IND5004 Digital Infrastructure and Transformation

AY 2020/21 Semester 2

Group Project

Digital Transformation at The Company

Andi Satyawangsa	A0218878J	e0545891@u.nus.edu
Lim Ee Hwee	A0088490U	e0545130@u.nus.edu
Phun Li Teng	A0218981U	e0545994@u.nus.edu
Poh Wee Chin	A0013649E	e0545075@u.nus.edu
Wong Sin Wee	A0225653E	e0583333@u.nus.edu

Table of Contents

1. Company Background

"The Company" is a subsidiary of a MNC company to serve the engine overhaul shop owned by the same parent company. "The Company" is an airplane engine turbine repair and overhaul factory for large commercial aircraft engines & industrial gas turbines using advanced coating technologies. The total workforce is 300 operators and 100 functional staffs. There are high numbers of employee having worked for more than 20 years in the same company.

The nature of the business and current factory condition is tabulated in Table 1 which also include the possible challenges for the implementation of technologies been delay or seen as less priority to help the factory output. The component received by the "The Company" is relatively small and with defects. Each part disposition of repair scope is non-standard as the defect will differ from part to part, refer to Figure 1. Some of the parts require to through 2 processes and some may be 5 processes to complete the repair of the part.

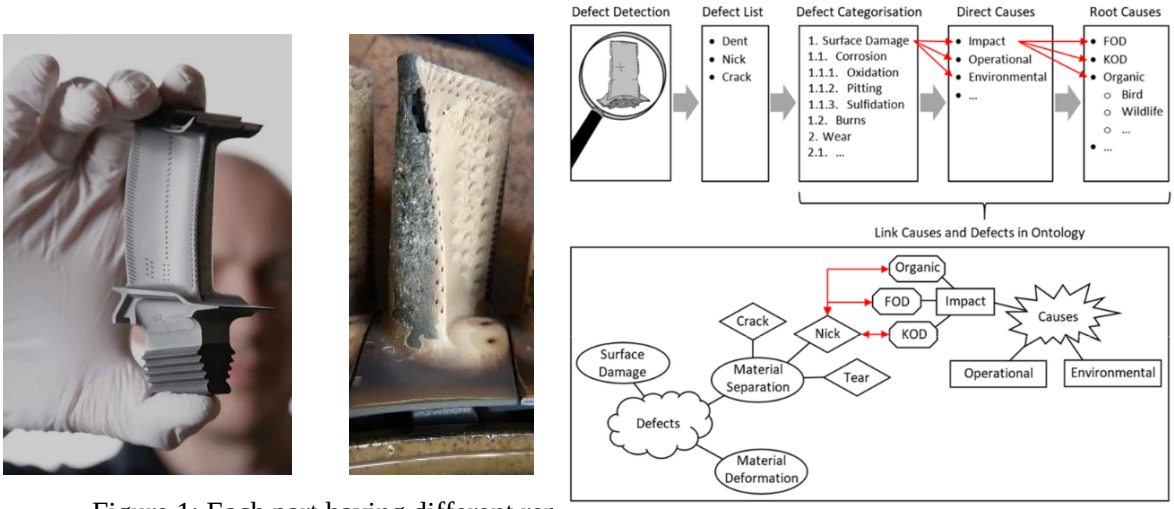

Figure 1: Each part having different repair scope as the defect is unique and complex

	Business Nature	Challenges preventing user to adopt Agile Culture
a	Long service workforce.	Very difficult to replace legacy operation, culture etc.
b	The parts are relatively small as big as a palm size, easily handled by human.	The transfer of small part may be faster and flexible with human.
c	The parts in the shop are customer asset, they are disassembled from overhaul engine shop run by sister company.	Work on each order based on contract. Scope and repair management dependent on customer.
d	Parts are in low quantity per model (high SKU low quantity).	Models change setup time long for automation.
e	Each part's repair job scope may vary as it is dependent on the deterioration severity.	Non-standard processes for each part.
f	If the part found with high repair cost or beyond repair, "The Company" needs to wait for customer's decision on the next course of action.	Many ad-hoc issues that cause job stoppage and postponement.
g	The repair process include cleaning, coating striping, welding, machining, heat treatment, coating and testing.	The processes are able to function without dependency on others and focus on individual cell performance, i.e., silo.
h	Criteria of the repair must follow the original part maker specification (OEM spec).	Limited option to change the manufacturing methodology in-house.
i	The processes yield and speed highly depend on the skilled and experienced employees.	If the part failed test criteria, the experienced worker will do a 'magic' touch up on the part and retest. Not easy to use machine. Heavily reliant on skilled manpower.

Table 1: Business nature of "The Company"

2. The Strategic vision (Mission, Vision, Values)

At the end of 2018, “The Company”, which was under “The Parent” subsidiary, initiated digital transformation program. During the transformation preparation and planning, the parent company, “The Parent”, merged with “The New Parent” and now “The Company” is under “The New Parent” subsidiary. The merger started from Jun 2019 and completed in Apr 2020. Since Mar 2020, “The Company” business has slowed down and faced layoffs as aviation industry is hit by COVID-19.

As “The Company” digital transformation is to be aligned with the parent company mission, vision and value (MVV), a comparison of the MVV before and after the parent company merger showed that the after-merger MVV is clearly defined - transformation through innovation with speed and agility.

Corporate Level MVV:

Stronger together: advancing diversity, equity and inclusion.

“The 2020 merger of “The New Parent” and the “The Parent” aerospace businesses brought together two companies with distinctive legacies of developing and deploying advanced technologies to solve some of the world’s most pressing and complex challenges. As a newly merged company, “The New Merged Parent” is building on this rich heritage of innovation, integrity and excellence.”

Mission Statement – aspires to be the most admired defense and aerospace systems company through our world-class people, innovation and technology.

Vision – One global team creating trusted, innovative solutions to make the world a safer place.

Values:

- Trust: We act with integrity and do the right thing.
- Respect: We embrace diverse perspectives and treat others the way they want to be treated.
- Accountability: We honor our commitments, expect excellence and take pride in our work.
- Collaboration: We share insights, learn together and act as a team.
- Innovation: We **experiment**, design, build and **transform with speed** and **agility**

On the digital side, the corporate Digital Technology office has the **Digital Mission** of delivering new forms of innovation that create value for the customers, employees and shareholders, by unleashing the power of digital technology. It has the **Digital Vision** of accelerating the impact digital technology has on the aerospace industry by delivering outcomes that matter to people and the world. There are three areas of focus, namely:

- Business efficiency: To improve business efficiency by connecting the employees, processes and data to run the enterprise more securely, efficiently and operate at peak velocity.
- Customer experience: To focus on customer experience by creating compelling digital experiences and data-driven insights that customers refuse to live without.

- Increased sales: To improve sales by deploying intelligent solutions that improve outcomes for the customers and create new sources of growth.

Business Unit MVV is directly in alignment with Corporate MVV:

We believe that powered flight has transformed – and will continue to transform – the world. It's an engine for human progress and an instrument to rise above.

That's why we work with an explorer's heart and a perfectionist's grit to design, build, and service the world's most advanced and unrelenting aircraft engines. We do this as a way of turning possibilities into realities for our customers.

This is our mission, and a challenge to which we rise every day. It's about more than transporting people reliably to their destinations. It's about more than providing the care and intelligence to service aircraft engines expertly. It's about **innovating** and engineering a new and exciting future for aviation – one in which the full potential of human progress can be unleashed.

We are **laser focused on innovation and performance** – it's how we design, manufacture and maintain the world's best and most advanced aircraft engines. The same can be said of our corporate social responsibility (CSR) program, where we focus our support on programs and partnerships that:

- Inspire the next generation.
- Empower our employees to positively impact their communities.
- Emphasize innovation and technology.

The legacy (prior merger) Business Unit MVV

The legacy MVV did not emphasize on transformation and how the company wanted to implement innovation and agile culture.

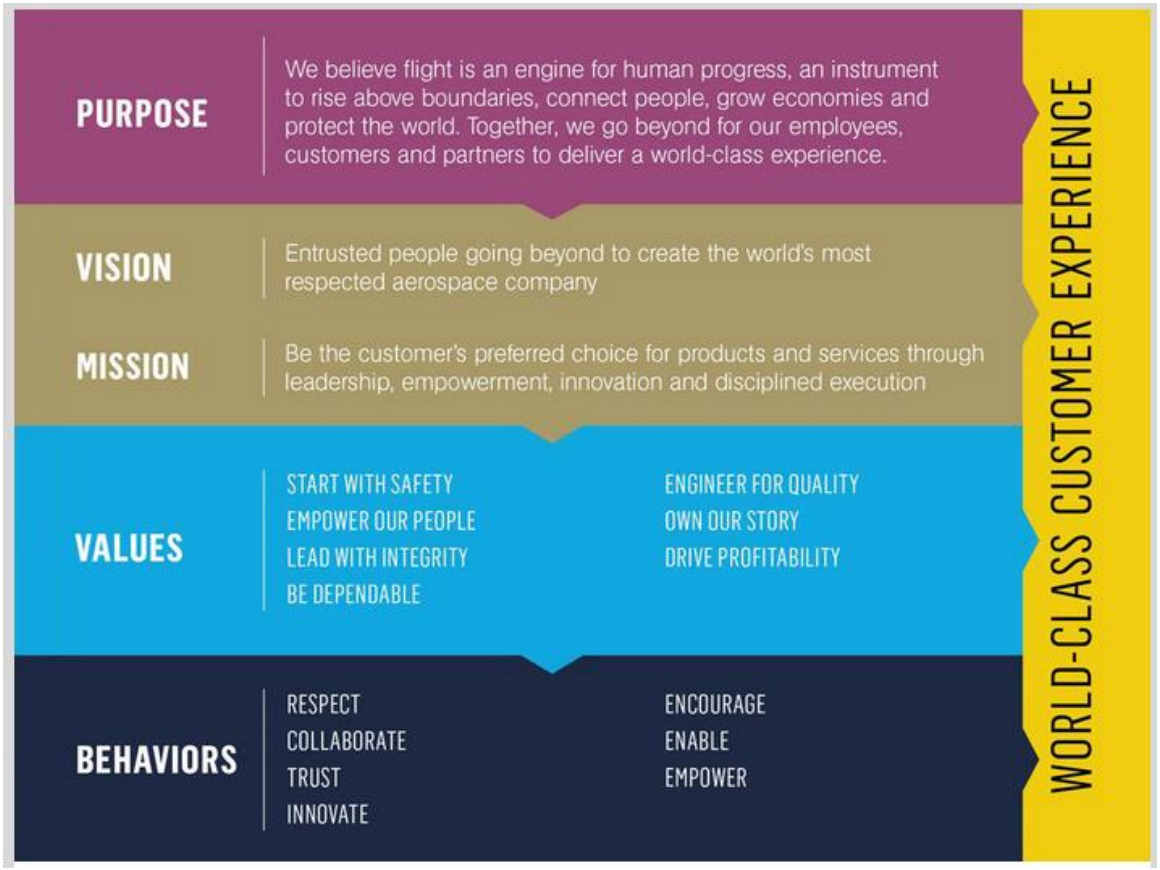

Figure 2: Legacy MVV

3. Digital Readiness Assessment – SIRI

1. The Singapore Smart Industry Readiness Index [1] is based on a framework to systematically assess the company's plants and facilities based on 3 Building Blocks (Process, Technology, Organization) with 8 Pillars broken down into 16 Dimensions being evaluated with six Bands.

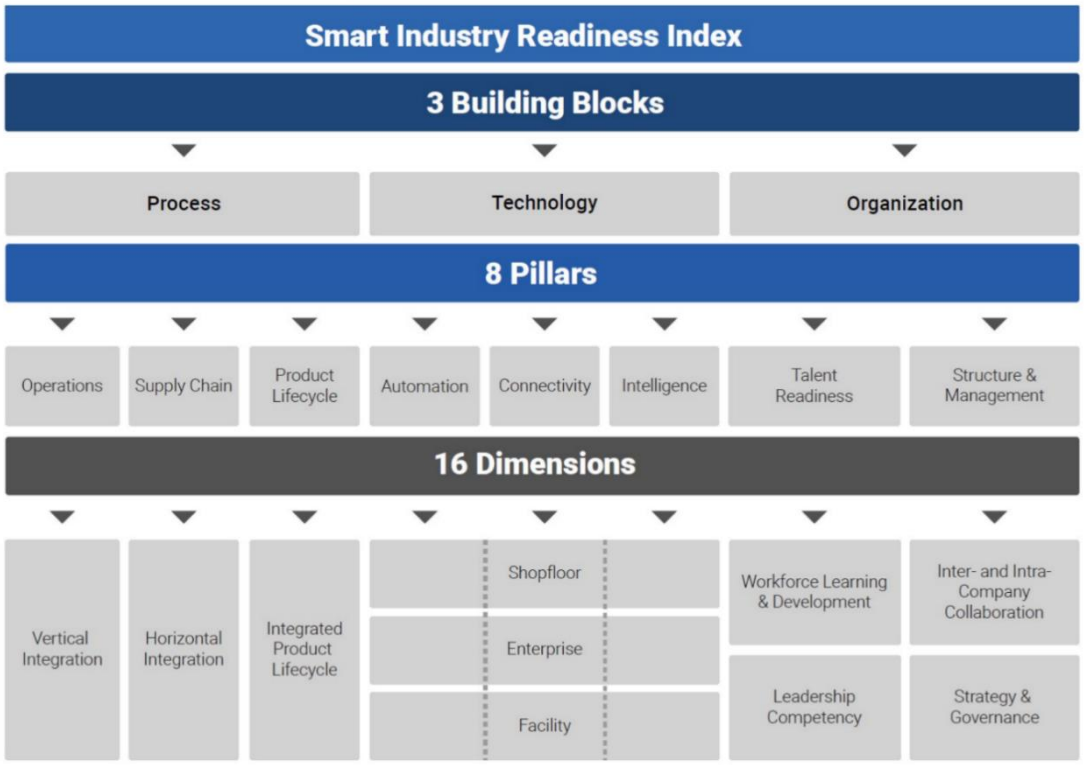

Figure 3: Smart Industry Readiness Index

Smart Industry Readiness Index, SIRI, Figure 3 assessment was conducted based on the framework shown above in partnering between TUV and "The Company". The following bands have been established and consistent in the last 2 readiness assessment. This assessment evaluates the 3 fundamental building blocks of Industry 4.0: Process, Technology and Organization. Refer to Figure 4 for the results obtained.

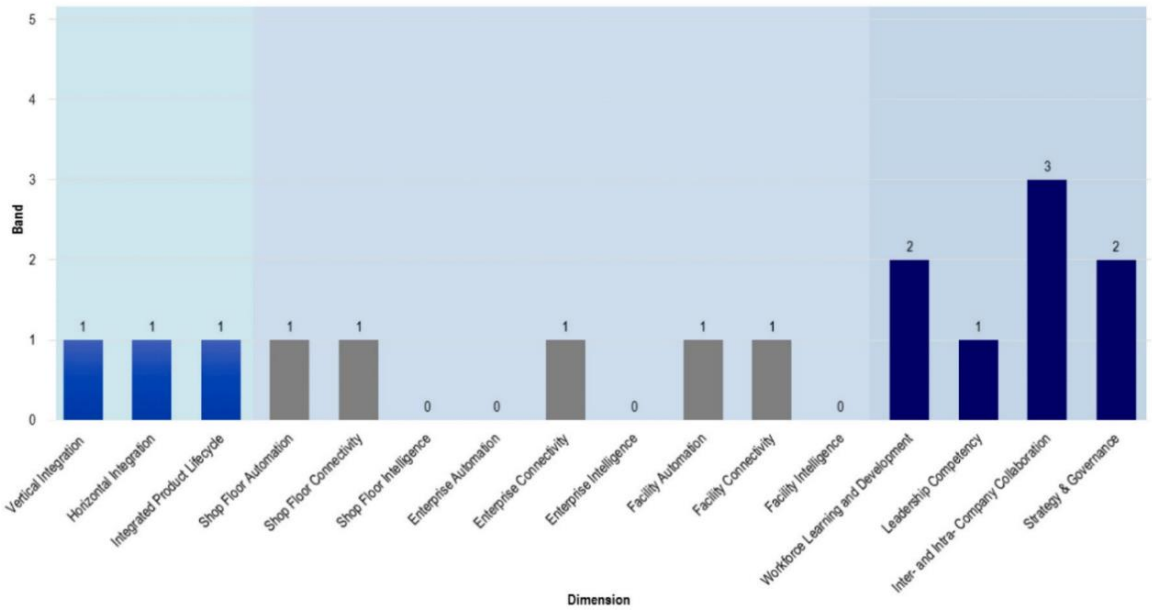

Figure 4: Results of the SIRI assessment for "The Company"

3.1 Process

"The Company" scored band 1 for all 3 dimensions under Process building block, namely *Vertical Integration*, *Horizontal Integration,* and *Integrated Product Lifecycle*. Which means in general there is defined process in place, however it is executed by humans, with the support of analogue tools.

Under *Vertical Integration*, it was identified that the information flow from shop floor to enterprise level is not digital and is managed in silos. While a significant amount of manual intervention is needed to process information and that many process flows need to be automated in *Horizontal Integration* area. *Integrated Product Lifecycle*, "The Company" has no specific PLM tool used for the entire product life cycle, while the engineering process is digitalized as data is processed through a digital tool. However, workflows are processed manually and all the interaction with the end user is done through conventional, analogue methods.

3.2 Technology

Assessment for the 9 dimensions under Technology building block varies between Band 0 and Band 1. Under connectivity: *Shopfloor*, *Enterprise* and *Facility* are all under Band 1, which means machines in the *Shop Floor*, *Enterprise IT* systems and *Facility* assets are connected via multiple communication technologies and protocols. However, the machines or systems are operating in silos and there is information exchanged or interactions between machines or systems.

In the area of automation, "The Company" has automated certain standalone processes in *Shop Floor* and *Facility*, but the repetitive ones such as loading, and unloading in *Shop Floor* area are performed manually. While *Enterprise Automation* is in Band 0, the enterprise processes are partially automated with major sections handled manually. i.e., purchase orders are generated through SAP, but information is entered manually.

There is no system intelligence in place in all the three areas (*Shop Floor, Enterprise,* and *Facility*) due to lack of data processing and analysis used to optimize existing processes and create new applications, products, and services.

3.3 Organization

Under Organization building block, dimension *Inter & Intra Collaboration*, "The Company" has a good structured intra collaboration between cross-disciplinary teams but lack of inter collaboration with their group companies. All the important discussions and decision making are done collaboratively based on important stakeholders' input. On the Dimension *Workforce Learning & Development*, "The Company" acknowledged workforce competency is key for their operations and that there is structured learning

and development programs in place to upskill their workforce. However, it is limited to the Engineering department and positioned themselves on Band 2.

4. Analysis and Recommendation

Based on these results, the team has made an assessment benchmarking with the 3B criteria (**B**est-In-Class, **B**road Middle, and **B**ottom Performers) and with its industry, Aerospace. The Aerospace sector under consideration comprises companies that manufacture, assemble, repair, and/or service equipment, parts, and products for civil aircraft, military aircraft, and spacecraft. Products include but are not limited to engines, fan blades and remanufactured parts. Refer to Figure 5 for the comparison.

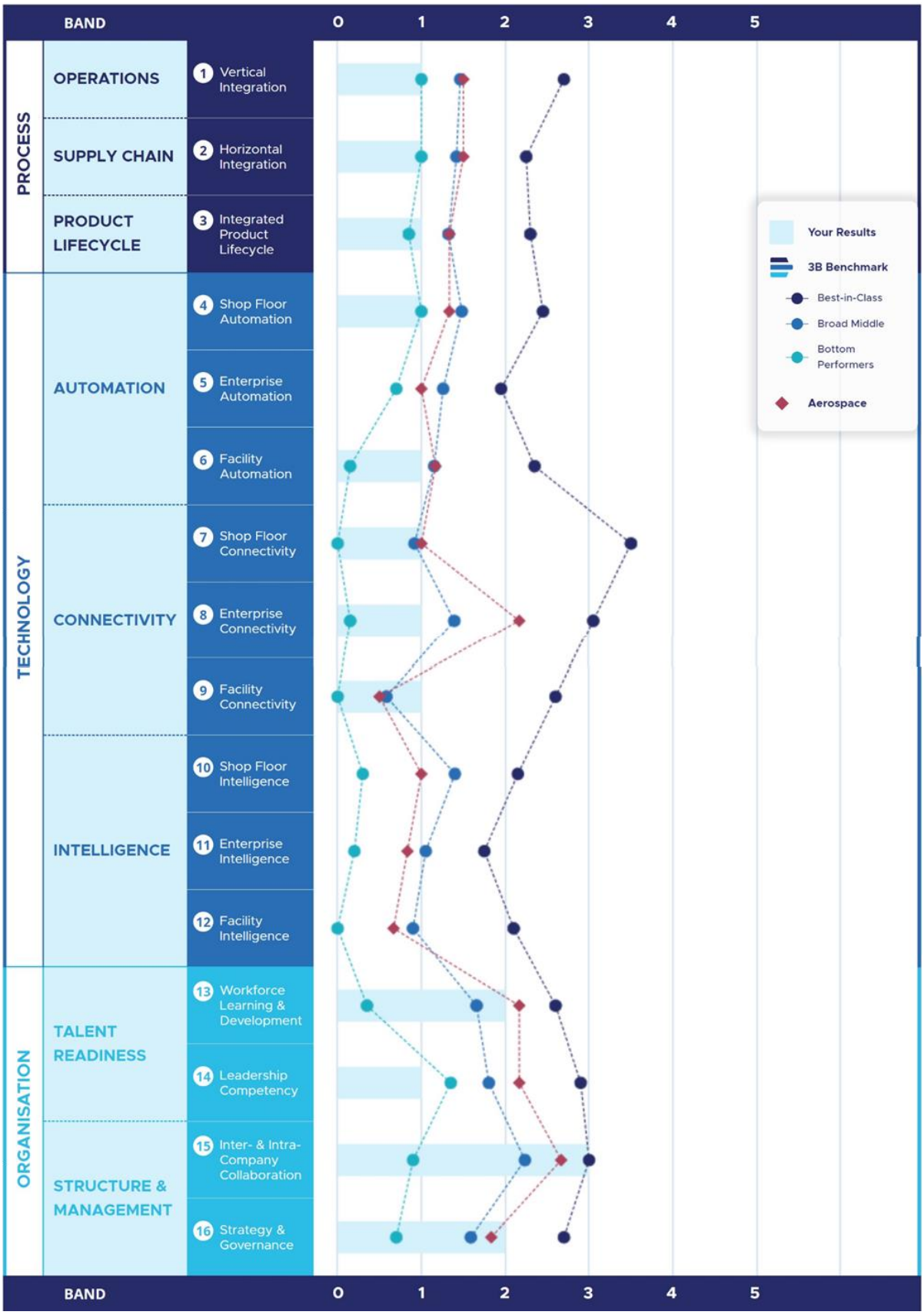

Figure 5: Comparison of "The Company" band against 3D and Industry standards [2]

4.1. 3B Benchmarking Analysis

Under the 3B criteria of (Best-In-Class, Broad Middle, and Bottom Performers), the assessment results present the following status of the current state of "The Company".

Under the **Process** building block, "The Company'' falls within Band 1 for all the 3 pillars and dimensions and is presented as the **Bottom Performer**. If the organization progress and meet band 2 of the rating, it will be presented as the **Broad Middle.** This should be attainable if the processes are still performed as per Band 1 by human BUT supported using digital tools instead. These dimensions will be important to achieve band 2 to transform from analogue to digital so as to set the foundation for other dimensions to leverage on.

Under the **Technology** building block and **Automation** pillar, only the facility dimension is heading beyond the **Bottom Performers** benchmark. It is unusual for a company to have some level of automation at both end of the dimension whereas enterprise has none of the process automated. To bring this pillar to the next band, it is necessary for the organization to start looking into some level of automation at the enterprise dimension. From this result, it is likely that the facility dimension has been separately managed by a 3rd party building management team.

Under the **Connectivity** pillar, all dimensions are well beyond the **Bottom Performers** benchmark where Shopfloor and Facility dimensions are even meeting the **Broad Middle** rating. It is promising that the Enterprise dimension can attain the same next level of benchmark results easily. These results have shown that the organization has emphasized all assets and system are connected to the network with good understanding of the defined communication protocols. This pillar we would propose to keep as one of the few lowest priority while focusing in some other pillars or dimensions that doesn't meet the marks.

Under the **Intelligence** pillar, all dimensions are not meeting the mark of **Bottom Performers** It is obvious "The Company'' are not using data form the OT and IT systems to optimize their processes. There could be a lack of expertise in this area. This would be the immediate area which "The Company" should be focusing at to effectively embark into the journey of Industry 4.0 providing that digitization has already been addressed in one way or another. It is important to note that **Intelligence** pillar is a given within this **Technology** building blocks as data will be made available from both the **Automation** and **Connectivity** pillars, but it is necessary to have the expertise to make use of them.

Under the **Organization** building block, all the dimensions except **Leadership Competency** are meeting the **Broad Middle** or even **Best-in-Class** marks. It is important to ensure this dimension to meet middle mark so that every individual get a clear direction to move forward along the journey.

Based on the 3B benchmarking, we may recommend the organization to focus on the following dimensions/pillars for the next 3 to 12 months period in order to meet the next nearest benchmarking.

1. Process building blocks – Must evolve towards digitization;

2. Intelligence (Shopfloor, Enterprise, Facility) – Must have but can only come after availability of digital data;
3. Talent Readiness (Leadership Competency) – Must have to drive for objective transformation.

4.2. Aerospace Industry Benchmarking Analysis

Next, we assess the results against the similar Industry benchmarking, Aerospace. "The Company" only meets the industry marks for 4 out of 16 dimensions. This tells that the organization may face challenges staying competitive if they do not start to understand and close the gaps.

The 4 dimensions that match or exceed the Aerospace benchmarking are shopfloor connectivity, facility connectivity, inter & intra-company collaboration, and strategy governance. These can be kept as the lowest priority areas to focus on further improvement in the near term where attention can be used on other areas which are far from the benchmark or those which can be easily attained with lesser efforts.

The next 6 dimensions which stand in close position to the Aerospace benchmarking are vertical integration, horizontal integration, integrated product lifecycle, shopfloor automation, facility automation, and workforce learning & development. In our opinion, for short term improvement strategy of less than 6 months, the organization can focus on improving these against the industry standard. These also set the foundation for other dimensions to leverage upon.

The rest of the 6 dimensions namely, enterprise automation, enterprise connectivity, shopfloor intelligence, enterprise intelligence, facility intelligence, and leadership competency are those that need more planning and attention. Activities to bring these to the industry standard may take longer than 6 months and more investment can be expected due to missing capability or bigger gaps identified. This can be placed as the next phase strategy but is a must to achieve in order to move closer to its competitors.

Based on SIRI assessment on more than 200 companies in Singapore-based manufacturing facilities, which spans over 12 manufacturing industries, Aerospace is classified under the **Tundra Archetype** of Transformation. It has been determined that this industry will face greater challenges in industrial transformation because the nature of their products and manufacturing processes limit the ease and feasibility of deploying certain Industry 4.0 improvements. Their products are highly customized and manufactured in small quantities, which may limit opportunities for commercially viable improvements in areas such as automation and digitization. Although opportunities for transformation exist in the Process and Organization building blocks, this must not stop the businesses to also focus on Technology building block to reap the maximum benefits from the transformation. Technological advancement has been the cornerstone of the last three major industrial revolutions. It 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 realize their Industry 4.0 ambitions, a high degree of automation, ubiquitous connectivity, and intelligent systems are all necessary.

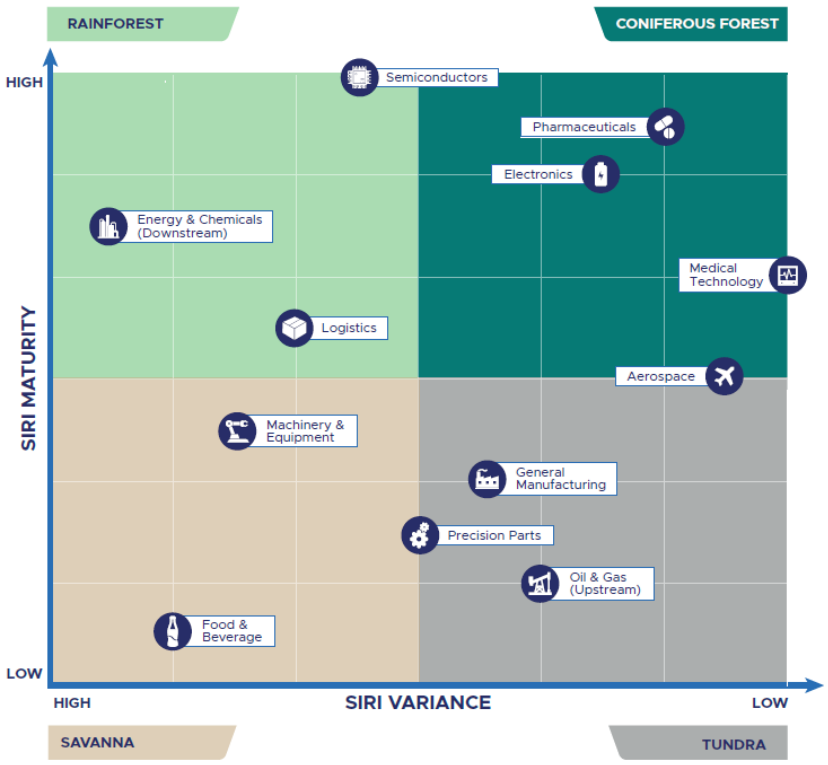

Figure 6: Archetypes of Transformation [3]

4.3. "The Company" Gap Analysis

The former sections discussed are based on our assessments against the market benchmarking without considering what "The Company" has in plan post its evaluation.

In this section, we will review and discuss the transformation roadmap drafted by the organization. Key Performance Indicators (KPIs) were included as part of the gap analysis done with the SIRI results. These KPIs are as follows:

KPI	Most Relevant Target Function
Financial Performance	Productivity
Compliance	Quality
On Time Delivery	Speed/Quality
Overall Productivity	Productivity

Table 2: KPIs used for gap analysis

Besides the use of KPIs, weighing factors of 3-point Scale: 1: Important, 3: Very Important and 5 Extremely Important were considered as part of the gap analysis.

The group including TUV and "The Company" started the gap analysis methodology through the following steps.

1. Identify and agree the migration target. In this step, the group has agreed to bring all the dimensions up by one band.
2. Understanding the important KPIs that are factoring into the 16 dimensions analysis.
3. Introducing a 3-point scale (1 – Important, 3 – Very Important, 5 – Extremely Important) as the weighing factor for each of the KPIs against the 16 dimensions

Through this exercise, the group is planning to achieve a more representable gap analysis based on the organization key target functions where they can achieve a target scoring for each of the 16 dimensions.

Figure 7: Gap analysis scoring for the 16 dimensions

Based on the scoring, the group has identified 6 areas which the organization should be focusing on throughout the journey to Industry 4.0, we reference this as the organization aspiration.

1. Vertical integration
2. Horizontal integration
3. Shopfloor connectivity
4. Enterprise connectivity
5. Workforce learning & development
6. Strategy and governance

5. Gap Analysis and Recommendation

5.1. Gap Analysis and Roadmap to Smart Factory

Our team performed a holistic analysis to review "The Company" current band, the organization aspiration on area to focus, 3B benchmark and Aerospace industry benchmark. Based on gap analysis, we outlined the digital transformation into 3 phases to achieve smart factory capabilities based on the urgency to address the gaps to enable the organization to stay competitive. This phase approach will enable the organization to start with manageable dimensions, achieve quick wins, and gain traction in transformation before scaling up to an enterprise-wide initiative.

Through the digital transformation journey to close the gaps, the organization will gain convergence of physical and digital process, which is pivotal foundation for smart factory. This in turn, will enable the organization to drive greater value both within the factory and across the supply network.

Our team analysis which disagrees with "The Company" on the action item, is the Leadership Competency dimension. The Leadership competency assessment at Band 1, while compared to the talent workforce learning and development is Band 2. For action item scoring, "The Company" scored the Leadership Competency as low as 16 which implies low impact and no urgency to bring up Leadership Competency to the next level (Band 2). On the other hand, the workforce L&D scored 48 and is the next immediate action to bring up from Band 2 to Band 3. This will widen the already inversely competency gap between the workforce L&D and Leadership, refer to Figure 7.

In contrast to "The Company" aspirations, our team has the opinion that the Leadership Competency shall be one of the urgent actions to be brought up to the next band to be in alignment with workforce Learning & Development, with following reasons:

a) The transformation shall be top-down from leader to workforce. Leader equipped with competency can at least understand and be familiar with the transformation prior to setting the strategy, budgeting and KPI for the next level to action on. The decisions of leader will create highest weight and impact to the transformation journey of "The Company".
b) "The Company" has been operating in the legacy way for decades. The management may consist of long serviced and new blood managers with diverse backgrounds. They shall go through the same transformation training and workshop to align their competency and the parent company transformation initiative and the way of agile culture to be nurtured in "The Company".
c) The Leadership Competency shall always be higher than the workforce in order to plan the roadmap for the transformation to next level. This is evidently finding when benchmarking to 3B and Aerospace industry.

d) Leadership Competency is crucial to steering and devising the Workforce Learning and Development to align to the transformation roadmap and strategies. Instead, The Company is focusing to develop the workforce first but not the leader first. This will risk the workforce development being not aligned to the transformation needs and instead towards meeting training attendance of Industry 4.0 courses.

e) Leadership Competency is required to structure the organization for transformation. Referring Table 2, there are business challenges that need careful planning from the leader to ensure the agile culture can be embarked and cultivated into "The Company", so that processes can be brought out of the silo to a cohesive and connected manufacturing workforce.

5.1.1. Phase 1

This phase is to address the dimensions where "The Company" should focus on establishing strong foundation to allow the organization to move forward with further digitalization initiatives. In general, this phase is aligned with the organization aspiration, however, our team recommends focusing on three fundamental dimensions that will enable improvement in other dimensions in the following phases. Our team thinks the low impact and weightage given to Leadership Competency capability skewed the total score, which resulted this capability being rated with very low score and overlooked in the focus are for digital transformation.

Leadership Competency is one of the most critical factors that determine the success of digital transformation journey. Big changes or upgrades to organization must start with selecting and developing top leaders, and competence of the most senior leaders will stand out and be the main differentiator and give the most value. [4]

Due to the nature of urgency, it is recommended to start this phase within 3 months. The areas that are identified to be addressed in this phase are:

- Vertical Integration, from band 1 (defined), where vertical processes are defined and executed by humans, with the support of analogue tools, to band 2 (digital), where defined vertical processes are completed by humans with the support of digital tools.
- Horizontal Integration, from band 1 (defined), where supply chain processes are defined and executed by humans, with the support of analogue tools, to band 2 (digital), where defined supply chain processes are completed by humans with the support of digital tools.
- Shopfloor Connectivity, from band 1 (connected), where production assets and systems are connected via multiple communication technologies and protocols, to band 2 (Interoperable), where equipment, machinery and computer-based systems are able to interact and exchange information without significant restrictions.
- Leadership Competency, from band 1 (limited understanding), where management is partially familiar with the latest concepts that can enable the next phase of advancement, to

band 2 (informed), where management is fully familiar with the latest concepts that can enable the next phase of advancement.

5.1.2. Phase 2

This phase is to bring the organization to level where it can stay competitive with peers in Aerospace industry by leveraging on the foundation that has been established in Phase 1. This phase is recommended to start in 6 months timeframe and shall focus on improving the capabilities in the following dimensions:

- Integrated Product Lifecycle, from band 1 (defined), where product lifecycle processes are defined and executed by humans, with the support of analogue tools, to band 2 (digital), where defined product lifecycle processes are completed by humans, with the support of digital tools.
- Shopfloor Automation, from band 1 (basic), where repetitive production processes are partially automated, with significant human intervention and repetitive support processes are not automated, to band 2 (advanced), where repetitive production processes are automated, with minimal human intervention and repetitive support processes are not automated.
- Enterprise Automation, from band 0 (none), where enterprise processes are not automated and are executed by humans, to band 1 (basic), where enterprise processes are executed by humans with the assistance of computer-based systems.
- Leadership Competency, from band 2 (informed), where management is well-informed, through formal channels and avenues, of the most recent trends and technologies, to band 3 (semi-dependent), where management with external assistance is able to apply the latest trends and technologies to enable improvements in at least one area of the organization.

5.1.3. Phase 3

Following Phase 1, which focuses on process optimization, and Phase 2, which focuses on must-have foundation for further digital transformation initiative, Phase 3 will focus on further improving band rating for some of the areas and starting in areas where fundamental readiness has been established during the earlier phases for those with no progress till date. This strategized approach allows the organization to gain good experience and obtain stronger support from leadership and workforce.

Phase 3’s ultimate objective is to bring “The Company” to a level where it gains competitive advantage and realizing the aspiration from management team. This phase will focus on improving the capabilities in the following dimensions:

- Shopfloor Intelligence, from band 0, where no OT and IT systems are in use, to band 1, where equipment, machinery and computer-based systems are able to perform tasks based on pre-program logic.
- Enterprise Connectivity, from band 1 (connected), where enterprise IT systems are connected via multiple communication technologies and protocols, to band 2 (interoperable), where enterprise IT systems are interoperable across multiple communication technologies and protocols.
- Enterprise Intelligence, from band 0 (none), where no electronic or digital devices are used, to band 1 (computerized), where enterprise computer-based systems perform tasks based on preprogrammed logic.
- Facility Intelligence, from band 0 (none), where no electronic or digital devices are used, to band 1 (computerized), Equipment, machinery and computer-based systems perform tasks based on pre-programmed logic.
- Facility Automation, from band 1 (basic), where facility processes are partially automated, with significant human intervention, to band 2 (advanced), where facility processes are automated, with minimal human intervention.
- Workforce Learning and Development, from band 2 (continuous), where 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 to band 3 (integrated), where there is a continuous L&D curriculum that is integrated with organizational objectives, talent attraction, and career development pathways.
- Strategy and Governance, from band 2 (development), where a long-term strategy and governance model to establish a Factory/Plant-of-the-Future is being developed or has been developed, to band 3 (implementation), where the long-term strategy and governance model to establish a Factory/Plant-of-the-Future has been put into action.

			Vertical Integration	Horizontal Integration	Integrated Product Lifecycle	Shopfloor			Enterprise			Facility			Workforce Learning & Development	Leadership Competency	Inter/Intra Company Collaboration	Strategy & Governance
						Automation	Connectivity	Intelligence	Automation	Connectivity	Intelligence	Automation	Connectivity	Intelligence				
	As-Is (Band)		1	1	1	1	1	0	0	1	0	1	1	0	2	1	3	2
SIRI Industry benchmark	Benchmark	Aerospace	1.5	1.5	1.33	1.33	1	1	1	2.17	0.83	1.17	0.5	0.67	2.17	2.17	2.67	1.83
		Bottom	1	1	0.85	1	0	0.3	0.7	0.15	0.2	0.15	0	0	0.35	1.35	0.9	0.7
		Middle	1.46	1.42	1.32	1.48	0.92	1.4	1.26	1.39	1.05	1.15	0.58	0.9	1.66	1.8	2.23	1.59
		Top	2.7	2.25	2.3	2.45	3.5	2.15	1.95	3.05	1.75	2.35	2.6	2.1	2.6	2.9	3	2.7
Team Recommendation	Target (Band) Phase 1		**2**	**2**	1	1	**2**	0	0	1	0	1	1	0	2	**2**	3	2
	Target (Band) Phase 2		**2**	**2**	**2**	**2**	**2**	0	**1**	1	0	1	1	0	2	**3**	3	2
Score by the company for action. Score >= 48 are considered priority	Impact	Flexibility	0	1	0	0	1	0	1	1	0	1	1	0	1	0	1	1
		Speed	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1
		Productivity	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
		Quality	1	1	1	1	1	1	1	1	0	0	1	0	1	1	1	1
	Weight	Flexibility	1	3	3	1	3	1	3	3	1	1	1	1	3	3	1	3
		Speed	5	5	3	3	3	3	1	1	1	1	1	1	3	3	3	3
		Productivity	5	3	3	5	5	5	3	5	3	3	5	3	3	1	3	3
		Quality	5	3	3	5	1	1	3	3	3	3	1	3	3	1	1	3
	Target (Score)		48	56	36	42	48	30	40	48	16	16	32	16	48	16	32	48
Team Recommendation	Target (Band) Phase 3		**2**	**2**	**2**	**2**	**2**	**1**	**1**	**2**	**1**	**2**	1	**1**	**3**	**3**	3	**3**

Table 3: Target Band Gap Analysis Assessment and Proposed Phases

6. Recommendation

Based on analysis and comparison results in Section 5.1, the team further deep dives into each of the phases and proposes some recommendations.

6.1. Phase 1

6.1.1. Vertical Integration

The Vertical integration is resource planning for the multi departments or functions within the factory. The current state of "The Company" is at Band 1, the organization has established processes for cross-functional workflow, and the operation are generally manual with help of digital tools. Due to the manually handling of shopfloor information (processes and records documented manually), the within production sometimes work in silo as the information does not flow to other departments for the factory-wide enterprise planning.

At the Phase 1, our team has same recommendation that the Vertical Integration has to be brought up to Band 2, which the various departments and functions have to convert the manual documentation to a single digital system. The digital information will be important for other dimensions like enterprise automation, connectivity and intelligence to kick off successfully.

To facilitate the first step of vertical integration of "The Company", all the manual handling information shall put into work in digital system like ERP. The ERP is able to integrate information from sales order, material supply, production capacity to even facility supports, which will allow seamless planning and monitoring of the factory resources, inventory, customer stock management (Figure 9) and also enable how each department collaborate with one another to meet the KPIs.

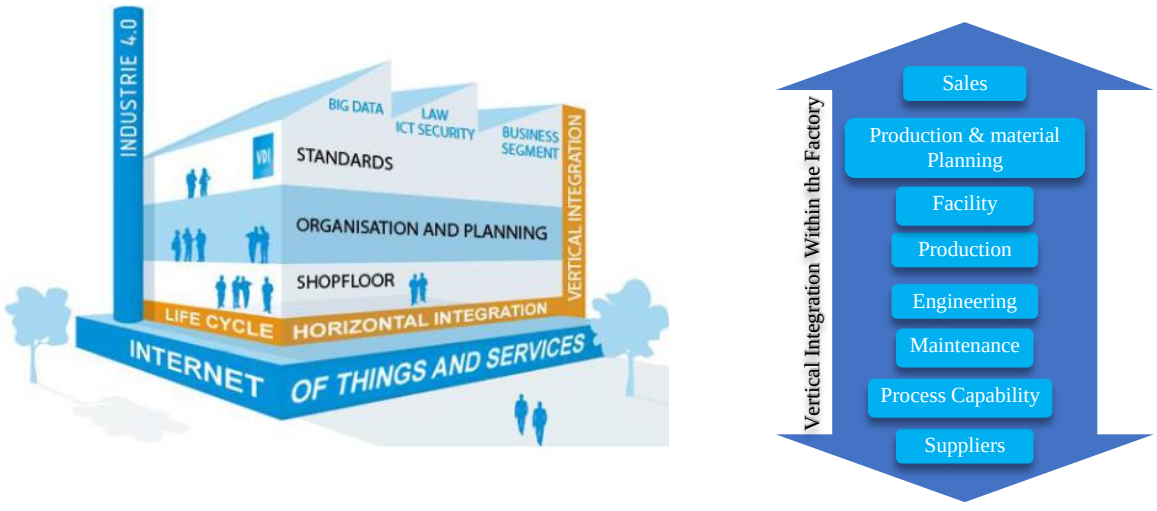

Figure 8: Vertical and horizontal integration under Industry 4.0 [5]

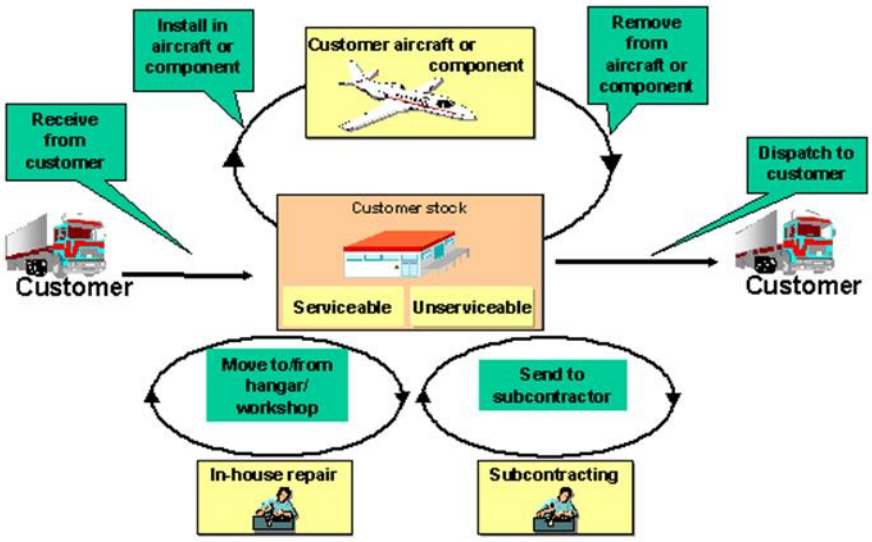

Figure 9: MRO Customer Stock Management [6]

6.1.2. Horizontal Integration

The current state of The Company's supply chain process at Band 1 has significant amount of manual intervention to process information. The communication between department and processes are poor and towards silo within the shopfloor. Each process follows the manual planning and the monitoring of status is not real-time transparent to other process without human intervention, examples in Table 4.

Department	Current Process/ Challenges	Solution Required
Cell Operations	• Manual Scheduling at start of shift using Daily flow rate (DFR) calculated by monthly commitments.	• Effective resource planning and forecasting of meeting promise date by integrating with operations in SAP, Solumina, Skill matrix, Machine availability and labor availability
Cell Operations	• Plan the operation once the material is received in cell • Receiving does not know which part is coming in and what is the quantity	• Ability to show the forecast orders
Cell Operations	• Currently cell operations use hand over / take over logs or manual sheets or just passing Kanban to pass on status of jobs work load for next shift	• Cell / Group leaders should be enabled to perform planning of shift level based on actual part progress, backlog and labor availability and operator should get visibility of TO-DO list
434A/B Cell	• Manual Scheduling at start of shift • Scheduling for high volumes • Meet TAT timeline • Large fluctuation in receiving part volume (none to 300 parts per day)	• Effective resource planning and forecasting of meeting promise date by integrating with operations Solumina, Skill matrix based on machine & process, Machine availability and labor availability • Ability to forecast for receive parts for repair
Special Process	• Schedule based on skillset available of the resources who clocked into the shift	• Ability to do intelligent scheduling and simulate different schedule scenarios based on machine and labor/skills availability

Table 4: Current state on some of the processes

Our team's view is aligned to "The Compony" scoring, the horizontal integration dimension is required to be at least brought up to Band 2 immediately by using a digital system. The digitalized horizontal system will increase the productivity of shopfloor and become the enabler of shopfloor connectivity and intelligence dimension.

For starting the horizontal integration at “The Company”, our team would recommend the use of Manufacturing Execution System (MES) to digitize the processes instruction, production records and monitoring between plan and actual status. As the handling of each repair part by “The Company” follows non-standardized process flow, the engineer will put the repair instruction for each part into MES. From there, the planning of the shopfloor can be performed with ease and will link each job order to the required processes through the shopfloor. Once each process is recorded completed in MES including timing and material used which will be valuable for production optimization and connected to other system like the ERP and PLM.

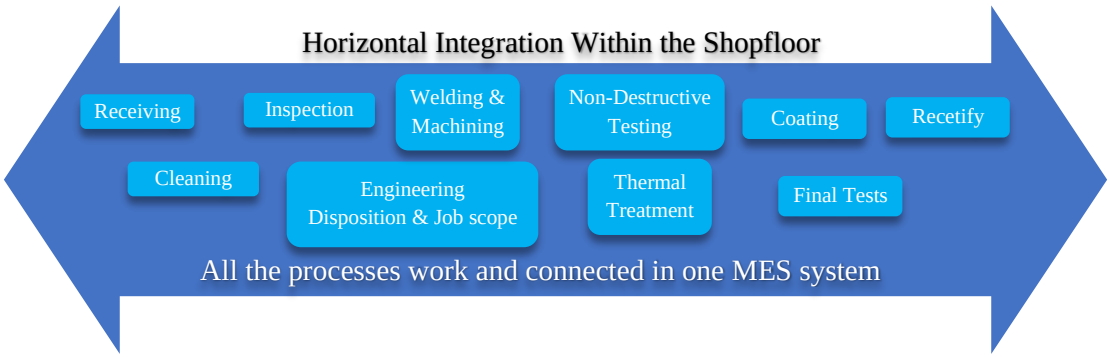

Figure 10: Horizontal integration of Shopfloor

6.1.3. Shop Floor Connectivity

A common school of thought is that automation forms the basis for industrial transformation. However, in this digital age, connectivity has become more critical. A highly connected factory, where all assets (machines, materials, labor, and peripherals) are linked via a common network, will not only enable more extensive and effective machine-to-machine and human-to-machine communications, but also enable firms to better leverage data to generate new insights and facilitate real-time decision making. [3]

At the current level (Band 1), the connectivity at the shop floor is generally high and as a result, measurable amount of data is being collected. However, the digital solutions were previously implemented independently without an overall roadmap in place. Coupled with the fact that the MRO shop floor contains many different types of machining and processing equipment that support different proprietary interfaces and communication protocols, inter-operability issues among different systems arises when real-time data exchange is restricted and hinder decision making. This needs to be addressed in Band 2 so that shop floor intelligence can be realized in the later phase of transformation to achieve more efficient utilization of machines and real-time optimization of repair processes. The key here is to standardize the communication interface so that the production assets and systems are more compatible with one another.

Although there exist open interfaces such as UMATI (Universal Machine Tool Interface) and MTConnect which serve to standardize machine-to-machine communication, they are not always supported by every machine's manufacturer either due to specific data requirements or the fact that the machine is outdated and only supports analog output. In this case, connecting the machines can be difficult and expensive, or the cost of upgrading to modern equipment might be prohibitive.

The recommended solution here is to augment existing machines and equipment with sensors that detect and measure physical characteristics or conditions of a device. On/off states, amperage drawn, temperature, pressure, vibration levels, sound patterns & levels, magnetic fields, quantities of supplies and images (machine vision) are examples of the 'symptoms' sensors can pick up. Besides sensing, there are also 'intelligent sensors' which perform other functions such as converting analog readings into digital format or even process and analyze captured data and be programed to react in a logical manner.

Top priority shall be to deploy sensors at locations and equipment where they can automatically detect and report changes that impinge on component viability. This information will provide warnings of impending failures and process bottlenecks that can be used to avoid unexpected downtime. Sensors are the key to monitoring, detection, intervention and prevention.

When it comes to inter-sensor communication in the wireless sensor network, data routes can be pre-configured via static routing table. Since the sensors operate on the same protocol at the physical layer, data exchange among production equipment can be realized.

In terms of connectivity among sensors and between sensors and the central data analyzer/coordinator (if there is one), wireless technologies such as Wi-Fi, NB-IoT, LoRa, ZigBee greatly simplifies the deployment of sensors in the shop floor as they cater for different application requirements. Selection of the wireless technology shall be based on criteria such as range, power consumption, spectrum, uplink/downlink speed, cost, security and maintenance requirement. In the application layer, IoT protocols such as MQTT and CoAP can be considered depending on application. For a more comprehensive and unified solution, the company can look at end-to-end IoT platforms such as PTC ThingWorx, Microsoft IoT Solution, etc. These will serve as benchmarks and references for any in-house development and future plans. (Source: EE5024 lecture)

6.1.4. Leadership Competency

Leadership capability is pivotal in a successful Digital Transformation program. Leadership capabilities consist of vision to shape new future, governance, engagement, and IT-Business Relationships. [7]

Assessment results show that Leadership Competency is at Band 1, which means management has some awareness, through ad hoc channels, of the most recent trends and technologies and lack of advanced digital capabilities in the company. This is classified as Digital Beginners in Digital Maturity chart; while leaders who truly understand how to drive value with digital transformation is classified as Digirati. To achieve this, the leadership must be able to combine a transformative vision, governance and engagement, with sufficient investment in new opportunities. Through vision and engagement, they develop a digital culture that can envision further changes and implement them wisely. By investing and carefully coordinating digital initiatives, they continuously advance their digital competitive advantage. [7]

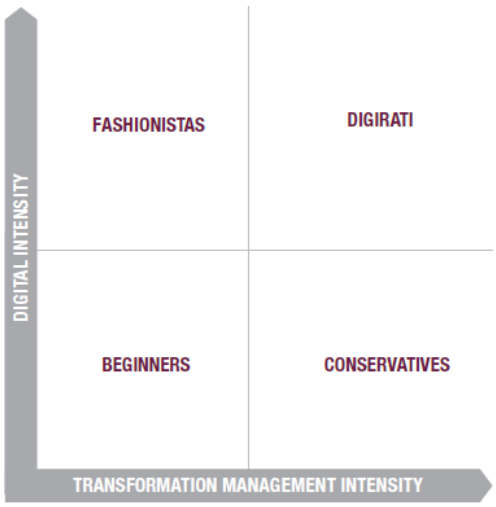

Figure 11: Four Types of Digital Maturity [7]

The current band score of leadership competence is less than band score of workforce learning & development. This means that there is a lack of digital leadership skills to drive and navigate the workforce to embrace the digital transformation. Therefore, our team proposed that leadership competence must be prioritized to leverage the technology and trends into organization for relevance and competitiveness in order to move toward Band 2. The management must understand the technology and drives the change within the enterprise. Digital literacy in management is crucial to organization as in reality transformation is most likely to succeed when driven top-down. The CEO of the company needs to oversee important decisions and changes pertaining to the company's digital strategy. Visionary and right skilled leaders will be able to lead the organization to digital success. Hence, it is suggested to increase digital maturity among top management as following:

a) Providing self-directed learning – attend technology conference.
b) Commit to digital tourism – visiting or engaging in conversation with leaders of other successful tech-driven companies. (E.g., ARTC from A*STAR, Digital Capabilities Center Singapore, Advance Manufacturing Transformation Center from Siemens etc.)
c) Recruit new leader with strong digital experience.

There are private and public agencies available in market that help to provide guidance and support in industry 4.0 adoption. The expertise from agencies can demonstrate and deliver understandings to organizations which are keen in digital transformation. Thus, it is beneficial to the company's management to gain full understanding through these platforms and how the technology has the positive impact on the company business. In order to introduce technological changes, the board of management must assign a digital leader who possesses the key qualities as shown in Figure 12. The most important trait in leadership is open-minded and accepting changes as these traits support all key qualities listed which enable leaders to respond in disruptive environment. Continuous learning helps the leaders to avoid obsolescence of skillset and minimizing the current gap with the workforce. The leadership competency must be at higher band than workforce learning and development dimension where the workforce of the company can work together under clear vision and mission to achieve company's ultimate goals.

Figure 12: Five Key qualities in Digital Transformation Leadership [8]

6.2. Phase 2

6.2.1. Integrated Product Lifecycle

Product lifecycle management involves product design, realization, manufacturing, service and disposal. Refer to Figure 13, "The Company" performs aerospace component repair which is at the mature part of the product lifecycle that involves maintenance support and disposal of aeroengine component. The product lifecycle requirement is not demanding for "The Company" and is still at Band 1 using analog as:

a) All the repair methods, drawings, specification are transferred from parent company.
b) Long product life cycle, introduction of new product type for repair not frequent.
c) The product handled are matured and stable, the processes has already been proven by the OEM, frequency of change management is low.

However, the integrated digital production lifecycle for “The Company” is important when the shopfloor started to become digitalized, PLM will be the enabler for:

a) Collaboration agent for product data management (PDM) of digital data flow among parent company, internal shopfloor, customers and suppliers.
b) Increases productivity by enabling factory to establish a library of standard and approved maintenance procedures, revision control, CAD/CAM data which are made readily available at workstation or can be part of information embedded in MES instructions.
c) Increases the capacity of the factory by combining work for repair scheme, modifications and discrepancies into production planning and MES and ERP.
d) Extending PLM to maintenance can incorporate work instructions that are delivered in 3D just like during the manufacturing process. Engineers and machine operators could interact with the model to quickly and thoroughly understand the exact issue and solution. Original designs and historical maintenance data recorded in the as-built history can be viewed and compared.

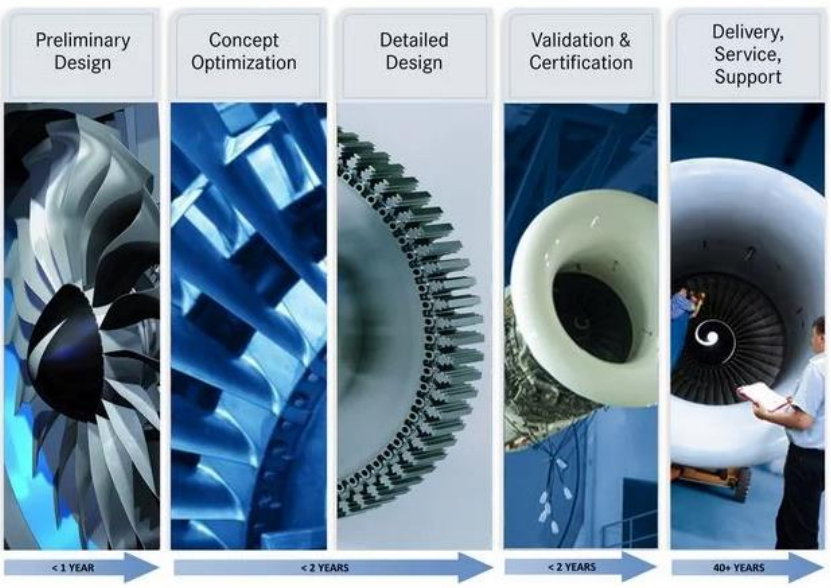

Figure 13: Product Lifecycle of Aeroengine [9]

6.2.2. Shopfloor Automation

The next initiative in shopfloor shall focus on optimizing flow of information from integrated equipment, machinery and computer-based systems which has been attained in phase 1, through shopfloor connectivity interoperability capability. This initiative will move shop floor automation dimension from Band 1 (basic) to Band 2 (advanced), where repetitive production processes are automated with minimal human intervention.

An optimized shopfloor execution will bring the organization closer to an ideal smart factory, which allows production processes to be executed with high reliability and efficiently. Shopfloor automation can help the organization to increase yield, uptime, quality as well as reduce costs and waste.

This capability can be achieved by integrating the equipment and machines with MES so that the data can be collected, interfaced with other machines for process automation.

a) In maintenance process, to capture vibration measurement from vacuum furnace pump and integrate this with MES to monitor and alert when the reading is out of tolerance.
b) In repair operation, the spare parts consumed in the repair job gets verified and validated to ensure the right components and when consumed it decreases inventory level in MES inventory module.

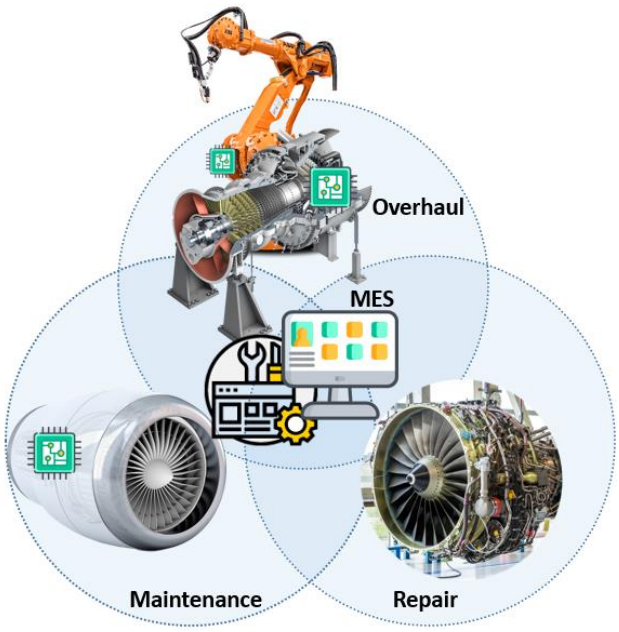

Figure 14: MRO Shopfloor Automation

6.2.3. Enterprise Automation

Enterprise automation is the systematic review of an organization process to ensure optimal performance while looking for manual process to be replaced with intelligent digital alternative. Assessment results show the current enterprise automation dimension is at Band 0 where the company executes all enterprise processes solely by human. This means the productivity of the enterprise process is dependent on human performance where the gains may vary in each condition. Our team proposes to start the enterprise automation at phase 2 as it is necessary for the company to plan and structure the necessary important features which suitable for their legacy system before implementing the new software or technology. The company should choose to digitize those relatively standard transactions such as financial transaction or ordering

system. Some planning and preparations are required to ensure the process could run effectively and improve productivity. The Company has to consider the following aspects when implementing enterprise automation solution. [10]

1) Ease of Implementation – Simple installation and rapid organizational implementation is the desired enterprise automation solution.
2) Powerful capabilities with ease of use – The automation must create value in short time. It allows IT organization to accelerate the workflow between organization and it moves the organization toward dynamic automation where changing business requirements are able to be addressed. Below is a guideline from Gartner research.

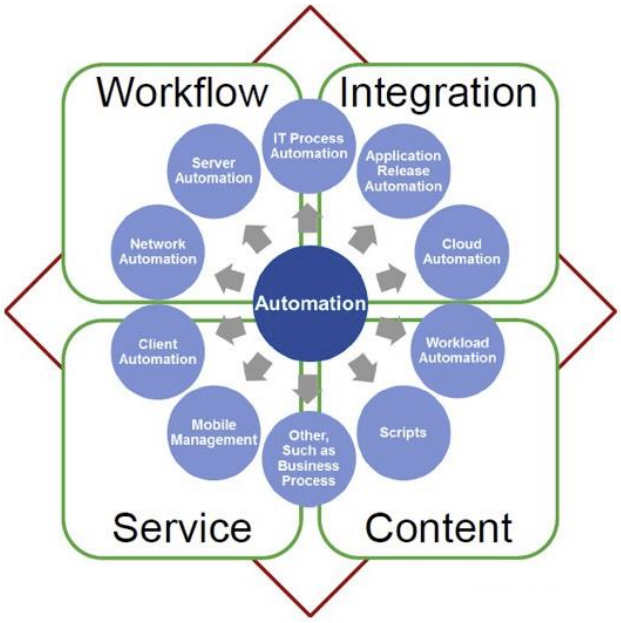

Figure 15: Powerful capabilities in enterprise automation [10]

3) Depth of automation capabilities – A cross-functional solution that coordinate and execute process for business and IT organization across the enterprise.
4) Breadth of functional integration – Most organizations have multiple automation tools and managed by separate team. This results in high cost of operation and low agility. Seamless cross-functional automation is beneficial to organization when it is able to consolidate all key business applications and manage workflows to deliver the critical services. It should offer the direct integration for third party applications or database where this reduces the reliance on multiple platform or tool to automate the process.
5) Support of the automation solution – Reliable support from automation solution vendor is essential to enterprise to ensure the organization operation is in smooth flow.

An example is illustrated on sale and finance department of how the company could start the implementation.

	Challenge	Action
Sales 1) Quotation approval	Low efficiency in quotation approval process as sending email or submitting paperwork for approval which may take certain time	Required a platform to give assessment which can reduce the cycle of approval.
	Challenge	Action
Finance 1) Expenses approval	Many paper works required for submission to get approval and increase workload for staff	Required a platform to give assessment and simplify the process where the staff could focus on higher value activity.

Table 5: Example of challenges that enterprise automation solution can tackle

Once the selection of software, server and license is done, this will lead to software development where important information and desired features are met in the automation process. The software development is vital to grow the enterprise automation and it has to integrate with all department (administrative process) within the company so that management could have a visibility of the progress. Then this has to be followed up by the hardware installation where sensor, electronic device, cable etc. help to provide real time data that enables the company to execute the processes. The progress will take several months for different departments to be on board the new enterprise automation solution.

A platform which can help the company establish online system, data is able to be collected and stored for its future use. The goal here is not just to improve the efficiency and productivity, the collected data is useful for new value creation for the company. This can build a foundation to lead the enterprise process adapt and converged with shopfloor and facility automation which allow dynamic interaction. [11]

6.2.4. Leadership Competency

The digital transformation has changed the leadership role and competencies. Our team's perspective is that in the long run when moving towards Band 3 at phase 2, management of the company shall start to embrace cultural change within organization. The top management is responsible for starting shot of change process where their contribution will help to drive clear objectives in digital transformation. In the journey of transformation, digital literacy plays a vital role and an utmost ability that help management to succeed. An overview of digital literacy is illustrated in Figure 16. Digital literacy does give the leader an edge and make people more productive leading to greater efficiency and influence people around him. Thus, management shall work on some new project by developing initiatives to leverage latest trends in one area of the organization. It is necessary for the management to engage with the organization and empower employee during the digital transformation journey. Contribution of individual

employee is utmost important and motivate them going through the digital transformation. Here we shared an eight steps changes process which introduced from a Professor Jon Kotter (Harvard Business School) in Figure 17. The model serves as a reference for the company's management to plan toward in phase 3.

Figure 16: Digital literacy

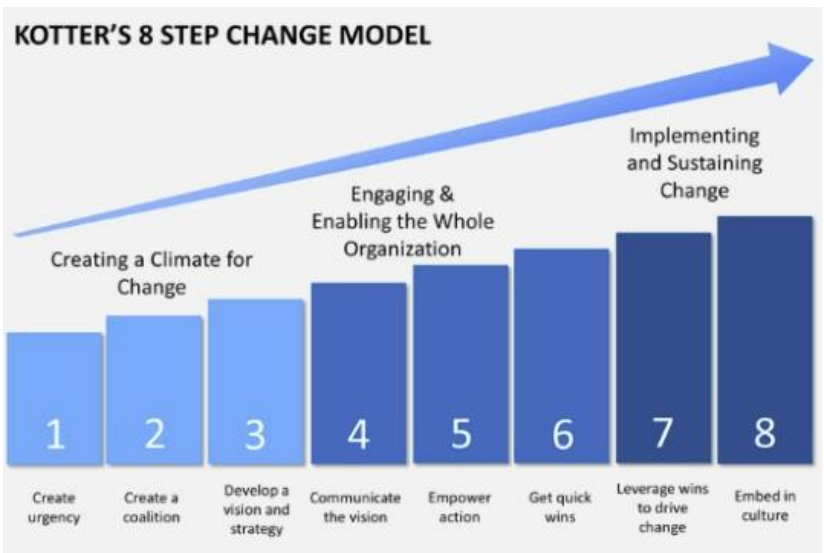

Figure 17: Kotter's 8 step change model

The company's management could work on new lighthouse project with external partner such as Tech company to initiate the digital transformation. As a leader in the organization, they need to think, act and react differently in order to succeed in digital world. There is no instruction and 'recipe' to direct and guide the leaders therefore the management have to experiment and examine the quick win projects to convince and deploy change in organization. The quick win will help management to drive the change toward digital transformation within organization.

6.3. Phase 3

6.3.1. Shopfloor Intelligence

The target for this phase is to achieve the Band 1 status where OT and IT systems are executed through pre-programmed tasks and processes. Leveraging upon phase 1 transformation in horizontal integration, and shopfloor connectivity dimensions, shopfloor intelligence can now be looked at in a more structured approach. MES which is one of the many IT systems requirements has been built during phase 1 transformation and has now enhanced the digital thread flow of instructions and product related status information. In addition, connectivity through sensors for equipment with incompatible data protocols has now created a possible option to performing initial phase of intelligence.

Automation transformation initiative in phase 2 has promoted the utilization of pre-programmed logics managed through the MES systems such as CNCs programming. Input and output formats have now been pre-defined with minimal manual intervention on-the-fly during processes. Output consistency can now be managed more effectively. Band 1 status in this case will be easily met. What we think is crucial in this band of intelligence is to be able to determine and strategize the data model structures of the input and output in each processes or tasks for ease of data management for future improvement. Simple intelligence logics such as independent process alerts including completion, error, and many can be introduced with the availability of data. These will aim to provide real time status information and increase productivity in operation.

Leveraging on these digital threads' readiness, we would encourage "The Company" to start understanding the business challenges in the current state which may include machine maintenance, product quality variation. Ability to make use of the digital data which is currently available to provide visual capability to alert any logic deviations such as machine parameters. Any abnormality observed with visual Key Process Variables (KPVs) against the defined thresholds allows early investigation to take place. This preparation activity can take place once more data is made accessible which helps move towards the next intelligence Band of 2. Accountable information and data in Band 1 and next band will assist by making advanced analytics for the future state much easier.

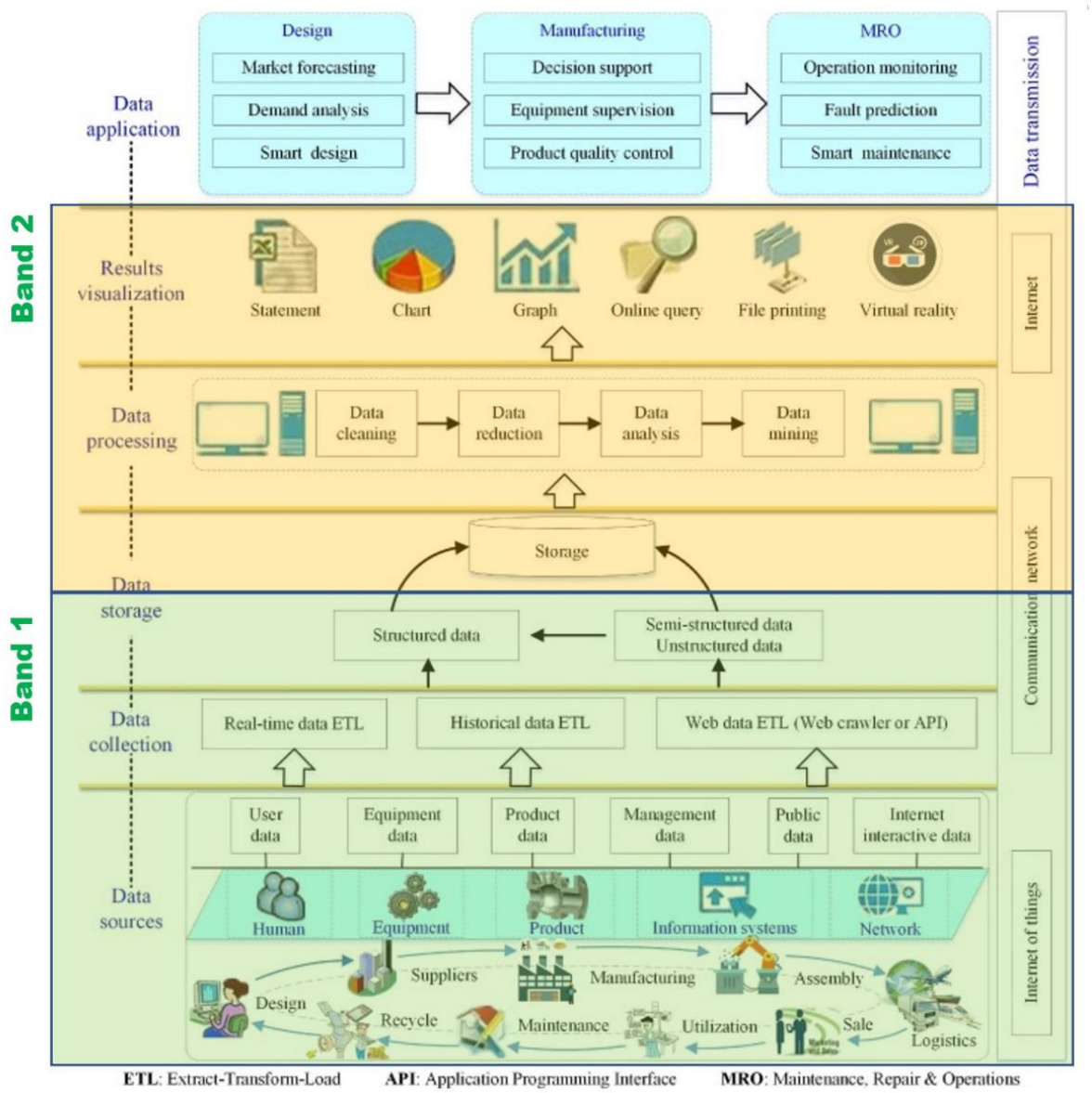

Figure 18: Illustration band 1 and band 2 digital data [12]

6.3.2. Enterprise Intelligence

Like shopfloor intelligence, the target for this dimension within this phase is to achieve the Band 1 status where enterprise IT systems are executed through pre-programmed tasks and processes. Leveraging upon Phase 1 transformation in vertical integration, and already connected systems, enterprise intelligence journey can be deep dived. ERP system is readily available now with digital information communicated through the connected network. Pre-programmed flow of information input into the ERP system can be looked at. Configurating the ERP system to pull or receive pre-defined information or data from other systems or sources can eliminate manual administrative process. Ability to create such pre-programmed flow will mitigate any risks to incorrect input which can result in incorrect output. This will also increase productivity and faster planning activities including load and capacity.

Within Band 1's scope, it is important to standardize the communication languages between systems to the enterprise systems e.g., ERP. The company must ensure they have determined the type of communication protocols exist in all the systems including legacy and new. This will allow standardization of input and output information automatically into ERP such as TCP/IP. Likewise, standard protocols will help in preparation for more advanced intelligence activities e.g., load and capacity prediction in the near future. Simple intelligence pre-programmed logic can be introduced in this phase including activity such as using the data and information flow to alert any delay of output to the scheduled plan, materials stock level against defined output and others. These can help personnel to make sound decision.

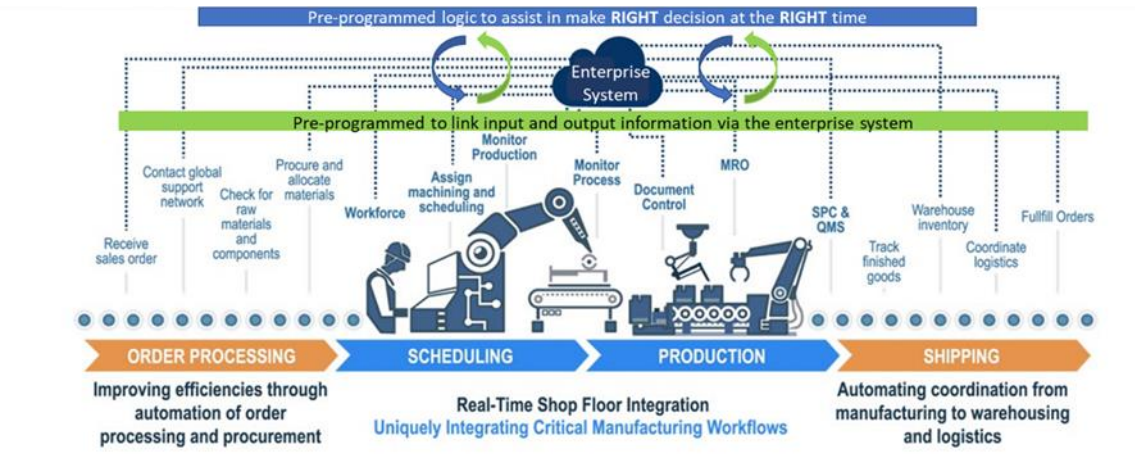

Figure 19: Importance of automatic information for informed decision-making

6.3.3. Facility Intelligence

In line with the other 2 intelligence dimensions, the target for facility is to achieve the Band 1 status where OT and IT systems are executed through pre-programmed tasks and processes. Leveraging upon its formal connectivity readiness and parallel Band 2 automation transformation where no manual intervention on-the-fly of the processes except during initiation and conclusion of the processes. This readiness will assist in allowing facility intelligence to attain Band 1 status easily where pre-programmed logics will be in place either in silos or common system and with simple intelligence capability. This capability includes and not limited to energy consumption threshold alert through simple pre-programmed logic in the energy monitoring system. Such intelligence allows facility management to understand and drive for targeted improvements.

Again, defining the standardized communication protocols is important as part of data management regardless of shopfloor, enterprise or facility systems. To be able to effectively communicate within all facility systems e.g., BMS, standardized protocols need to be defined through surveying of all assets and the associated systems. Protocols such as BACnet, Modbus may be identified as the standard languages to follow through this exercise. These preparations

will permit more advanced analytics to be developed against defined use cases in future phases of transformation.

In this MRO industry where shopfloor outweighs facility, lower maturity level of the facility system may be expected. In such condition, integrated systems in a standardized platform where data can be effectively analyzed for reporting or notification as required in Band 2 will take longer. However, intelligence should not put on hold as long as data is accessible and aggregated in one or more OT or IT systems.

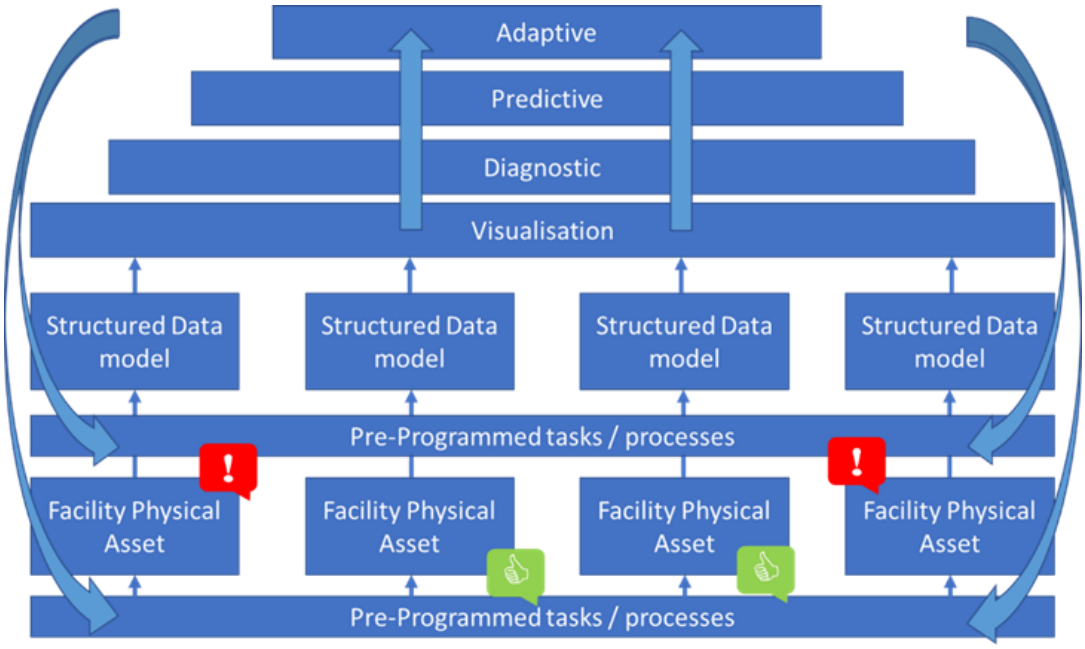

Figure 20: Overview of information structure for facility

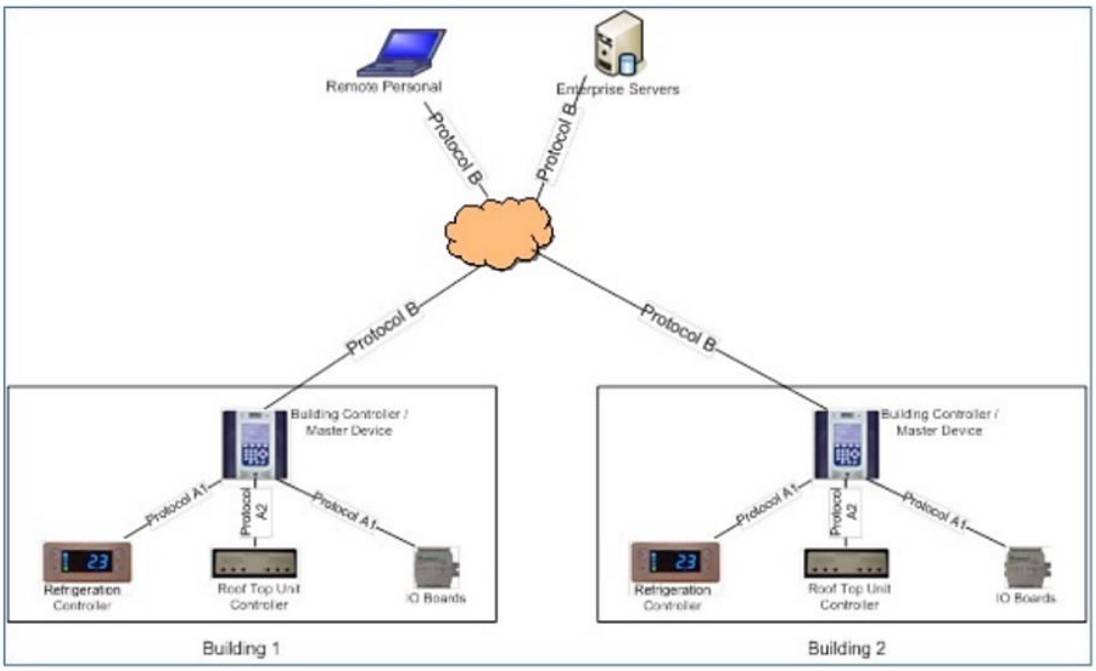

Figure 21: Understanding of protocols within the infrastructure

6.3.4. Facility Automation

Utilities contributes to significant component of overall operating expenses; an efficient facility automation could translate into significant operation cost saving opportunity, safety, staff productivity and security. Connected facility and partial facility automation in place provide the necessary foundation for the organization to pursue further automation in facility area to minimize human intervention. This will also bring facility automation dimension from Band 1 (basic) to Band 2 (advanced), which are indicated by processes are predominantly executed by equipment, machinery and computer-based system while human intervention is still required to initiate and conclude each process.

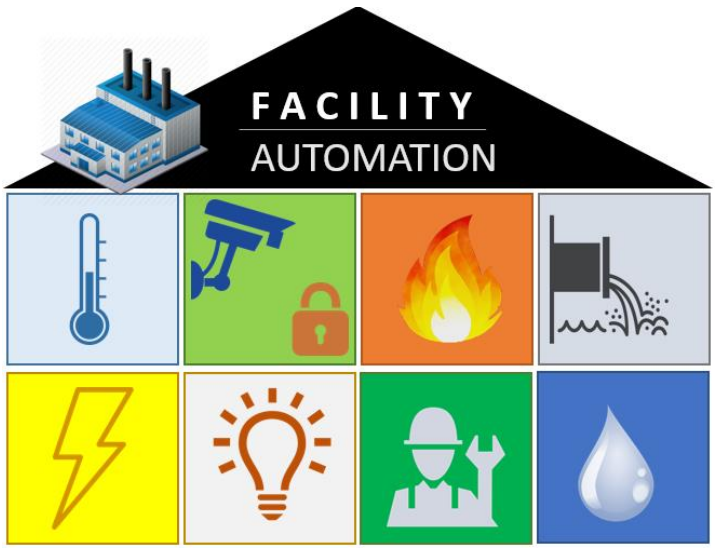

Figure 22: 8 Optimization Areas with Facility Automation

a) Myriad cost-effective sensors or smart Closed-Circuit Television (CCTV) that are capable of detecting human presence in the room can be utilized to automate in heating, ventilation, and air-conditioning (HVAC) systems and lightning systems. Hence, the electricity consumption can be reduced significantly when human traffic is low.
b) The smart CCTV system can also be used in surveillance system and combined with physical access door system this will tighten security control while reducing the number of security personnel. The same system can also be used as a control system in the areas that are classified as hazardous and improve safety management.
c) A highly connected facility that is integrated into a Building Management System (BMS) can be used in detecting anomalies and performance degradation in facility systems. This data can be used as alert system for the maintenance team; hence, preventive maintenance job can be carried out by facility technician to prevent breakdown that may cause shopfloor operation to stop and causing loss of productive hours. The long-term benefits of this

initiative will allow the organization to switch mode of preventive maintenance from time-based to predictive based on performance analysis, which in turn will reduce cost of maintenance and extend factory and equipment lifetime.

d) Energy monitoring will allow the consumption analysis per process, equipment energy usage monitoring, and provides data for engineering team for deeper facility energy consumption analysis.
e) Integrated water and chemical flow management, that can be used by operation team to manage the flow and monitoring water and chemical used in cleaning and maintenance operation.
f) Allows operation team to control the used chemical and solid waste weighing process that is currently being handled manually, with record maintained and calculated manually in excel.
g) Integrated fire detection is another area that can be pursued, which can be used by facility team to detect fire early, access control on the exit routes and elevators management in the event that fire is detected. This initiative will reduce cost of fire insurance and protect company investment.

6.3.5. Enterprise Connectivity

To achieve smart factory aspiration, the organization needs to further optimize enterprise connectivity dimension by moving to Band 2 (interoperable), where computer-based systems are able to interact and exchange information without significant restriction. This means to move beyond the shopfloor toward influencing the enterprise and broader ecosystem through integration of data from system-wide physical, operational, and human assets to drive manufacturing, maintenance, inventory tracking, digitization of operations through the digital twin, and other types of activities across the entire manufacturing network.

The main benefits can be derived from a smart factory are organization becomes more efficient, agile, less production downtime, greater ability to predict and adjust to changes in the facility or boarder network, possibly leading to better positioning in the competitive marketplace. [13]

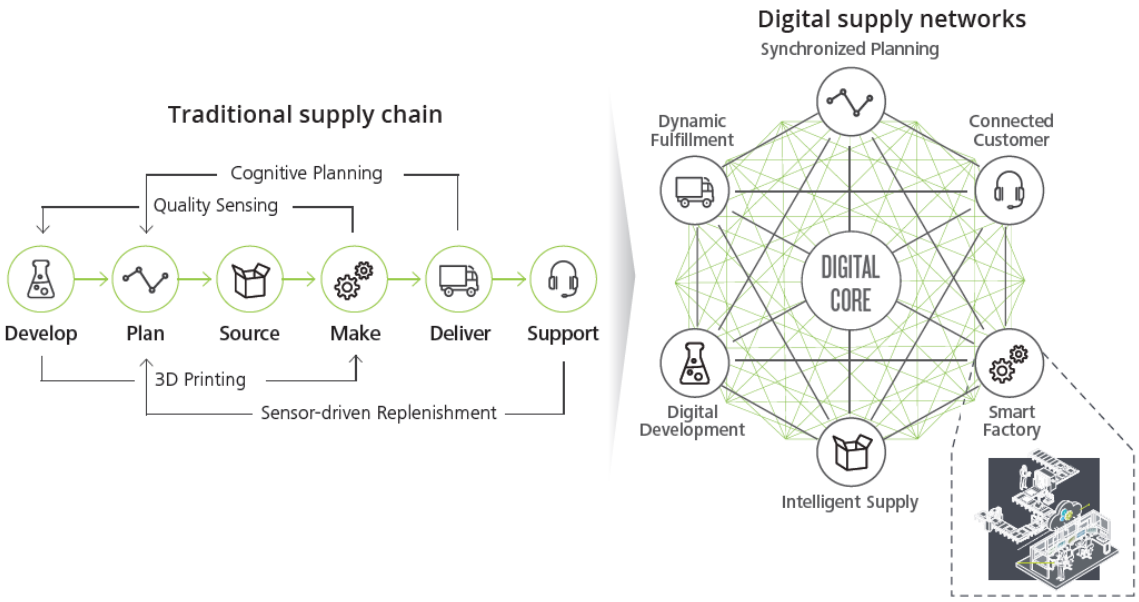

Figure 23: Shift from traditional supply chain to digital supply network [13]

A well-connected enterprise, through connected shopfloor, facility and enterprise systems, will enable the organization to transform its supply chain from a static linear supply chain to a dynamic, interconnected system that provide better foundation for operation evolution to a more optimal state over time. Through real-time data-enabling collaboration with suppliers and customers, it will enable the organization to respond to shifting customer demand, new markets and new products or services.

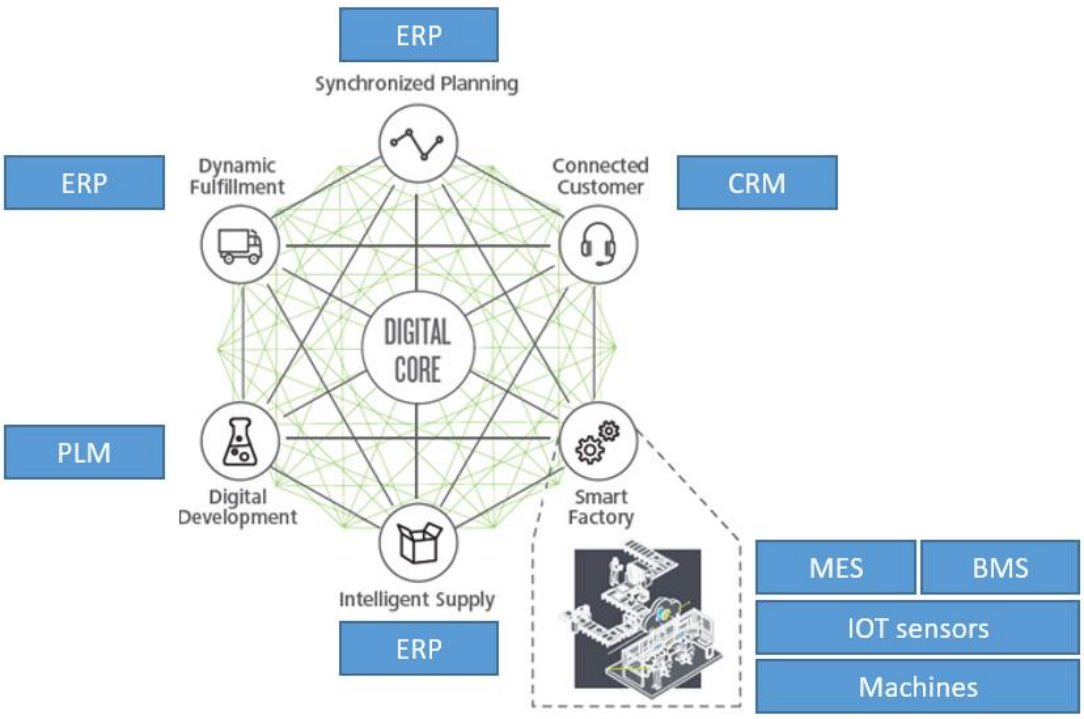

Figure 24: Enterprise System Connectivity Enabling Digital Supply Chain Network.

6.3.6. Workforce Learning and Development (L&D)

Workplace learning involves formal and informal learning initiatives for employees at every level of the organization to gain knowledge, skills, and expertise, leading to better way of accomplishing job tasks, fulfilment of career goals, and personal development.

In order to create better customer-focused solutions by advancing the level of digital skills across business units, a Digital University (a.k.a. Digital U) has been set up at "The Company's" parent company "The New Merged Parent" to provide employees across business units access to the latest learning and development opportunities. Course offerings from the Digital University encompass various skills and concepts that are critical to digital transformation, e.g., Agile culture, Digital Mindset, business intelligence, data analytics, digital infrastructure and so on.

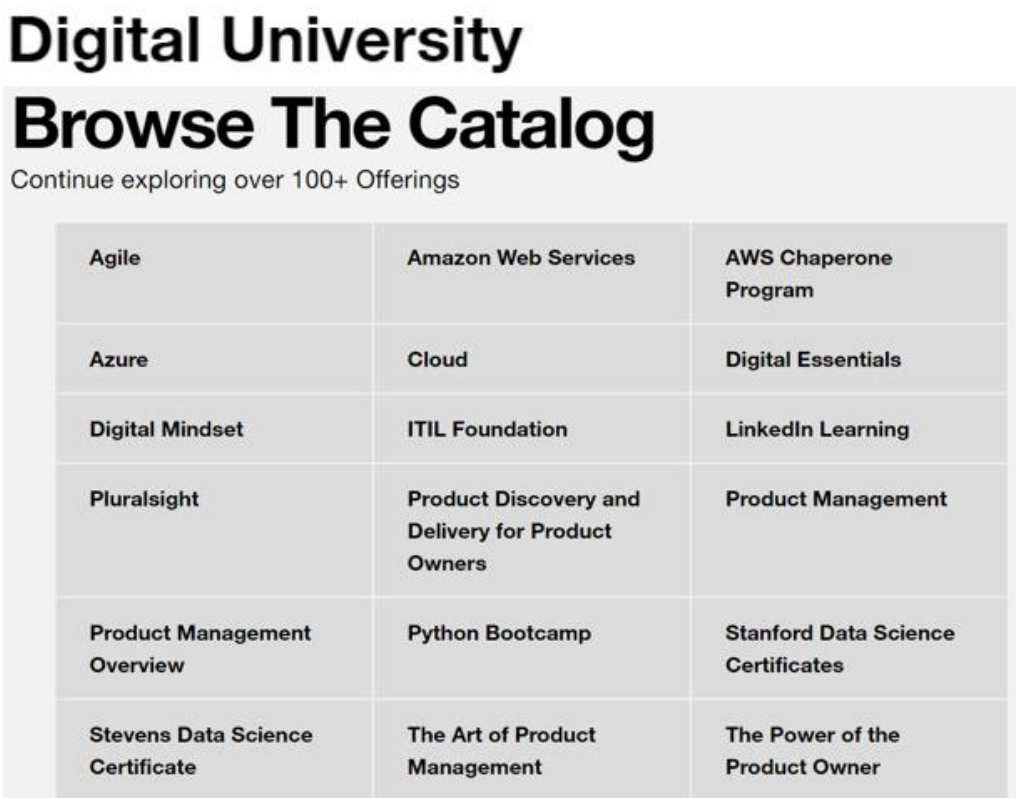

Figure 25: Digital University Online Course Offerings from Parent Company

Being a subsidiary of "The New Merged Parent", "The Company", which is currently in Band 2 of the workforce L&D dimension, is advised to tap onto the learning resources available at the corporate level. On one hand, this ensures alignment between the learning & development curriculum with the organizational objectives (requirement in Band 3); on the other, it provides continuous learning opportunities at minimal cost to the subsidiary. Team leaders and supervisors in this case are recommended to familiarize themselves with the development opportunities, make them known to the employees and keep the employees motivated in order

to create a continuous and relevant learning culture. Department leaders shall set yearly training targets aimed at supplementing employees' skill sets and competencies, and brainstorms together with respective team members to identify areas of application for the newly acquired skill sets. Furthermore, it is recommended to offer scholarship, mentorship and fellowship programs to help build a pipeline of diverse leaders and champions that are well-versed in the digital skill sets and are able to formulate and articulate digital strategies. Human resource has the lead here, especially in the area of talent identification and deeper talent inclusion. When it comes to talent development program, make sure clear objectives are set and reviewed on a regular basis.

6.3.7. Strategy and Governance

In the strategy and governance dimension, the company is evaluated at Band 2 as it is in the midst of developing long-term digital strategy and governance. When defining digital strategies, statistical analysis, stakeholder interviews, surveys, focus groups, competitor and market analysis shall be used to understand the current state the company is at and more importantly to secure buy-in for the digital transformation. Besides digital business strategies, transformation governance is crucial to sustaining this buy-in and to turn the insights gained into tangible improvement and adjustment plans for the subsequent transformation activities. [14]

Before moving on to band 3 (the implementation), it is recommended to put in place a governance structure which has clear definition of the roles and responsibilities for its key components. The key components may include:

1. An executive committee that down-selects and prioritizes workstream or user stories (based on ROI, timescale, urgency, etc. to maximize the value of transformation) that will be used as the basis for planning downstream transformation activities.
2. A digital board comprising members from senior management. The board is responsible for monitoring the execution of each iteration of transformation.
3. A digital transformation head (preferably an agile transition leader) who is responsible to oversee the project execution and report progress updates to and seek guidance from the digital board. The head of digital transformation also leads a core digital team that manages the overall coordination of the digital transformation.
4. Project leads having the role of championing respective transformation projects within the organization through adaptive or agile project management. They have a 'dotted line' report to the head of digital transformation.

In addition, it is important to set up digital transformation monitoring and reporting mechanism by defining effective outcome and process KPIs. It should be noted that having just the outcome

KPIs alone is not sufficient. There is a need to identify and measure activities that have significant impact on the outcome of each digital initiative. When formulating performance measures, it is advised to ensure there are aligned to the company's overarching mission and vision. The measures should be clear and understandable and ideally presented as interactive visuals. Besides tracking the actual performance change as a result of digital initiatives (timeliness, throughput, quantity, quality, etc.), these measures shall also allow the company to gain certain predictive and prescriptive insights.

A successful implementation of the transformation initiatives shall be carried out in an iterative manner, following the agile development framework if possible. After each development cycle, new tools are deployed for trials (with training as required) and stakeholders' feedback shall be genuinely sought (two-way communication) so that improvements can be planned at the next cycle. Involving the stakeholders through a collaborative process of designing and implementing the transformation is the best way of communication and engagement with relevant parties.

7. Digital Transformation Roadmap

The proposed transformation consists of 3 phases with the prerequisite of each dimension's capability taken into consideration. The whole roadmap of 36 months is designed to enable "The Company" to achieve SIRI smart factory readiness to the Aerospace industry standard. On the journey to develop "The Company" with the technologies towards smart factory, the working culture and agile workforce mindset shall also be developed to run a I4.0 smart factory to next level. How successful the digital transformation in elevating the business productivity and profitability will depend on the people who drive the transformation with integration of technologies.

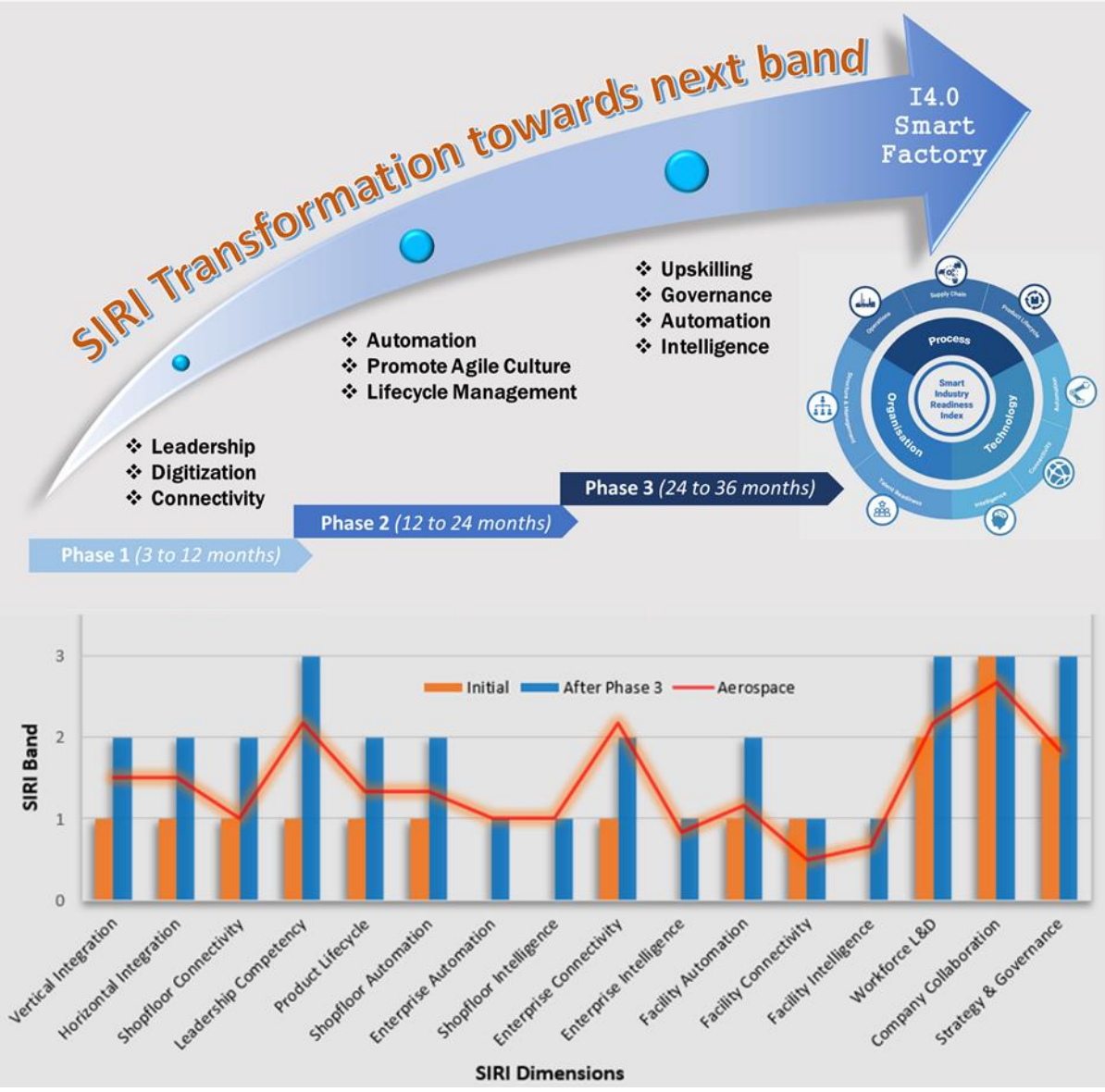

Figure 26: SIRI – Digital Transformation Roadmap

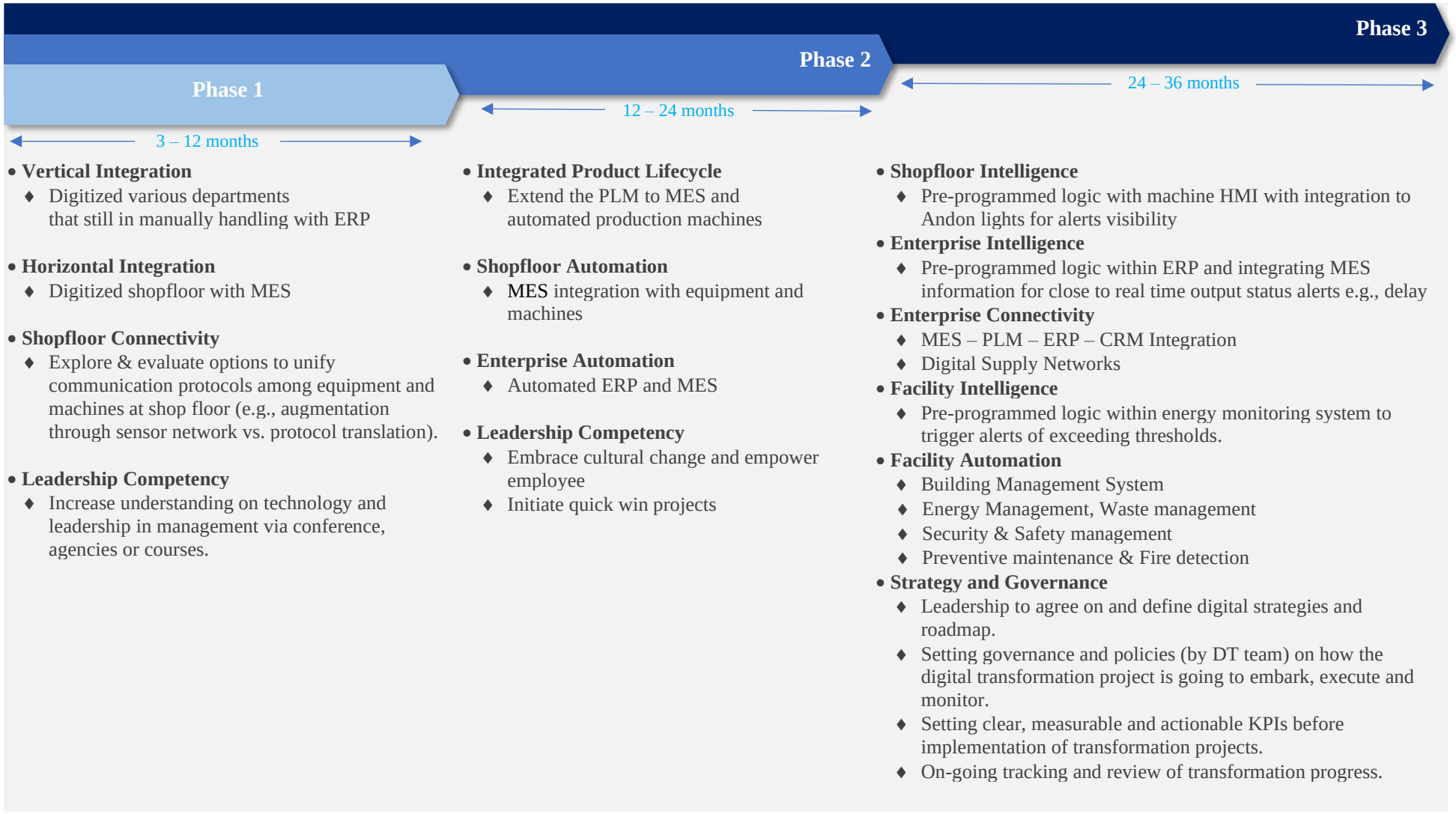

Figure 27: Digital Transformation Phase 1, Phase 2, Phase 3

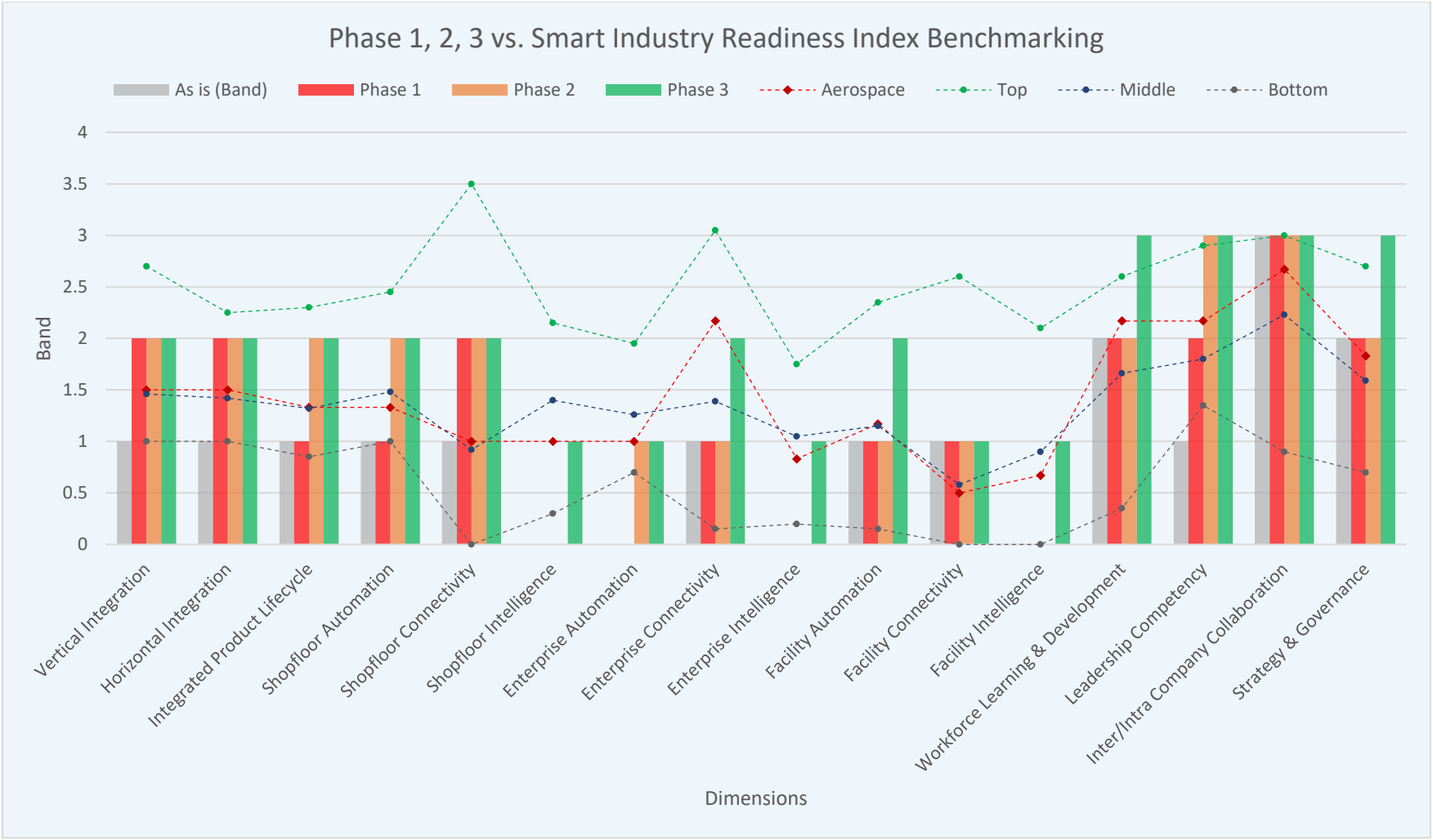

Figure 28: Capabilities Improvements vs. SIRI Benchmarking

8. Conclusion

One of the key findings from PricewaterhouseCoopers survey research in Industry 4.0 is that the biggest challenge in digital transformation is people; the success of the transformation journey lies on how well its leaders define, lead and communicate the transformation. Changes are not always comfortable for people who make it happen, change management is critical factor to have smooth adoption. [15]

True Smart Factory is a more holistic endeavor, moving beyond the shop floor toward influencing the enterprise and broader ecosystem. The smart factory is integral to the broader digital supply network and has multiple facets that manufacturers can leverage to adapt to the changing marketplace more effectively. [13] The result of Smart Factory can be a more efficient and agile system, less production downtime, and a greater ability to predict and adjust to changes in the facility or broader network, possibly leading to better positioning in the competitive marketplace. It is important to note, however, that smart should not be considered the "end state". Rather, it represents an ongoing evolution, a continuous journey towards building and maintaining a flexible learning system.

Globally, companies struggle to understand what Industry 4.0 means for them. SIRI framework breaks the key concepts down into various building blocks and dimensions and provides clear articulation of benefits to the companies. "The Company" has taken an important first step using SIRI as the diagnostic tool in better understanding its current state of the facility. Ability to understand its gaps will better position "The Company" in creating and delivering targeted goals through phases of transformation initiatives and moving closer towards a Smart Factory objective and importantly aligning with its MVV.

With increasing system connectivity and interoperability, the organization will gain efficiency in production and maintenance, reduce operation cost and increase quality of the work. Digital transformation will also increase the level of cyber risk, this dimension is not covered in SIRI framework and in this report, however, it is worth highlighting that a good security policy and framework need to be embedded in every aspect of the digital transformation initiatives.

9. References

[1] EDB Singapore, "The Smart Industry Readiness Index." Nov. 13, 2017, Accessed: Mar. 15, 2021. [Online]. Available: https://www.edb.gov.sg/content/dam/edb-en/about-edb/media-releases/news/the-smart-industry-readiness-index/the-sg-smart-industry-readiness-index-whitepaper%20(1).pdf.

[2] "Self Assessment," *SIRI*. https://siri.gov.sg/self-assessment (accessed Apr. 23, 2021).

[3] EDB Singapore, "The Smart Industry Readiness Index (SIRI) Manufacturing Transformation Insights Report 2019." Oct. 22, 2019, Accessed: Mar. 15, 2021. [Online]. Available: https://www.edb.gov.sg/content/dam/edb-en/about-edb/media-releases/news/the-smart-industry-readiness-index/SIRI%20Manufacturing%20Transformation%20Insights%20Report%202019.pdf.

[4] B. Frankiewicz and T. Chamorro-Premuzic, "Digital Transformation Is About Talent, Not Technology," *Harvard Business Review*, May 06, 2020.

[5] L. Gehrke *et al.*, *A Discussion of Qualifications and Skills in the Factory of the Future: A German and American Perspective*. 2015.

[6] S. SE, "Customer Stock." https://help.sap.com/doc/bdd7c353b677b44ce10000000a174cb4/3.6/en-US/9fd7c353b677b44ce10000000a174cb4.html (accessed Apr. 23, 2021).

[7] Capgemini Consulting and the MIT Center for Digital Business global research, "The Digital Advantage: How Digital Leaders Outperform their Peers in Every Industry," *Capgemini Worldwide*, Nov. 05, 2012. https://www.capgemini.com/resources/the-digital-advantage-how-digital-leaders-outperform-their-peers-in-every-industry/ (accessed Apr. 23, 2021).

[8] "The hunt for digital leaders: A talent perspective on navigating the Industrial Internet transformation | Thought Leadership," *Russell Reynolds Associates*. https://www.russellreynolds.com/insights/thought-leadership/the-hunt-for-digital-leaders-a-talent-perspective-on-navigating-the-industrial-internet-transformation (accessed Apr. 21, 2021).

[9] "Product Life Cycle - MTU Aero Engines." https://www.mtuusa.com/engineering-services/product-development-integration/product-life-cycle/ (accessed Apr. 15, 2021).

[10] Frank Melchiorre, "Finding the Perfect Enterprise Automation Solution," *IT Automation Without Boundaries*, Jul. 01, 2015. https://www.advsyscon.com/blog/enterprise-automation/ (accessed Apr. 23, 2021).

[11] D. Lomanto, "The Fully Automated Enterprise Is Here (And Looks Like This) | UiPath." https://www.uipath.com/blog/fully-automated-enterprise-is-here-now (accessed Apr. 15, 2021).

[12] F. Tao, Q. Qi, A. Liu, and A. Kusiak, "Data-driven smart manufacturing," *J. Manuf. Syst.*, vol. 48, pp. 157–169, Jul. 2018, doi: 10.1016/j.jmsy.2018.01.006.

[13] Rick B. et. al., "The smart factory," *Deloitte Insights*. https://www2.deloitte.com/us/en/insights/focus/industry-4-0/smart-factory-connected-manufacturing.html (accessed Apr. 23, 2021).

[14] H. Tardieu, D. Daly, J. Esteban-Lauzán, J. R. Hall, and G. Miller, *Deliberately Digital: Rewriting Enterprise DNA for Enduring Success*. Springer International Publishing, 2020.

[15] PricewaterhouseCoopers, "Industry 4.0: Building the digital enterprise." Accessed: Apr. 21, 2021. [Online]. Available: https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf.