

CAPABILITIES AND SERVICES OFFERED BY MALAYSIAN LEARNING CENTRES IN ASSISTING MANUFACTURING ENTERPRISES IN THEIR DIGITAL TRANSFORMATION JOURNEY

(Date received: 12.01.2022/Date accepted: 01.04.2022)

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ABSTRACT

Industry 4.0 encompasses a plethora of notions and technologies aimed at assisting manufacturing entities, particularly small and medium-sized firms, in gaining a competitive edge. Hence, an effective implementation of technology in the domains of asset integration, digitization, and automation is dependent on meeting plenty of demanding requirements. The role of learning centres in assisting these firms is critical to ensuring the country's overall digital transformation is a success. An exploratory quantitative survey was carried out in Malaysia to ascertain the learning centres' strengths and gaps in aiding the country in spearheading the Industry 4.0 (I4.0) agenda. The survey's primary result is that learning centres must further equip themselves to act as a catalyst in assisting the manufacturing industry in realising the I4.0 potential, albeit there is also a need to strengthen commercialization between learning centres and manufacturing enterprises. Additionally, the survey discovered that learning centres should strengthen their collaboration and affiliation with the country's primary industries in order to accelerate the adoption of I4.0 in Malaysia. Another significant outcome of the survey is the call for the establishment of a one-stop-centre for I4.0 services such as funding and policy inquiries, as well as the promotion of learning centres' services, which are critical to assisting manufacturing enterprises in their digital transformation journey.

Keywords: Manufacturing value chain, digital transformation, Industry 4.0

1.0 INTRODUCTION

The First Industrial Revolution was driven by steam and waterpower, which enabled the mechanisation of manufacturing processes, whereas the Second Industrial Revolution was spurred by electric power and mass manufacturing techniques. The Third Industrial Revolution was ushered in by information technology. This has resulted in the subsequent phase of evolution, dubbed Industry 4.0 (I4.0) (Neugebauer *et al.*, 2016).

The European Commission estimates that 99.8% of enterprises in the European Union are classified as Small and Medium-sized Enterprises (SME) (Safar, *et al.*, 2018). According to Malaysia's National Policy on Industry 4.0 (2018), the manufacturing industry is a significant economic sector, accounting for around 22% of GDP between 2014 and 2018. Malaysia's manufacturing sector is predicted to increase at a rate of roughly 5.1% under the 11th Malaysia Plan, with 98.5% of SMEs accounting for 42% of total employment.

Recognizing the importance of manufacturing and small and medium-sized enterprises (SMEs), Malaysia, like other countries, has developed a National Policy on Industry 4.0, commonly known as Industry 4WRD. The purpose of this Industry 4WRD strategy is to create a more organised national agenda through measures that will hasten Malaysia's

transformation into a smart and modern manufacturing system in the age of Industry 4.0.

Likewise, Germany has established its High-Tech Strategy 2020 Plan, while the United States of America has established the Advanced Manufacturing Partnership (AMP) and National Advanced Manufacturing Strategic Plan. The European Commission also sponsored the Factories of the Future Program (2008-2020) with the same objective, while the United Kingdom has its own Industrial 2050 Strategy (Zhang, *et al.*, 2019).

China developed the Made in China 2025 policy, whereas the Republic of Korea developed the Strategy for Innovation in Manufacturing Industry 3.0, and Taiwan developed Productivity 4.0. (Kuo, *et al.*, 2019). On the other hand, Japan devised the Industrial 4.1J and Revitalization Strategy, which included the establishment of the Science and Technology Industry Alliance to lead the I4.0. Singapore developed the Future of Manufacturing (FoM) through the Advanced Remanufacturing and Technology Centre (ARTC) and the Singapore Institute of Manufacturing Technology (SIMTech).

In Malaysia, the Industry 4WRD policy encourages the participation of I4.0 service providers and their engagement with manufacturing entities to assist in the implementation of relevant processes, technologies, and skill development. This plan is contingent upon the existence of I4.0 learning centres in

Malaysia capable of providing such services. This is consistent with Moeuf *et al.* (2020) assertion that research need to also consider strategic opportunities and operational factors in addition to I4.0 technology.

As a result, Collaborative Research in Engineering, Science, and Technology (CREST), a consortium of academia and industry, conducted an exploratory survey. The purpose of this survey is to ascertain the present capacity of I4.0 learning centres to provide consultation and training services to manufacturing entities in order to function as a catalyst for these entities' success in implementing I4.0. The analysis of the results is explored in greater detail in the remaining sections of this article, and the article's main research contribution is summarised in the conclusion segment.

2.0 METHODOLOGY

This exploratory quantitative survey was conducted from March 1 to May 31, 2021, with the population frame consisting of universities, research centres, and state-sponsored skill development centres in Malaysia; and the sampling frame consisting of technology centres that offer I4.0 services such as training, implementation, and consulting. These learning centers are associated with CREST, undertaking I4.0 initiatives in Malaysia. To reach out to Malaysia's widely spread learning facilities, a quantitative survey was chosen over a qualitative one. The sample size is sixteen recognised learning centres participating in this exploratory survey. Each state with learning centres replied to the survey, with the exception of Johor. The response rate was 75%.

The questionnaire consisted of six components and was administered via an online survey platform. The survey questions were distributed via an online link to the learning centres for completion. The sections include information about the centres' demographics, the technology and services they provide, the vertical and horizontal technologies they adopt, their affiliations or partnerships with other entities, their existing industrial engagement, and a section on the challenges and proposals for I4.0 from the centres' perspective.

3.0 RESULTS ANALYSIS

3.1 Demographic and Distribution of Technology Learning Centres

One of the analyses conducted using the 16 identified I4.0 learning centres is to look into the distribution of the centres in relation to the concentration of manufacturing enterprises in Malaysia. According to the Malaysian Department of Statistics' Economic Census 2016 Manufacturing Sector, manufacturing establishments are concentrated in Selangor (20.4%) and Kuala Lumpur (10.7%). In comparison to the location of the learning centres, the distribution is shown in Table 1.

It was discovered that 53.3% of learning centres cater to the top three locations with the biggest distribution of industrial establishments, namely Selangor, Kuala Lumpur, and Johor, which account for 47.5% of the population. This indicates that learning centres are available in the top three locations with manufacturing companies. However, seven states in Malaysia,

Table 1: Distribution of manufacturing establishments in Malaysia and the availability of learning centers

	Location: State (and Federal Territory)	Percentage of manufacturing entities (%)	Availability of learning centers
Klang Valley			
1	Selangor	20.4	2
2	Kuala Lumpur	10.7	4
Northern Corridor Economic Region (NCEC)			
3	Perak	8.9	0
4	Pulau Pinang	8.5	3
5	Kedah	6.7	1
6	Perlis	0.8	0
East Coast Economic Region (ECER)			
7	Terengganu	4.1	0
8	Pahang	3.6	2
9	Kelantan	3.8	0
Sarawak Corridor of Renewable Energy (SCORE)			
10	Sarawak	5.2	1
Sabah Development Corridor (SDC)			
11	Sabah	3.7	1
Others			
12	Johor	16.4	2
13	Negeri Sembilan	3.9	0
14	Melaka	3.1	0
15	WP Labuan	0.2	0

accounting for 46.7% of the total, lack learning centres in their respective states. This could be perceived as a shortage of important industrial and training facilities.

3.2 Capabilities and Services Offered by Learning Centres

The services rendered by the I4.0 technology learning centres is depicted in the Table 2.

To drive I4.0 in Malaysia, training, solution workshops, and the availability of solution demonstrations and hands-on labs are all essential. Malaysia's labour productivity has improved by 3-4% in recent years, according to the Malaysia Standard Classification of Occupations (MASCO) 2013, as mentioned by Economic Census 2016, although the country's worldwide position and use of high-skilled labour has remained stationary. In 2016, Malaysia's labour productivity was rated 44th, the same as it had been since 2009. The proportion of high-skilled workers in the workforce has decreased from 19% in 2010 to 18% in 2017. As a result, the availability of I4.0 learning centres' training and skill enhancement workshops is considered as a significant driver in empowering Malaysia's human resources to adopt I4.0. This aligns with the Industry 4WRD goal of raising the number of high-skilled people in manufacturing from 18% to 35% by 2025.

Table 2: Services provided by learning centres

	Services Rendered	Description of services	Percentage %
1	Training	I4.0 awareness, conceptual, best practices including tools and solution training from learning centres	100
2	Demo machines or software	Availability of prototype or facility within the learning centres as an aid to facilitate learning	67
3	Solution workshop	Hands-on lab on tools, software and hardware/ machines related to I4.0 technology enablers	58
4	Consultancy	Provision of best practices and implementation of I4.0 technologies for the manufacturing entities	58
5	System integration	Services by learning centres to assist with the assets integration in the manufacturing value chain in the hierarchical and vertical axis of architectural model	50
6	Deployment project support	Provision of project management services for manufacturing entities in their I4.0 related projects	33
7	Funding Facilitation	Cooperation and joint-project arrangement with sponsorship between learning centres and manufacturing entities to realise specific I4.0 initiatives adoption	8

Table 3: Technologies offered by learning centres

	Technologies at learning centres	Availability percentage (%)
1	Internet of Things (IoT)	92
2	System integration	92
3	Autonomous robots	67
4	Simulation	75
5	Cloud computing	67
6	Artificial Intelligences (AI)	58
7	Big data analytics	58
8	Augmented reality	33
9	Cybersecurity	33
10	Additive manufacturing	33
11	Advance material	8

One of the pillars of Industry 4WRD is funding and outcome-based incentives. According to the survey, technology learning institutions only provide finance facilitation in 8% of cases. This finding is in line with the findings of the study, which classify learning centre responsibilities as accelerators (8%), technology funding facilitators (8%), and commercialization facilitators (17%). Learning centres identified themselves as training provider (83%), technical and skill development centre (92%).

This suggests that learning centres in Malaysia are not pursuing commercialization initiatives with manufacturing companies, preferring to focus on training and skill development. While funding for the I4.0 journey can come from a variety of sources at the macro or national level, the survey shows that manufacturing entities can benefit from partnership with learning centres. In addition, there is a need to improve commercialization between learning institutes and industrial companies.

Equally important is the availability of technology that can be used and supported by I4.0 learning centres. Table 3 shows the capabilities of the learning centres based on the various technologies used, as well as the experience and information that can be imparted through know-how trainings.

Adoption of these enabling technologies adds a substantial new dimension to the production landscape, resulting in a noticeable boost in industrial productivity. According to the exploratory study, learning centres are prepared to act as a catalyst in assisting the manufacturing industry in realising the I4.0 potential. Some of the available capabilities cited by the survey respondents include Drone Center providing development and commercialization of drone technologies, Autonomous Mobile Robot (AMR) Center which focuses on mechanical design, fabrication, PCB design, and application development, 3D Printing Center for rapid prototyping, XR Center with augmented reality programs, and other Center of Excellence (CoE) labs equipped with the latest systems for applied engineering to further develop I4.0 future ready workers.

These high-tech services supplied by I4.0 learning centres are critical for Malaysia's I4.0 implementation. According to the World Economic Forum's 2018 Readiness for the Future of Production Report, Malaysia's competitive position is jeopardised by increasing competition from countries such as Indonesia, the Philippines and Vietnam, as well as established global manufacturing leaders such as Germany, China, Japan, and the Republic of Korea.

3.3 Affiliation and Collaboration with Industries and Countries

Additionally, the accomplishment of I4.0 learning centres is contingent upon their affiliation with industrial partners engaged in genuine manufacturing. Close partnership to better connect market needs with the assessment of the centres' training and technological capabilities would be critical to ensuring that the explicit manufacturing sectors that require I4.0 catalysts receive adequate backing. Table 4 indicates the many forms of industrial involvement that the I4.0 learning centres engage in.

Electrical and electronics, machinery and equipment, chemical, medical device, and aerospace are the five primary industries mentioned in the Industry 4WRD policy for I4.0. According to the survey's findings, learning centres should

increase their partnership with industry associates, particularly in the rubber, aerospace, chemical and medical device sectors, to ensure that industrial requirements are considered more fully in their R&D and skillset competency training to avoid programme gaps. Simultaneously, the majority of learning centres (75%) are directly affiliated with manufacturers in the electrical, electronic, and mechanical sub-sector. The survey's respondents also indicated that they expect to collaborate with industry partners more in the future, both locally and internationally, with the latter including associates from Europe and China, notably Germany. This is in line with the World Economic Forum's (WEF) Readiness for Future of Production Report (2018), which places countries like Germany, China, Italy, Poland, and France in the 'Leader' quadrant of the report, where learning centres' collaboration with industry partners from these countries would boost closer knowledge sharing that could be employed for the benefit of local manufacturing.

Table 4: Types of industry engaged by learning centres

	Manufacturing sub-sectors	Affiliation and engagement by learning centres (%)	Identified as focus sectors of I4.0 in 4WRD
1	Education	83	Not identified
2	Electronics, Electrical and Mechanical	75	Primary
3	R&D	75	Not identified
4	Agriculture	67	Not identified
5	Food and beverages	58	Secondary
6	IT and digital business	58	Not identified
7	Public sector	50	Not identified
8	Medical device	43	Primary
9	Telecommunication	42	Not identified
10	Construction	42	Not identified
11	Aerospace	33	Primary
12	Rubber	33	Primary
13	Hospitality	33	Not identified
14	Professional services	29	Secondary
15	Chemical / petro chemical	25	Primary

Learning centres should, nevertheless, explore forming partnerships with industry partners from the Republic of Korea and Japan as well, as these nations are also ranked in the report's 'Leader' quadrant.

3.4 Vertical and Horizontal Integration of Learning Centres

A segment of the questionnaire was devoted to determining the digitalization maturity of the learning centres' systems. The survey questions were developed using the Industrie 4.0 Reference Architecture Model (RAMI 4.0) as a guide. The German Electrical and Electronic Manufacturers' Association (ZVEI)

developed this model to support Industrial 4.0 aspirations. This three-dimensional framework establishes a shared knowledge of standards among community stakeholders (Birtel, *et al.*, 2019).

The 3-dimensions of RAMI 4.0 consist of:

- Hierarchy level – where product, field devices, control devices, station, work units, enterprise to connected world are interfaced through standards defined by ISO/IEC62264 International Standard: Enterprise-control System Integration and ISO/IEC61512, where it is made up of four concerted standard documentations
- Lifecycle and value stream – where product development to post product production activities standard is defined by ISO/IEC62890 Industrial-process Measurement, Control and Automation
- Architectural layer – where assets are represented in the physical world with a digital twin and illustrate how asset integration up to the functional and business layers benefits manufacturing entities in a value chain. The Asset Administration Shell (AAS) provides a guiding principle on assets' digital representation (Grangel-Gonzalez, *et al.* 2016).

There are ten steps to perform vertical and horizontal integration based on RAMI 4.0 through the technology enablers or the I4.0 technology pillars, in Industry 4.0 deployment. As a result, it is critical to comprehend how the technological pillars of learning centres map to the vertical and horizontal integration technology solutions, as shown in Tables 5(a) and 5(b). Every stage of the vertical and horizontal integration is assisted with the required technology enablers. By mapping the technology services provisioned by the learning centers, it is possible to deduce the capabilities of the learning centers in assisting manufacturing companies in their I4.0 quests.

Learning centres will be able to support the execution of steps one to five in vertical integration. At the highest levels, the learning centres offer very rudimentary support. Learning centres' help for horizontal integration is limited due to its technical pillars' specialisation, which is mostly focused on vertical integration.

Figure 1 shows the number of centres required to support vertical integration (VI) and horizontal integration (HI). According to RAMI 4.0, VI and HI must take ten steps to achieve Industry 4.0 (Tables 5(a) and 5(b)). From the survey, there are 7, 9, and 10 learning centres supporting the execution of vertical integration phases 1 to 3, with 6 learning centres focusing on networking and communication, integration and interoperability, and database management. In addition, in vertical integration, 5 and 8 centres offer visualisation dashboards with analytics, and in horizontal integration, digital enterprise, business analytics, and AI, respectively. The result corresponds to the services given by the previously mentioned centres.

Figures 2(a) and 2(b) demonstrate the breakdown of the number of centres that support vertical and horizontal integration based on investment corridors. The Klang Valley and the NCER are two investment corridors that can enable vertical and horizontal integrations from steps 1 through 5 and 9 in general. Nonetheless, from steps 6 to 8, there is a general lack of support for vertical and horizontal integration. It's also worth noting that the I4.0 deployment in East Malaysia, such as Sabah and Sarawak, indicating insufficiency to support manufacturing organisations within the investment corridors.

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Table 5(a): Technology pillars of I4.0 learning centres map to vertical integration table

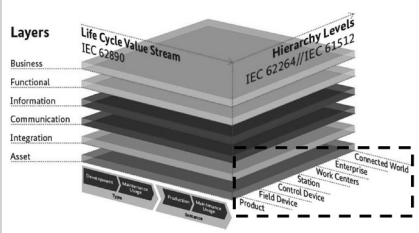
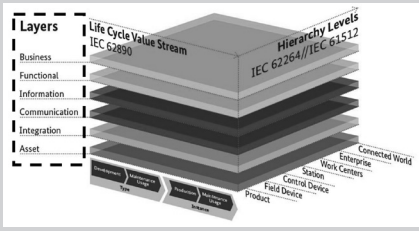
HI Steps	Reference Architecture: RAMI 4.0											
	 Vertical Integration (VI) Technology Solutions	Advanced Materials	Additive Manufacturing	Simulation	Internet of Things	Autonomous Robots	Augmented Reality	System Integration	Big Data Analytics	Artificial Intelligences	Cloud Computing	Cybersecurity
1	Product, tracking and traceability	●	●	●	●							
2	Field devices, smart devices and robot				●	●	●					
3	Control devices (PLC, IPC and others)				●	●	●					
4	SCADA and data acquisition solution				●							
5	Control devices and SCADA integration							●				
6	Manufacturing Operations Management											
7	SCADA and MES integration							●				
8	Enterprise Resource Planning											
9	MES and ERP integration							●				
10	Visualization dashboard with analytics								●	●	●	●

Table 5(b): Technology pillars of I4.0 learning centres map to horizontal integration table

HI Steps	Reference Architecture: RAMI 4.0	Industry 4.0 Technology Enablers										
	 Horizontal Integration (HI) Technology Solutions	Advanced Materials	Additive Manufacturing	Simulation	Internet of Things	Autonomous Robots	Augmented Reality	System Integration	Big Data Analytics	Artificial Intelligences	Cloud Computing	Cybersecurity
1	Asset identification and definition				●							
2	Asset digitalization and integration				●							
3	Networking and communication							●				
4	Integration and interoperability							●				
5	Database management										●	
6	Hybrid data management										●	
7	Manufacturing chain management							●				
8	Data protection and access control											●
9	Data and information brokering							●			●	
10	Digital enterprise, business analytics, AI										●	●

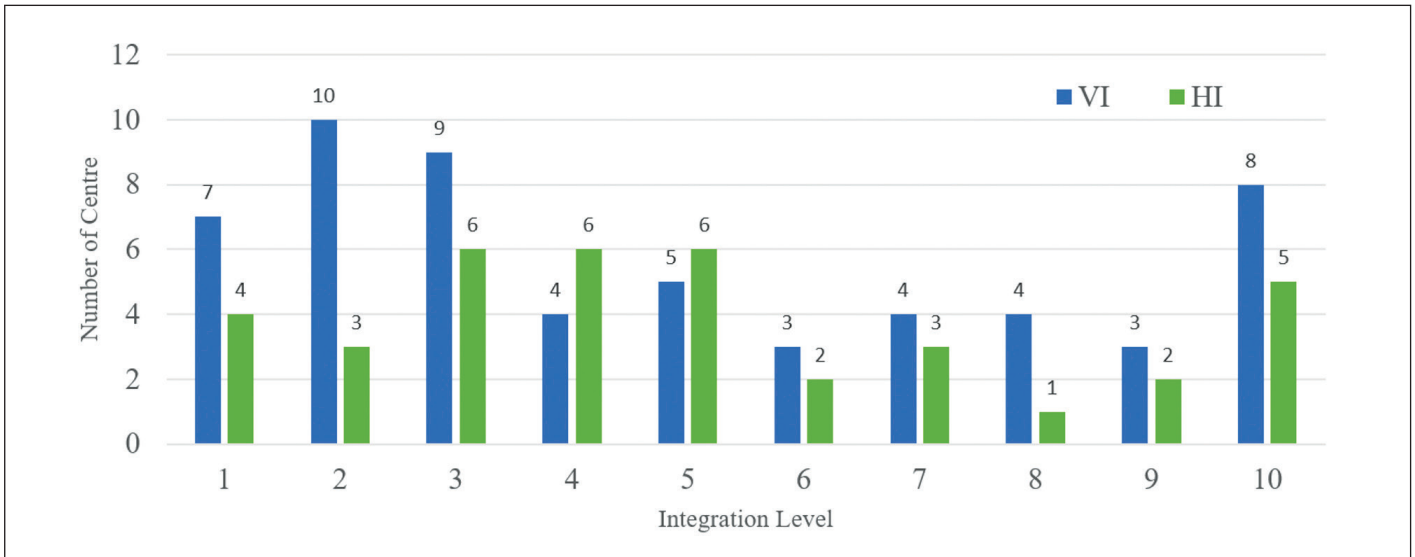


Figure 1: Support of learning centres in the vertical and horizontal integration

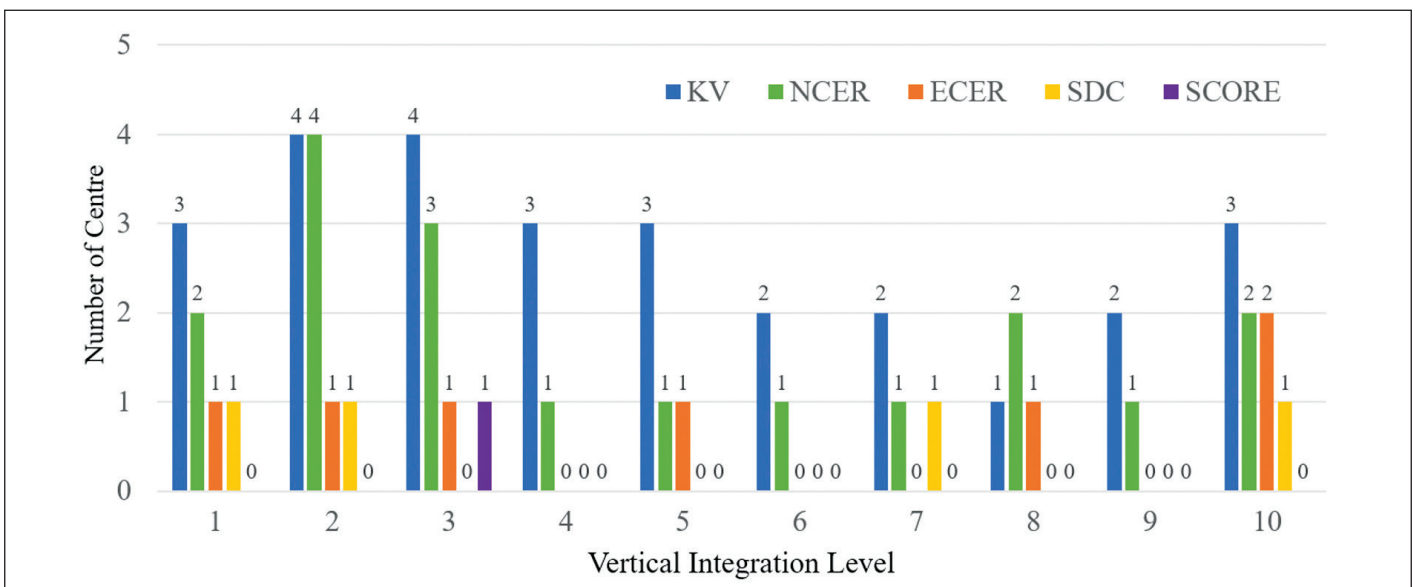


Figure 2(a): Learning centres to support the vertical integration based on investment corridors

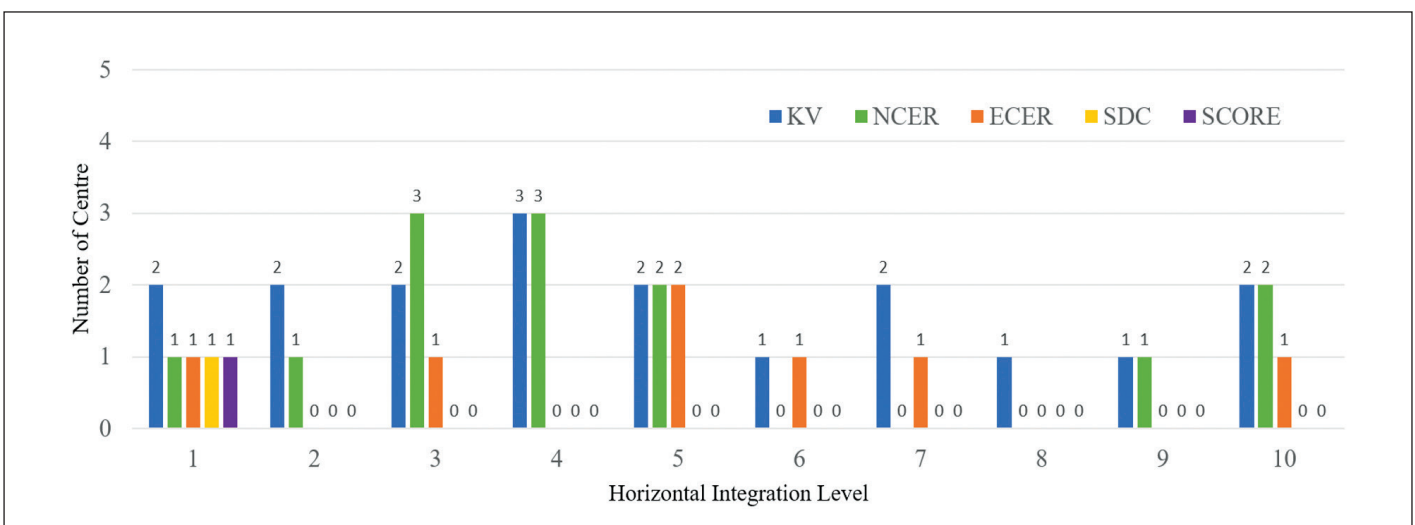


Figure 2(b): Learning centres to support the horizontal integration based on investment corridors

3.4 Challenges and Opportunities

The common issue mentioned in the survey on the topic of obstacles faced by manufacturing companies as assessed by learning centres is funding, which is divided into two categories. The first is learning centres and service providers' funding. For example, the Ministry of International Trade and Industries (MITI) and the Ministry of Science, Technology and Innovation (MOSTI) should put more resources into advancing learning centres' facilities with cutting-edge platforms to show how technology can help manufacturing businesses adopt I4.0 roadmaps faster.

Another type of support is funding for manufacturing companies to enable them to implement I4.0-related technologies. Industry 4.0 deployment results in horizontal, vertical, and end-to-end integration for manufacturing entities (Wang, *et al.*, 2016). A significant initial financial and time commitment is necessary to create and execute an architecture that is tailored to the needs of such enterprises (Singer, 2015). To implement Industry 4.0, significant capital expenditures are required, and funding must be raised (Rojko, 2017).

Other form of financial assistance could be tax incentives or tax exemptions on the adoption of technology and even on the services obtained by the manufacturing enterprises. Under the funding programme, the 4WRD Policy specifies two strategies. The much-anticipated action plans stated in the said strategy, according to survey respondents, should be hastened, such as the formation of a government-led expansion fund for I4.0.

One more issue raised in the survey is that manufacturing companies lack the know-how to get started with I4.0 adoption and application. There are few local success stories to promote I4.0 since manufacturing companies believe such initiatives will have a low return on investment (ROI). These notions are in line with the findings of Sony's (2020), which found that cybersecurity concerns, trade union concerns, the initial high cost of implementation, workforce readiness and the negative impact of data sharing between enterprises in the value chain would all pose challenges to a successful I4.0 adoption. Furjan *et al.* (2020) add to this by stating that digital transformation faces a high chance of failure if the business processes and environment are neglected.

The necessity for a coordinated effort among the various parties in the country to establish a one-stop-centre for I4.0 services such as funding and policy inquiries, and the promotion of learning centre services is among the suggestions made by the survey respondents. The provision of a readiness assessment for manufacturing companies, followed by the referral of appropriate learning centres to provide guidance, training and implementation services, is one of the anticipated services from this one-stop-centre.

The function of the one-stop-centre in promoting increased awareness of learning centres' capabilities and services was also mentioned by respondents in the survey as a way to address the problem of learning centres' lack of visibility in the country. Another crucial success factor (CSF) in I4.0 in the country is the adoption of a single marketing platform, which includes the use of social media to boost learning centres' visibility.

Respondents also recommended that learning centres continue to put up actual assembly lines to demonstrate I4.0 competencies, as well as a call for learning centres to undertake

vertical and horizontal integration among themselves to further demonstrate their competency. Other learning centres around the country may be able to acquire data for training purposes by connecting to the digital twin, which is a virtual version of the real-time physical production line in both centres.

4.0 CONCLUSION

The survey's conclusions are provided in this article, with the primary finding pointing to the learning centres' inability to deliver the essential services and training to manufacturing companies in Malaysia to promote I4.0 development. A defined vertical and horizontal execution strategy is necessary to support I4.0 learning centres in planning and enriching their training and services based on the technology pillars in which they specialized in. Additional learning centres should be developed in other states throughout the country, as seven locations in Malaysia, accounting for 46.7% of the country, now lack the provision of learning centres.

Additionally, there is a need to strengthen commercialization between technological learning centres and manufacturing firms. To further accelerate the adoption of I4.0 in Malaysia, learning institutes should strengthen their collaboration and affiliation with the country's primary industries, as well as with other countries. Another potential comprises the need for a coordinated effort among the country's various stakeholders to establish a one-stop-centre for I4.0 services such as funding and policy inquiries as well as the promotion of learning centre services. ■

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PROFILES



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