to identify the most pressing opportunities for positive change.

A comprehensive and neutral evaluation of their manufacturing facilities will also allow companies to review any existing beliefs or preconceived notions that may be outdated or inaccurate.

Awareness and willingness to address potential misperceptions is also a critical early step in developing a well-defined transformation plan.



IMPACT TO BOTTOM LINE

Analyse how distinct Industry 4.0 areas affect the company's profits and identify those that can generate the greatest financial return

Companies exist to sell goods and/or services for profit, and their fundamental aim is to maximise profits. While there may be numerous initiatives that a company finds exciting and appealing, some might not be financially feasible. Even initiatives that are economically viable will vary in their return on investments and profitability.

Hence, a company must constantly decide how to allocate its resources while bearing in mind its profit maximisation objective.

Any manufacturer that intends to adopt Industry 4.0 concepts and technologies must therefore carefully consider the potential impact on profits. For instance, if a company's utilities costs make up a significant percentage of revenue, investing in digital technologies that reduce energy and water consumption will likely result in bigger savings compared to investments in another area like IT integration.

By being mindful of the impact of an Industry 4.0 area on the bottom line, companies will be better equipped to identify action areas that will yield the greatest financial benefits and consequently, ensure a more sustainable Industry 4.0 transformation.



ESSENTIAL BUSINESS OBJECTIVES

Determine the business objectives that are most critical to the company to guide the selection of relevant Industry 4.0 areas

Understanding the current state of a manufacturing facility is not enough for prioritisation. It is also vital to determine the aspirational state that a company is striving towards, which is guided by its essential business objectives.

As such, the third principle of prioritisation involves determining the business objectives that matter to a company, and the extent to which they matter. Business objectives are measurable indicators of what constitute success to a company, which may not necessarily have a direct or immediate impact on the company's bottom line. They can be described by specific outcomes like achieving net zero emissions in production or significant reductions in Time to Market.

When companies are clear about which business objectives matter and how much they matter, they will likely have more success in narrowing down the list of Industry 4.0 areas and selecting the ones that best help them move from their current states to their aspirational states. This ensures that manufacturers spend time and effort on areas that will address their own unique problems and yield outcomes that matter most.



REFERENCES TO THE BROADER COMMUNITY

Emulate successes and learn from the mistakes of the broader manufacturing community

As companies seek to transform their manufacturing facilities, it is not enough to rely solely on introspective and retrospective data points to guide the architecture of their future states. Even though there are no universal Industry 4.0 maturity benchmarks today, conducting a comparative analysis of firms across the manufacturing industry enables companies to establish objective reference points against Industry 4.0 leaders and laggards.

Therefore, the final principal of prioritisation encourages companies to look outwardly toward the rest of the manufacturing sector. No company is alone on its journey towards Industry 4.0 transformation. By discerning the factors of success and avoiding the common mistakes of others, all firms in the manufacturing community can each develop reference models for potential Industry 4.0 areas that have the highest probability of delivering value.

"Many companies that have begun their Industry 4.0 transformations find themselves stuck at the pilot stage. Our research shows the successful ones are those that holistically tackle business processes, technology architecture, and organisation challenges. With this logic, the Prioritisation Matrix helps companies understand where to further diagnose, design, and ultimately implement Industry 4.0 at scale."

- Dr Alpesh Patel, Director of Digital Capability Centre, Singapore, McKinsey & Company

The Smart Industry Readiness Index Prioritisation Matrix

Objectives and Intent

The TIER framework is a high-level conceptual guide for companies that wish to embark on a comprehensive and rigorous prioritisation exercise. To translate the four TIER principles into practice, the Prioritisation Matrix was developed to help provide recommendations that are company-specific and directionally correct.

The Prioritisation Matrix is a management planning tool for manufacturers to identify high-impact Industry 4.0 focus areas, after they have used the Assessment Matrix to determine the Industry 4.0 maturity of their manufacturing facilities. Specifically, the Prioritisation Matrix aims to equip companies with knowledge of which Index Dimensions to prioritise and the corresponding Assessment Matrix Bands ("Bands") to aspire towards.

Development Process

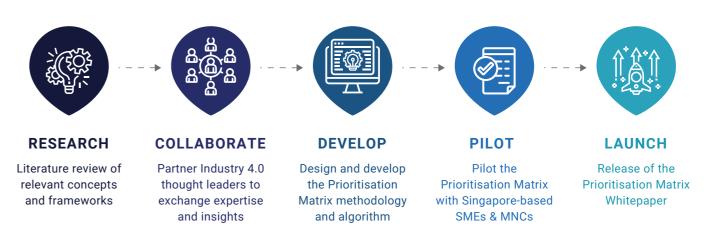


Figure 5: Development Methodology

The development of the Prioritisation Matrix began with a wide-ranging literature review 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.

McKinsey & Company, SAP, Siemens, and TÜV SÜD were consulted as knowledge partners in the development process to ensure the technical robustness of the Prioritisation Matrix. As established leaders in their respective fields, the knowledge partners provided their expertise, counsel, and repository of over 200 case studies to enhance the integrity of the tool.

The Prioritisation Matrix was then piloted with a group of Singapore-based manufacturers, ranging from small and medium-sized enterprises ("SMEs") to multinational corporations ("MNCs") across both discrete and process industries.

Each pilot was conducted through a workshop involving the company's senior management, operations, and finance teams. The insights, suggestions, and feedback gained from each pilot were used to further refine the Prioritisation Matrix.

"There is no shortage of technologies, products and solutions for the average manufacturing facility that wants to start its digitalisation journey. The challenge is in knowing which areas to work on to realise the greatest amount of benefit given a certain amount of resources available. The Prioritisation Matrix serves as a useful and neutral tool to guide companies to identify those areas."

- Dr Andreas Hauser, Director, Digital Services, TÜV SÜD

The Prioritisation Matrix Formula

The Prioritisation Matrix formula brings together four inputs, each reflecting a key principle of prioritisation represented in the TIER framework.

To identify the high-priority Index Dimensions, the formula generates the Impact Value per Band improvement ("Impact Value") across the 16 Index Dimensions.

The Impact Value represents the relative benefit that a company will gain from progressing by a single Band within a particular Index Dimension. By comparing the Impact Values of the different Band improvements, manufacturers will be able to quantitatively identify the specific Index Dimensions to prioritise, and the precise Bands to aspire towards.



Figure 6: The Prioritisation Matrix Formula

"The strength of the Prioritisation Matrix lies in its data-driven, quantitative mode of analysis. This ensures credibility and precision in identifying digital transformation opportunities from the factory floor to the board room. We strongly believe that the enhanced Smart Industry Readiness Index will help businesses realise their Industry 4.0 vision."

- Mr Chern Chuen Khor, Managing Director, SAP

Inputs into the Prioritisation Matrix

- Assessment Matrix Score
- 2 Revenue-Cost Profile
- 3 Key Performance Indicators
- 4 Proximity to Best-in-Class

Assessment Matrix Score

The Assessment Matrix helps companies identify the current Industry 4.0 maturity levels (ranging from Band 0 to Band 5) of their manufacturing facilities across 16 Index Dimensions. This is referred to as the Assessment Matrix Score.

The Assessment Matrix Score is the first input into the Prioritisation Matrix because it serves as the baseline for companies to measure the impact of potential changes and track the progress of their transformation. Using the Assessment Matrix Score also provides companies with a common language for goal-setting in their digital transformation roadmaps.

To learn more about the Assessment Matrix

Companies may refer to "The Singapore Smart Industry Readiness Index" published in November 2017 for the full Assessment Matrix, which contains detailed descriptions of each Band across the 16 Index Dimensions.

"The Prioritisation Matrix factors in elements like cost categories and KPIs which are important considerations for my company's management team. This tool has been helpful in guiding our planning and progress along our digital transformation roadmap."

- Mr Amos Leong, CEO, The Univac Group

Revenue-Cost Profile

The Revenue-Cost Profile refers to the breakdown of a company's profit and loss ("P&L") categories as a percentage of its overall revenue. For instance, if a company has an annual revenue of \$100 million and spends \$15 million on maintenance and repairs, then maintenance and repair costs can be represented as 15 per cent of the company's overall revenue.

This information is essential for the Prioritisation Matrix as it prompts companies to place more

emphasis on Index Dimensions that have greater influence over the key cost drivers. This ensures that the recommended Index Dimensions for prioritisation will be those that deliver the greatest financial benefits to companies.

This whitepaper distils the Revenue-Cost Profile into ten P&L categories that are commonly reflected in companies' financial statements.

How a company's Revenue-Cost Profile influences the prioritisation of Index Dimensions

If a company's direct labour cost is 50 per cent of its overall revenue while its utilities cost is only five per cent, then directing resources to achieve improvements in a Dimension like Shop Floor Automation (strongly correlated to reducing labour costs) is likely to be more valuable than investing in another Dimension like Facility Connectivity (strongly correlated to reducing energy costs).

"At Rockwell Automation, we recognise the urgency to bring the Connected Enterprise to life to maintain our competitiveness. The TIER framework provides us with a comprehensive, yet easy-to-use approach to guide our digital transformation efforts towards areas that are of high-impact to our company."

Smart Industry Readiness Index | The Prioritisation Matrix

- Mr Yeoh Pit Wee, Director of Operations for Asia-Pacific, Europe, Middle East and Africa, **Rockwell Automation**

P&L Category	Description
Aftermarket Services / Warranty	Expenses that the company expects to or has already incurred for the repair or replacement of goods that it has sold. The total expense is limited by the warranty period that the company provides.
Depreciation	A non-cash expense representing the portion of all fixed assets owned by the company that has been considered consumed over an accounting or financial period.
Labour	The sum of all wages paid to employees, as well as the cost of employee benefits and payroll taxes paid by an employer. This covers employees who are directly involved in the maintenance and production processes, and support teams that ensure the smooth running of the entire facility.
Maintenance & Repair	All expenses required to bring capital assets – such as building, infrastructure, equipment, and machinery – back to good working order, or to keep them operating in optimal condition. This includes fixing broken assets and routine servicing.
Raw Materials & Consumables	Inventory of all component parts currently in stock that have not yet been used in work-in-process or finished goods production. They include both direct materials, which are incorporated into the final product, and indirect materials that are consumed during the production process but not incorporated into the final product.
Rental & Operating Lease	Costs associated with the use of assets which the company does not own. These include but are not limited to property, plant, and equipment.
Research & Development	All expenses relating to activities for the development or improvement of products or processes. Such activities can include product design improvement and production process enhancement.
Selling, General & Administrative Expenses ("SG&A")	All operating expenses which are not directly tied to the cost of making a product. These include corporate, accounting, legal, sales, and marketing expenses.
Utilities	Cost of electricity, heat (gas/fuel), sewer, and water used by a factory or plant to ensure the smooth running of both the direct manufacturing process and its surrounding environmental conditions.
Earnings Before Interest & Taxes ("EBIT")	A calculation of the operational earnings or profitability of a company. It excludes interest, which is a finance cost, and taxes, which are imposed by a governmental entity.

Figure 7: The 10 P&L Categories

Key Performance Indicators

Key Performance Indicators ("KPIs") are measures used to evaluate a company's success or effectiveness in achieving its key business objectives and strategic directives. The third input into the Prioritisation Matrix requires a company to rank a list of KPIs in a way that best reflects its desired future positioning and business outcomes. When companies are clear about the results that

matter for long-term success, they can better identify the most relevant Index Dimensions in which to focus their investments.

The Prioritisation Matrix considers the following 10 KPIs that are grouped into three categories — Efficiency, Quality & Assurance, and Speed & Flexibility.

THE 10 KEY PERFORMANCE INDICATORS

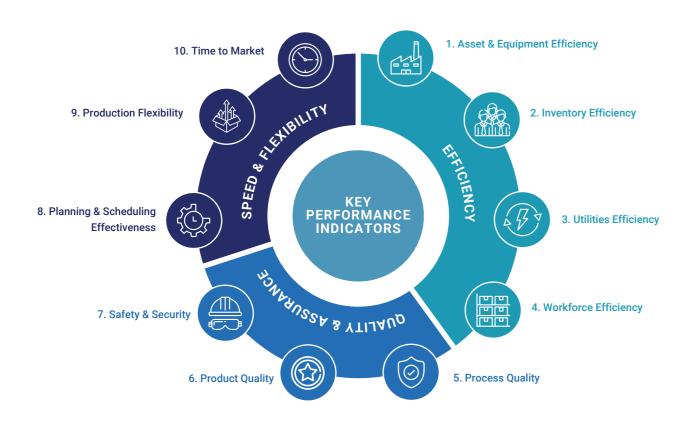


Figure 8: The 10 Key Performance Indicators

How a company's strategic direction influences its KPI rankings

Consumer Goods Industry

A shoe manufacturer that aims to position itself as the go-to company for high-end customised sneakers will place greater importance on KPIs such as Product Quality and Production Flexibility. Performing well in those KPIs allows the company to manufacture a diverse range of long-lasting, hyper-personalised shoes while maintaining a healthy profit margin.

Chemicals Industry

Polyethylene is the most commonly used plastic in the world, with global production topping more than 80 million tons in 2017. However, it is also highly commoditised. As polyethylene manufacturers are unable to set the price of the product, they typically strive to be the most cost-competitive to extract the highest possible profit margin. These manufacturers would place a larger emphasis on Efficiency-linked KPIs such as Asset & Equipment, Workforce, and Utilities.

"As a medium-sized enterprise with limited resources, it is especially important that we invest our time and effort in the right areas. The Prioritisation Matrix is a valuable tool because it highlights the high-impact areas that we should focus on for our Industry 4.0 plans."

- Mr Aaron Teo, CEO, Shine Precision

EFFICIENCY

"Efficiency" is a measurable concept that is quantitatively determined by the ratio of useful output to total input. It signifies a level of performance or a desired state that comes from using the least amount of input – such as time, energy, materials, manpower, and money – to achieve the highest amount of output. Apart from pursuing bottom-line benefits, companies striving for efficient operations could also be motivated by strategic business considerations. Under the category of "Efficiency", there are four subcategories of KPIs.

KPI 1: Asset & Equipment Efficiency

This KPI refers to a company's ability to maximise the utility of assets and equipment that are used for production in its factory or plant. Parameters used by manufacturers within this KPI include overall equipment efficiency ("OEE"), frequency of unplanned downtime, duration of assets' lifespan, and unit throughput. Improvements to asset and equipment efficiency will increase a manufacturing facility's production volume, leading to revenue gains and reduced excess capital spent on repairs and replacements.

KPI 2: Workforce Efficiency

Companies that strive for workforce efficiency aim to improve the labour productivity in their plants or factories by reducing the man-hours spent per task and/or enabling individual employees and teams to perform a wider range of job functions. Depending on the companies' Human Resources policies, employee turnover and training effectiveness could also be additional parameters in determining workforce efficiency. Improvements in workforce efficiency not only result in greater revenue contributions per employee, but also enhance intangible elements like workforce morale.

KPI 3: Utilities Efficiency

This KPI considers the amount of energy and water consumed, as well as emissions and waste produced by a company's manufacturing operations. If utilities costs make up a significant portion of a company's production expenses, improvements in utilities efficiency will enable it to produce at a lower cost or operate with a higher profit margin. In addition, given the growing spotlight on climate change and sustainability, companies operating at a higher utilities efficiency level may also be perceived as more environmentally responsible. This could be a significant consideration for companies in brand-conscious, consumer-facing industries.

KPI 4: Inventory Efficiency

An efficient inventory is one that is optimised to minimise the average volume of inventory required. Storing excess inventory creates unnecessary burdens and costs, particularly for plants and factories that have limited land or storage space. In addition to locking up working capital, manufacturing facilities with large volumes of unutilised inventory can experience increased costs resulting from higher land and/or building rentals, extra manpower to manage the inventory, and greater material wastage due to expiring inventory. In extreme cases, excess inventory can even cannibalise space that could have been designated for new manufacturing lines or synergistic functions such as product design or testing.

QUALITY & ASSURANCE

KPIs grouped under the "Quality & Assurance" category reflect a company's desire to prevent defects in its work-in-process and finished goods during the manufacturing process, as well as faults in its products after customer delivery. While the importance of "Quality & Assurance" KPIs has always been to ensure that a manufacturer is able to meet the ever-rising demands and expectations of customers, a growing number of manufacturers today are voluntarily holding themselves to higher standards in this area. This is because excellent performance in these KPIs not only strengthens customer trust and loyalty, but also reduces costs associated with re-manufacturing or replacing faulty products. Over time, this establishes a stronger reputation and brand premium for the manufacturer. This category includes three closelyrelated KPIs.

KPI 5: Process Quality

This KPI evaluates a manufacturer's ability to achieve and maintain the optimal performance specifications of its manufacturing processes, while minimising deviations and irregularities from intended system parameters and conditions. Success in this KPI enables a manufacturer to increase production output, lower defect rates, and reduce material wastage.

KPI 6: Product Quality

Manufacturers that value this KPI will place emphasis on ensuring that the percentage of defective products – among both work-in-process and finished goods – remains low, and that all products are manufactured as closely to the target specifications as possible. Achieving this will reduce the defect rate of finished goods, as well as the likelihood of after-sale failures and product rejections. This will enable the company to sell more products per batch and reduce the costs associated with product repairs, replacements and warranties.

KPI 7: Safety and Security

"Safety & Security" is fast becoming an important focus area for manufacturers globally. Traditionally, "Safety & Security" KPIs aim to create safe and secure working environments to reduce functional safety incidents and physical security lapses. This translates into a more productive workforce as well. In recent times, the increasing digitisation of manufacturing facilities and growing interconnectivity of assets have led to a heightened level of vulnerability in production systems and networks. This has resulted in a greater need for more robust and resilient cybersecurity to lower the risk of cyberattacks that may disrupt the smooth running of manufacturing facilities.

SPEED & FLEXIBILITY

With the advent of the Fourth Industrial Revolution, the growing interconnectivity of systems and rise of new digital technologies like big data and advanced analytics are providing companies with richer insights into their products, customer preferences, and market expectations. This has led to shorter product life cycles and increasing product customisation. With this overall trend, "Speed & Flexibility" is evolving to be less of a differentiator and more of a necessity for manufacturers to remain competitive. Increased speed to market enables a manufacturer to reach a wider pool of consumers and maximise sales. Greater flexibility in manufacturing operations allows a manufacturer to adapt quickly to changing consumer demands and reduce downtime in reconfiguring production lines. This category can be described by three main KPIs.

KPI 8: Planning & Scheduling Effectiveness

This KPI ascertains a manufacturer's ability to respond quickly to changes in market volume demand and can typically be measured by improvements to response time, lead time, and the number of delayed delivery incidents. Manufacturers that are proficient in planning and scheduling can effectively handle the volatilities of market demand, take on and fulfil orders

on short notice, and balance demand-supply volumes without significant disruption to their manufacturing and supply-chain operations. In addition to driving top-line growth through an enhanced ability to take on more businesses, success in this area will also foster a strong reputation of reliability and adaptability around the company.

KPI 9: Time to Market ("TTM")

This KPI measures the length of time it takes for a company to conceive a new product, or augment an existing one, and deliver it to customers. The digitalisation of industrial sectors has led to increased information flow and data exchange across the entire product value chain and allowed companies today to have greater access to customer feedback. This reduces the amount of time needed to augment or develop products that can better respond to changing market needs. Having a short TTM will allow a company to capitalise on emerging business trends, especially those with a narrow window of opportunity. By ensuring its products reach the end-customers ahead of its competitors, a company with a shorter TTM can capture larger market shares through its first-mover advantage.

KPI 10: Production Flexibility

The "Production Flexibility" KPI measures a manufacturer's ability to augment its production processes through a plug-and-play approach. Flexible production is where equipment, machinery, and computer-based systems can be modified, reconfigured, and re-tasked quickly and easily when needed, thus enabling a manufacturer to manage various permutations of product mix and volume. This allows the manufacturer to promptly achieve a high number of stock keeping units ("SKU") in accordance with changing customer needs and market demands, while incurring relatively low cost.

Proximity to Best-in-Class

The final input into the Prioritisation Matrix is a company's proximity to the best-in-class. Best-in-class is defined as the highest current performance level among manufacturers, and is the benchmark that other companies seek to meet or exceed. Knowing and comparing with the best-in-class is important for two reasons.

Firstly, a company that knows what the best-in-class looks like has a better sense of what is achievable. Not every Industry 4.0 technology or solution in the market is financially practicable to procure today. Even among the technology and solutions that are currently commercially viable, many are often beyond what a typical manufacturer needs to become industry-leading. By recognising what the best-in-class have attained, companies have a more realistic point of reference and are better able to set pragmatic goals and aspirations.

Secondly, by comparing their facilities against the best-in-class, manufacturers are better able to identify aspects where they lag the most, which are often the areas with the greatest scope for

improvements. Companies that are already bestin-class in certain aspects could still find the information useful. It can help justify deliberate efforts to further widen the gap against their competitors, thus extending their leadership position.

Either way, when companies know where they stand relative to the best-in-class, they can better articulate the rationales for embarking on transformation in specific Industry 4.0 areas.

The Band descriptors in the Index provide companies with extensive details so they can recognise the profile of a best-in-class facility. Subsequently, companies can determine their proximity to best-in-class by calculating the difference between the average Band of the best-in-class and their own Band across the 16 Index Dimensions.

The Way Forward

Planning and executing an Industry 4.0 transformation plan is no small undertaking. It requires companies to invest significant resources into areas such as conducting research, engaging potential solution providers, performing cost-benefit analyses, and monitoring the progress of projects. It is therefore not surprising that to date, only a few companies have taken the plunge. However, more might be willing to follow suit in future, if they have greater confidence that implemented projects can help them achieve their desired outcomes.

The TIER framework and the Prioritisation Matrix precisely aims to help bolster that confidence and reduce uncertainty, by offering manufacturers a

data-driven approach to prioritising focus areas. An application has been developed to automate the calculation of Impact Values across all 16 Index Dimensions. Companies interested to use the application, may approach the authors or any of the knowledge partners. This whitepaper also provides an illustrative exercise in the section "Using the Prioritisation Matrix" to help companies understand how the Prioritisation Matrix is applied in practice.

EDB and its knowledge partners look forward to companies making full use of the TIER framework and the Prioritisation Matrix, to move in the right direction and forge ahead with their Industry 4.0 transformation.

"For a company like Infineon that has embarked on our Industry 4.0 plans, the Prioritisation Matrix serves as a useful tool to help us review whether our on-going efforts are in the right direction."

- Dr Laurent Filipozzi, VP and Site Head Plant Singapore, Infineon

Using the Prioritisation Matrix

Deriving the Impact Value of a Band Improvement

Impact Value

■ KPI Weightage • P&L Weightage • Proximity Score • Prioritisation Factor

The following case study provides companies with an illustrative exercise and sample prioritisation tool to identify the high-impact Index Dimensions and Band Improvements to focus on.

Case Study

Company A is a leading process manufacturer with a diverse portfolio of consumer products generating an annual revenue of over US\$30 billion. It has a 20-year old factory in Southeast Asia. To ensure that the manufacturing facility continues to be cost competitive, the General Manager has decided to tap on the Smart Industry Readiness Index to help kickstart the facility's digital transformation journey.

Having completed the Assessment Matrix to understand the facility's current Industry 4.0 maturity level, the company is now using the Prioritisation Matrix to identify the priority Index Dimensions to focus on.

Taking into consideration the company's current state, P&L components, KPIs, and proximity to best-in-class, the Prioritisation Matrix has identified the following 3 Index Dimensions as the high-impact areas for Company A to focus its resources and attention on:

- 1. Shopfloor Connectivity
- 2. Shopfloor Intelligence
- 3. Strategy & Governance

Improvements to "Strategy & Governance" will enable Company A to develop a more structured programme within the organisation, so that it can design an action plan which will help it identify opportunities for improvement.

Enhancing the maturity level of its "Shopfloor Connectivity" and "Shopfloor Intelligence" will allow Company A to be more effective in its planning and scheduling abilities, which will in turn help optimise the management of its raw materials and consumables.

		Company A's Inp	outs		
Assessment Matrix Sco	ore	P&L Categories as a Percen Annual Revenue	ntage of	KPIs and their Level of Imp (1 to 5)	ortance
Vertical Integration	1	Aftermarket Services / Warranty	0%	Asset & Equipment Efficiency	2
Horizontal Integration	1	Depreciation	5%	Workforce Efficiency	3
Integrated Product Lifecycle	1	Labour	15%	Utilities Efficiency	1
Shopfloor Automation	1	Maintenance & Repair	5%	Inventory Efficiency	3
Enterprise Automation	2	Raw Materials & Consumables	50%	Process Quality	1
Facility Automation	2	Rental & Operating Lease	0%	Product Quality	4
Shopfloor Connectivity	0	Research & Development	0%	Safety & Security	5
Enterprise Connectivity	3	Selling, General & Administrative Expense ("SG&A")	10%	Planning & Scheduling Effectiveness	5
Facility Connectivity	2	Utilities	5%	Time to Market	4
Shopfloor Intelligence	0	Earnings Before Interest & Taxes ("EBIT")	10%	Production Flexibility	2
Enterprise Intelligence	2				
Facility Intelligence	2				
Workforce Learning & Development	1				
Leadership Competency	1				
Inter-/Intra- Collaboration	2				
Strategy & Governance	1				

Calculation Methodology

Step	Instructions
1	Table 1: Summary a. In the "Assessment Matrix Score" row, input the manufacturing facility's Assessment Matrix Score for the 16 Index Dimensions.
2	 Table 2: P&L Weightage a. In the "Decimal Representation" column, input the manufacturing facility's P&L categories as a decimal representation of latest annual revenue. b. For each Index Dimension, multiply the "Degree of Relevance" (if any) with the corresponding P&L category's "Decimal Representation" and sum all values to obtain the cumulative P&L Weightage. c. In the "P&L Weightage" row, input the cumulative P&L Weightage of each Index Dimension. Example calculation: P&L Weightage for Vertical Integration = (0.5*1) + (0.05*1) + (0.1*3) = 0.85
3	 Table 3: KPI Weightage a. In the "Level of Importance" column, rate the importance of each of the 10 Key Performance Indicators ("KPI") on a scale of 1 to 5, with 1 representing the lowest importance and 5 representing the highest. Each number of the scale must be used 2 times. b. For each Index Dimension, multiply the "Degree of Relevance" (if any) with the corresponding KPI's "Level of Importance" and sum all values to obtain the cumulative KPI Weightage. c. In the "KPI Weightage" row, input the cumulative KPI Weightage of each Index Dimension. Example calculation: KPI Weightage for Vertical Integration = (1*1) + (3*2) + (1*1) + (4*1) + (5*3) + (4*3) + (2*1) = 41

Step	Instructions
4	 Table 4: Proximity Score a. In the "Assessment Matrix Score" row, input the manufacturing facility's Assessment Matrix Score for the 16 Index Dimensions. b. For each Index Dimension: i. If the Assessment Matrix score ("Y") is lower than the "Best-in-Class" Score ("X"), use the formula "X-Y+1" and input the result into the "Proximity Score" row. ii. If the Assessment Matrix score is equal to or higher than the "Best-in-Class" Score, input the value of "1" into the "Proximity Score" row. Example calculation: Proximity Score for Vertical Integration = 4 - 1 + 1 = 4
5	Table 1: Summary a. In the corresponding coloured rows, input all the P&L Weightages, KPI Weightages, and Proximity Scores calculated in Steps 2 to 4 for all 16 Dimensions.
6	Table 1: Summary a. For each Index Dimension, shade all "Bands" which are equal to or lower than its Assessment Matrix Score. All shaded Bands are not applicable for Steps 7 and 8.
7	 Table 1: Summary a. For each unshaded Band, calculate the Impact Value by multiplying the "P&L Weightage", "KPI Weightage", "Proximity Score" and its corresponding Prioritisation Factor. Prioritisation Factors for all Bands and Index Dimensions can be found in Table 5. b. In the "Bands" rows, input the Impact Value for each unshaded Band. Example calculation: Impact Value for Vertical Integration (Band 2) = 0.85 * 41 * 4 * 0.14 = 5.74
8	Completed Table 1: Impact Value Table The Index Dimensions and Band Improvements that have the highest Impact Values for Company A's manufacturing facility are: 1. Shopfloor Connectivity, Band 0 to Band 1 2. Shopfloor Intelligence, Band 0 to Band 1 3. Strategy & Governance, Band 1 to Band 2

							Table	Table 1: Summary	ary							
		Process						Technology						Organi	Organisation	
Input	Vertical Integration	Horizontal Integration	Integrated Product Lifecycle	Shopfloor Automation	Enterprise Automation	Facility Automation	Shopfloor Connectivity	Enterprise Connectivity	Facility Connectivity	Shopfloor Intelligence	Enterprise Intelligence	Facility Intelligence	Workforce Learning & Development	Leadership Competency	Inter-/Intra- Collaboration	Strategy & Governance
Assessment Matrix Score	-	-	-	-	2	2	0	т	2	0	2	2	-	-	2	-
P&L Weightage	1.85	1.80	1.35	1.95	1.60	1.45	2.15	0.95	1.85	2.00	1.65	1.80	1.85	1.55	2.10	2.15
KPI Weightage	1.85	1.80	1.35	66.00	46.00	33.00	50.00	46.00	37.00	68.00	55.00	25.00	60.00	56.00	68.00	62.00
Proximity Score	41.00	38.00	35.00	3.00	2.00	1.00	3.00	2.00	1.00	3.00	2.00	1.00	3.00	4.00	2.00	3.00
Bands					Impact Valu	ue = KPI W	eightage • l	Impact Value = KPI Weightage • P&L Weightage • Proximity score • Prioritisation Factor	age • Proxi	mity score	• Prioritisa	tion Factor				
0																
-							242			245						
2	102	92	64	174			145			184			200	208		220
က	68	62	43	58	22	7	48		10	184	54	14	150	104	86	120
4	34	31	43	58	22	7	48	13	10	122	54	14	50	52	43	80
ro	34	31	21	58	22	5	32	б	7	61	27	7	50	35	43	09

							Tabl	Table 2: P&L Weightage	Weightage	O)							
									Degree of F	Degree of Relevance ¹							
P&L Category	Decimal Representation		Process						Technology						Organisation	sation	
		Vertical Integration	Horizontal Integration	Integrated Product Lifecycle	Shopfloor Automation	Enterprise Automation	Facility Automation	Shopfloor Connectivity	Enterprise Connectivity	Facility Sonnectivity	Shopfloor Intelligence	Enterprise Intelligence	Facility Intelligence	Workforce Learning & Development	Leadership Inter-/Intra Competency Collaboration	Inter-/Intra Collaboration	Strategy & Governance
Raw Materials & Consumables	0.5	ю	ю		2	-	-	ю		2	2	-	2	2	-	2	2
Utilities	0.05	-		-	2	-	2	-	-	ю	е	2	ო				2
Labour	0.15				ю	ю	е	2	2	2	ю	ю	ю	ю	ю	ო	ю
Maintenance & Repair	0.05				ю		-	က		-	က		-	ю	-	-	2
Rent & Operating Lease	0	2	е		2	-	-	2	2	1	2	ю		-			2
Depreciation	0.05				င		1	က		L	က		1	1	1	2	2
Research & Development	0	3	3	3	1	3	2		3	2	1	8		1	2	2	1
Marketing & Sales	0			က		2	L		3	2		8	1	2	1	2	2
Aftermarket Services / Warranty	0	1		3	3	L	L	3			2			1	2	1	2
SG&A	0.1					ဇ	٦		ဇ	L		3	-	-	2	2	2
Others	0	3	3	2	٦	1	1	1	1	1	1	1	1	1	1	1	1
Earnings Before Interest & Taxes ("EBIT")	0.1	င	3	ဇ	٦	င	2		ဇ	2	Г	က		-	က	က	2
P&L Weightage	Jhtage	1.85	1.8	1.35	1.95	1.6	1.45	2.15	0.95	1.85	2	1.65	1.8	1.85	1.55	2.1	2.15
washara 190 a no avad and animamih a tott tomani avitales of I	a tadt toan		2	100													

¹The relative impact that a dimension can have on a P&L category.

			Strategy & Governance	2	က	2	2	3	2	3	1	2	-	62
		sation	Inter-/Intra - Collaboration	3	3			3	1	3	3	3	2	89
		Organisation	Leadership Competency	-	3			2	2	က	2	2	-	56
			Workforce Learning & Development	ო	အ		-	က	2	က	2	-	-	09
			Facility Intelligence	-	1	က		2		1	2			25
			Enterprise Intelligence		2	1	ဗ	ı		l	3	3	3	55
			Shopfloor Intelligence	3	3	3	2	3	3	2	3	-		89
<u>o</u>	Degree of Relevance ²		Facility Connectivity	1	1	2	1	2		l	2	2	L	37
weightag	Degree of F	Technology	Enterprise Connectivity		1	1	2			l	3	3	2	46
Table 3: KPI weightage			Shopfloor Connectivity	3	1	1	2	2	3	2	2			50
Tak			Facility Automation	1	2	2	-	1	1	1		2	-	33
			Enterprise Automation		2	1	1	l	1	l	2	3	2	46
			Shopfloor Automation	က	3	2	2	2	3	3	2	l		99
			Integrated Product Lifecycle			-			က		2	က		35
		Process	Horizontal Integration				က	1			2	က	က	38
			Vertical Integration			-	2	1	-		3	က	-	41
		Level of Importance (1 – 5)		2	က	-	က	-	4	5	5	4	2	ghtage
		ΚΡΙ		Asset & Equipment Efficiency	Workforce Efficiency	Utilities Efficiency	Inventory Efficiency	Process Quality	Product Quality	Safety & Security	Planning & Scheduling Effectiveness	Time to Market	Production Flexibility	KPI Weightage

² The relative impact that a dimension can have on a K

							Table 4:	Table 4: Proximity Score	Score							
		Process					·	Technology						Organi	Organisation	
	Vertical Integration	Horizontal Integration	Integrated Product Lifecycle	Shopfloor Automation	Shopfloor Enterprise Facility Automation Automation	Facility Automation	Shopfloor Connectivity	Enterprise Connectivity	Shopfloor Enterprise Facility Shopfloor Enterprise Facility Connectivity Connectivity Intelligence Intelligence	Shopfloor Intelligence	Enterprise Intelligence	Facility Intelligence	Workforce Learning & Development	Leadership Competency	Workforce Leadership Inter-/Intra- Strategy & Leaning & Competency Collaboration Governance	Strategy & Governance
Best-in-class Score	4	4	4	4	4	က	3	5	က	က	4	က	4	5	4	4
Assessment Matrix Score	-	-	1	1	2	2	0	3	2	0	2	2	1	1	2	2
Proximity Score	က	ო	က	က	2	_	က	2	1	3	2	-	3	4	2	2

							Table 5: Prioritisation Factors³	rioritisatio	n Factors							
		Process					F-	Technology	ا ا					Organisation	sation	
Bands	Vertical Integration	Horizontal Integration	Integrated Product Lifecycle	Shopfloor Automation	Enterprise Automation	Facility Automation	Shopfloor Connectivity	Enterprise Connectivity	Facility Connectivity	Shopfloor Intelligence	Enterprise Intelligence	Facility Intelligence	Workforce Learning & Development	Leadership Inter-/Intra- Competency Collaboration	Inter-/Intra- Collaboration	Strategy & Governance
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-	0.75	06:0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	09:0	0.75	0.75	0.75	0.75	0.75	0.75
2	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	09:0	09:0	0.45	0.55
ო	0:30	0:30	0:30	0.15	0.15	0.15	0.15	0.15	0.15	0.45	0:30	0:30	0.45	0:30	0:30	0:30
4	0.15	0.15	0:30	0.15	0.15	0.15	0.15	0.15	0.15	0:30	0:30	0:30	0.15	0.15	0.15	0.20
rc	0.15	0.15	0.15	0.15	0.15	0.15	0.10	0.10	0.10	0.15	0.15	0.15	0.15	0.10	0.15	0.15

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"We began our transformation journey back in 2014, where Industry 4.0 was a relatively new concept. The Prioritisation Matrix is therefore timely as it not only validates our ongoing initiatives, but also helps provide greater clarity on their desired outcomes. We will be using the recommendations from the Prioritisation Matrix to review our implementation plans and ensure that we are able to harness the full potential of Industry 4.0 over time."

- Ms Maeve Lynch, Plant Manager of Pacific Refreshments Pte. Ltd. (Coca-Cola)





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