Asia-Pacific
Economic Cooperation

Advancing Free Trade
for Asia-Pacific Prosperity

Policy Recommendation on Improving Supply Chain Performance with Digital Manufacturing Technology amid Pandemic Crisis

APEC Policy Partnership on Science, Technology and Innovation

June 2022

Asia-Pacific
Economic Cooperation

Policy Recommendation on Improving Supply Chain Performance with Digital Manufacturing Technology amid Pandemic Crisis

APEC Policy Partnership on Science, Technology and Innovation

June 2022

APEC Project: PPSTI 06 2020A

Produced by
Chinho Lin, Bo-Wei Chen, Hong-Chun Wang, Cheng-Chun Wu and Chia-Yun Chien
Chinho Lin, Department of Industry and Information Management, National Cheng Kung University

For
Asia-Pacific Economic Cooperation Secretariat
35 Heng Mui Keng Terrace
Singapore 119616
Tel: (65) 68919 600
Fax: (65) 68919 690
Email: info@apec.org
Website: www.apec.org

APEC#222-PP-01.4

TABLE OF CONTENTS

KEY ABBREVIATIONS

AEC	ASEAN Economic Community
AI	Artificial Intelligence
AM	Additive Manufacturing
APEC	Asia-Pacific Economic Cooperation
ASEAN	Association of Southeast Asian Nations
CPTPP	Comprehensive and Progressive Agreement for Trans-Pacific Partnership
DISER	Department of Industry Science Energy and Resources
DISF	Domestic Investment-Specific Fund
DNA	Deoxyribonucleic Acid
EPU	Economic Planning Unit
ESG	Environment, Social Responsibility and Corporate Governance
FDI	Foreign direct investment
ICT	Information and Communications Technology
IOT	Internet of Things
ITRI	Industrial Technology Research Institute
RA	Readiness Assessment
RCEP	Regional Comprehensive Economic Partnership
SCRI	Supply Chain Resilience Initiative
SME	Small and Medium Enterprises
STI	Science Technology Innovation

1. Introduction and the current situation of the supply chain.

Prior COVID-19 pandemic in an emerging Asia, the membership of RCEP (Regional Comprehensive Economic Partnership) and CPTPP (Comprehensive and Progressive Agreement for Trans-Pacific Partnership) has become the focus of eastward shift of the global economic and trade development center, where the ASEAN economies are the new starting point for future regional integration in Asia. The ASEAN Economic Community (AEC) integrated the ten economies in the region in 2016. The diversified industries and economic growth of these economies have effectively attracted a great deal of worldwide attention. They have been committed in promoting digital transformation and Industry 4.0 policies to improve industrial business flow and information flow exchange efficiency. It also strengthens flexibility of manufacturing and facilitates implementation. These days, the Asian supply chain has become a professional division of labor economies, and they are linked to each other. First is the trade agreement regarding simple manufacturing with Viet Nam, India and Bangladesh. Second, it absorbs technology from Thailand and Malaysia. Third, it uses independent technology and management technology to provide creativity, manufacturing high-quality products from Chinese Taipei, Korea and China. Finally, it completes and innovates product design capabilities from the United States, Japan and the European Union (TIER, 2021).

Specifically, Southeast Asia is already a new area of global FDI (Foreign direct investment), with abundant labor and low manufacturing costs. According to Global Investment Trend Monitor statistics, Southeast Asia's FDI has reached US$156 billion in 2019. Even if it were affected by the epidemic in 2020, there would still be US$107 billion in FDI.

In 2021, the global supply chain faced several risks repeatedly, for instance, chip shortage, port congestion and logistics traffic, which mainly involve environmental, political/policy and logistics issues. In consequence, when companies are restructuring the supply chains, they must require more forward-looking perspectives and more diversified strategies to enhance supply chain resilience. The changes in post-COVID19 have impacted worldwide economic.

However, the COVID-19 pandemic caused global investment activates to fall but ASEAN has been an attractive investment area. The region’s share of global foreign direct investment (FDI) rose from 11.9 percent in 2019 to 13.7 percent in 2020. The

intra-ASEAN share of FDI in FDI in the region increased from 12 percent to 17 percent. According to the first-of-its-kind ASEAN Development Outlook (ADO) report, the total combined GDP of 10 ASEAN economies in 2019 was valued at USA3.2 trillion. It shows that ASEAN is the fifth-largest economy in the world and well on track to become the fourth largest by 2030. The outlook remains promising with the under ways that coordinated pandemic response efforts and several key developments in the region. The ASEAN-led Regional Comprehensive Economic Partnership (RCEP) Agreement came into force on January 1, 2022 for Australia, Brunei Darussalam, Cambodia, China, Japan, Lao PDR, New Zealand, Singapore, Thailand and Viet Nam. The agreement also came in to force on February 1, 2022 in Korea and on March 18, 2022 in Malaysia.
It shows that 40 per cent of investment in ASEAN comes from RCEP members. The opportunities exist to boost more sustainable FDI in the region. Recently, the adoption of the Consolidated Strategy on the Fourth Industrial Revolution (4IR) for ASEAN and the ASEAN Agreement on Electronic Commerce will facilitate the region's advance for digital transformation and private investment in digital infrastructure development with the ASEAN Comprehensive Recovery Framework (ACRF) identified digital connectivity as a priority to facilitate regional connectivity and economic recovery (Lee, 2022).

2. The importance of an enhanced and localized supply chain.

2.1 The Importance of enhanced supply chain

With the enhancing adaption of outsourcing and specialization, the global extended supply chain has launched worldwide among several economies over the recent years. However, as regionalist sentiment rises and geopolitical uncertainty heats up, global companies must build more resilient supply chains to respond to the chaotic world. As a result, this global economic situation and geopolitics are more diversified. Under the influence of the coronavirus disease, COVID-19 pandemic, the labor costs are gradually rising, automation technology upgrades, trade war tariff barriers and the pandemic have caused supply chains disconnection issues, such as factory shutdowns, transportation interruptions and shortages of critical materials. Therefore, speeding up the restructuring mode has shifted from reducing costs in the past to reducing risks and at the same time, shortening the distance of the supply chain or localized production.

In the new normal after the impact of the epidemic, the mixed long-distance and physical business model has become the "new normal," and enterprises acceptance of digitalization has been accelerated by 5-10 years (TAITRA, 2021). To prevent chain

disconnection caused by the resurgence of the epidemic, decentralized and regionalized manufacturing will continue to advance. In logistics reforms and natural and man-made disasters, the lengthy supply chain is exposed to natural and man-made disasters and other environmental risks have also increased. The multiple factors hidden in this reorganization can be summarized as production costs, customer demand and risk management (TAITRA, 2021). The construction of an appropriate large-scale and complete industrial supply chain in neighboring markets has gradually become the mainstream of corporate strategies. The purpose of supply chain reorganization is to appropriately deal with the impact of these variables and enhance the adjustment and resilience of the supply chain.

3. Research and analysis on the implementation of digital manufacturing in the supply chain in the APEC region.

Digitalization has impacted nearly every element of human life worldwide, including supply chain procedures. These technologies enable enterprises from different supply chains to collaborate on the design, supply, manufacture and distribution of goods and services (Remko, 2020). As a result, firms are accelerating digitalization toward core functional areas such as supply chain and manufacturing, among others, to prepare for the future of the workplace. Therefore, digital manufacturing technologies could promote value chain analysis to consider unpredictable operation disruption, where businesses can gain a more significant competitiveness (Linkov et al., 2020). In general, enterprises see digital manufacturing as a chance to improve their current business strategy to increase revenue and value-added.

3.1 Chinese Taipei

Chinese Taipei's digital manufacturing consultations are predominant in semiconductor industries or ICT (Information and Communications Technology) manufacturing, which offers insufficient support for traditional industries, including textile, steel, or automobiles. Therefore, with the perspective of building a comprehensive ecosystem, several essential factors involving infrastructure, technology and system integration should assist SMEs in accelerating the road toward digital transformation (Lee, 2021).

With the coordination of Industrial Technology Research Institute (ITRI) over recent years, consulting with various companies from different industries,

those who are providing medical equipment, industrial material components, the aviation industry, etc., have led Chinese Taipei's manufacturers toward a more flexible response over the crises. For instance, despite global automotive chip shortage crisis in 2021, Chinese Taipei, with its reputable semiconductor industry cluster and flexible use of digital manufacturing technology, has been actively coordinating and collaborating with supply chain members to increase the supply capacity of auto-chips (Chang et al., 2021).

According to domestic supply chain survey, industry faces various challenges, thus, the upcoming issue is how to predict the need of talent gap? The survey showed that the top 3 challenges for the industry. First, the rapid change business environment with existing forecasting methods is unable to accurately predict market demand. Second, changes in regulations or pandemic events has caused the decrease in forecast accuracy. Third, increasing supply chain size has caused increasing delivery time. Since 2020 the impact of pandemic, in response to market demand, the crisis of lack of labor, materials, and high costs, the trend of cultivating citizen data scientists in enterprises has emerged accordingly (Common Wealth Magazine, 2022).

The collaboration among manufacturing companies and the ITRI have raised digital manufacturing technologies to a higher level of maturity. Recently, additive manufacturing has been applied to multiple industries, ranging from personal equipment from dentures to industrial apparatus. This technology prevents massive amounts of damage if there is a shutdown or suspension, and it also builds a more robust resilience supply chain. Besides, the government has attempted to establish a complete industrial chain on a single platform by integrating domestic industries and academic research in the university has intended to support the development of additive manufacturing (TAAMIA, 2019).

3.2 Japan

In 2020, Japan is still ranked 27th in digital competitiveness and 22nd in digital talent. Therefore, more efforts should be made to enhance digital transformation capabilities for matching its regular economic strength (McKinsey & Company, 2021). Since some of the most interesting AM companies try to bridge manufacturing and digital culture, Japanese additive manufacturing is rising. NIKKEI estimated the Japan additive manufacturing market would reach a compound annual growth rate of 9.1% between 2017 and 2022 (Sher, 2020).

This program provides measures to evaluate if the Government of Japan can quickly implement with priority, leading to digital society. Measures taken by the Digital Agency, which takes an initiative in realizing the digital society, as well as by other ministries and agencies. Digital society that Japan is pursuing for: "Society where each citizen can choose services that satisfy his/her demands and achieve various happiness through digital technology." There are 6 basic policies: (1) growth strategy through digitalization; (2) digitalization in semi-public sector e.g., medical care, education, disaster management, and children; (3) vitalizing local areas through digitalization; (4) digital society where no one will be left behind; (5) securing development of digital human resources; (6) global cooperation strategy including promotion of DFFT (i.e. data free flow with trust). The philosophies of this program are: (1) anyone can enjoy the benefits of digital technology anywhere and anytime; (2) digital 3 principles (administrative procedures through online): digital first/once only/connected one-stop (Digital Agency, 2022).

3.3 Korea

Korea Trade Promotion Corporation report assumes that corporates should foresee the imperative of regionalizing in the value chain and to generate greater added value toward the range of services. Therefore, the report actually suggested that the supply chain should convert its position from "just in time" to "just in case," implementing digital manufacturing technology towards different industries to gain more flexibility and elasticity, enhance the role of supply chain and services (Lee, 2020). The Korean economy needs to highlight a comprehensive digital transformation. However, more than 70% of companies that conducted the transformation are stuck in the pilot stage (Song, 2019).

According to Korea Chamber of Commerce and Industry in 2021, over 70% of Korean firms have suffered a massive fallout in the global supply chain, but it also indicated the essential of supplier diversity to prevent lack of materials and components, which might cause stoppage or suspension of work in the later stage. During the Russia-Ukraine crisis, supply chains in manufacturing sector are exposed to potential geopolitical risks. However, Korea is already taking steps to work out which critical raw materials could be vulnerable as could as closely monitoring a spike in the energy price. Also, Korea is building an "early warning system" which can flag risks to some of these key materials for in advance respond to that potential risk right away and stockpiling system or some sort of swap system could be developed with other economies hard on risk severity for the

shortage material (Tan, 2022).

The Korean government announced Innovation Advancement Policy based on AI and Big data for building Smart Factory (Intelligent Factory) in July 2020. It aims to spread leading innovation examples, which mainly develops new products based on artificial intelligence (Gil, 2021). Additionally, establishing “a basic plan for the promotion of the additive manufacturing industry” every three years regarding three main points which were: 1) to extend the range of the application of additive manufacturing technology; 2) to secure advanced additive manufacturing technologies; and 3) to improve the business environment and education of the additive manufacturing industry (Song, 2021).

3.4 Australia

Digital technologies are generating opportunities across the entire manufacturing value chain, from pre- to post-production, through the creation and optimization of new products, processes and business models. Digital manufacturing can facilitate real-time data analytics (Clochet, 2021) by accelerating the transition from concept to prototype, design and production. Australia has established facilities such as the Industry 4.0 Testlab network at 6 Australian universities; the Cooperative Research Centre (CRC) program, which includes the Innovative Manufacturing CRC and Cyber Security CRC; and the National AI Centre. The above demonstrates that Australia’s collaborative manufacturing ecosystem has been constructed with the aim of helping manufacturers harness the capabilities of these new tools and processes. Australian manufacturers are increasingly using digital technologies such as robotics and artificial intelligence (AI), as well as advanced modeling software and additive manufacturing, to ensure that only the highest quality products leave the factory. Additionally, better data applications, e.g. using customer feedback data, are being used to anticipate demand and inform higher value product development (Department of Industry Science Energy and Resources [DISER], 2018).

Australia experienced its first taste of supply chain disruption when the COVID-19 pandemic began in 2020. The shortages of medical equipment and supplies caused some local manufacturers to pivot to producing essential goods. The lockdowns brought global manufacturing to a halt and caused chaos in global transportation channels. Furthermore, Australia experienced another crisis: workers at every link in the regional supply chain – workers from farms to distribution centers as well as truck-drivers to supermarket staff – were forced into

isolation while Omicron infections surged. It was not only a lack of goods that caused shortages but also a lack of mobile, skilled workers (Cooper, 2022).

The Australian Government announced the Modern Manufacturing Strategy (MMS) in 2020 to improve industry collaboration, commercialization and global value chain integration, as well as to support technology adoption and address critical short and long-term skills gaps. Meanwhile, Australia's Digital Economy Strategy has targeted investment in Australia's digital economy and infrastructure, underpinning improvements in jobs and productivity and making Australian businesses more resilient. By consolidating regulations, reducing bureaucratic obstacles to action and lowering input costs, Australia has been making efforts to improve economic conditions for businesses (Department of Industry Science Energy and Resources [DISER], 2021). The Government is responding in partnership with industry to the damage resulting from the pandemic, and helping businesses become more competitive and resilient over the long term. Australia, recognizing the need to build its manufacturing capabilities to support economic growth and diversity, launched the MMS and prioritized 6 National Manufacturing Priority areas in which Australia has a strategic advantage. This work included the Supply Chain Resilience Initiative, which (1) identified essential products and services during the crisis; (2) outlined the supply chain in terms of destination and relevance; and (3) appraised supply chain resilience under normal circumstances and predictable crisis situations (DISER, 2021).

Accordingly, the Australian Government has aimed to incentivize innovation and support digital transformation across the industry ecosystem. Australia aims to enable Small and Medium Enterprises (SMEs), as well as medium to larger firms, to apply innovative technologies and business models generated with Industry 4.0 approaches in pre-competitive settings to minimize technical and financial risk (Fox, 2020). In 2019, for example, an additive manufacturing cluster was set up through a grant focusing on education and additive manufacturing (AM) to activate mitigations of disruption in local manufacturing industries. Therefore, in response to COVID-19's significant impact on supply chains, the Australian Government accelerated a substantial increase in additive manufacturing, which was an attempt to reduce supply chain uncertainty, especially in the healthcare sector. As stated above, the Australian Government foresaw the value of AM in response to situations in which demand for goods and services dramatically increased in a short period of time (Tillmann et al., 2021).

3.5 Viet Nam

Science, technology, innovation and digital transformation are the driving elements behind Viet Nam's "socio-economic development strategy 2021-2030," which aims to support high-end technologies that contribute to sustainable development, smart cities and a green economy. The Vietnamese government views the construction of digital infrastructure and the creation of data and domestic digital platforms as vital tasks and believes that Vietnamese enterprises involved in digitalization will play a vital role in the economy's future corporate development (TAITRA, 2021).

According to the European Business Review, Viet Nam will be one of the leader in 2022 for coming most sought-after sourcing destination. Furthermore, a recent conference for connecting supply and demand organized by Global Sources in cooperation major international buyers proposed that Viet Nam is their preferred sourcing destination. It shows that there is strong demand for sourcing from Viet Nam among buyers around the world. With such strong demand, Vietnamese suppliers should act fast to grab the opportunity and world-wide. The Viet Nam small and Medium-sized Enterprise Association shifted from their traditional sourcing channels, like trade shows to a new online model. Buyers want to source directly from manufacturers and are looking for Vietnamese suppliers. Though global supply chain disruptions have caused uncertainty for businesses, Viet Nam has been advanced its business climate. This notable strength is its stable economy, which has been growing despite the impact to the economy because that Vietnam people are likely to honor promises (Asia News Network, 2022).

Viet Nam will work to improve communication and cooperation between government departments and the business sector in the future and will advocate for the internationalization of digital transformation. According to the belief, economies should cooperate in developing a more comprehensive, greener and equitable digital world (Ministry of Economic Affairs/ Taipei Economic and Cultural Office in Ho Chi Minh City, 2021). Siemens, as an industry partner for digital transformation, provides digital transformation as a paving a way for innovation services, and data-based business models for the firms in Viet Nam. Viet Nam is very pleased to work with a number of enterprises that are pioneers in digital transformation, such as Vinfast and Thaco. For example, a well-established auto manufacturing, assembly, ad distribution enterprise in Viet Nam. It results in a Siemens Digital Industrial Software for many years. It can help to maximize the journey toward digitalization and Industry 4.0 by unlocking the full potential of

digitalization for all (Newswires, 2022).

3.6 Thailand

Thailand is focusing on developing aviation, medical care, biotechnology, a new generation automotive sector and intelligent electronics and machinery as part of its "Thailand 4.0" initiative. Thailand's government unveiled the "Thailand 4.0" domestic development strategy in 2016. The purpose is to encourage upward manufacturing industry development along the value chain and the use of technology and innovation to aid the region's economic transition. "Thailand 4.0" focuses on the growth of ten target industries, which are separated into two categories: using sophisticated technology to upgrade current sectors and launching new ventures. Furthermore, additive manufacturing is a valuable instrument for Thailand's economic development. AM continues to grow by incorporating more local and international businesses. As a result, the government is assisting in adopting AM by building a shared digital manufacturing platform to encourage the adoption of cutting-edge 3D technologies and digital manufacturing capabilities across the industry (The Nation, 2019).

The Thai economy dropped to a more moderate rate of 5% during the 1999~2005 period following the Asian financial crisis. In this period, Thailand increased job availability and number of young people have obtained better educations (The World Bank, 2021). For the third year in a row, Thailand’s and the global economic recovery will hinge on progress in fighting the COVID outbreak. The rising cost of living and the decline in income highly impact on making people vulnerable to any kind of coming shocks. It implies that the government, businesses, and consumers need play their roles properly for riding out the difficulties. Thai PBS World’s Business Desk examines the five key areas of concern in 2022. 1) Challenge of business-as-usual amid COVID; 2) Risk of serious supply chain disruption; 3) Rising cost of living; 4) Getting out of the debt trap; 5) Will the fragile labor market improve (Thai PBS World’s Business Desk, 2022). For Bangkok-based exporter, it is clearly that Putin’s military campaign in Ukraine has disrupted the flow of goods among continents. The big shipping firms announce that they will no longer serve Russian ports. Thailand is the southeast Asia’s second-largest economy which had experienced the hardest-hit during the pandemic, the economic aftershocks of Russia’s invasion are being largely felt in specific sectors (Duanadee, 2022).

A vital element of the Thailand 4.0 is to facilitate the adoption and innovation

of digital, automation and robotic technologies among SMEs, manufacturers and service sectors will support the strong demand for data centers. Thailand will use the power of digital technology to improve the economy's economic competitiveness by implementing programs to support the quality of life of its citizens, participation in public services for all and these factors. For example, Thailand 4.0 will grow in this segment, thanks to initiatives such as smart city development projects, big data platforms, agricultural analytics, education and health policy and investment in digital infrastructure. With competitiveness in information and communication technology (ICT), the strength of basic infrastructure, skilled workforce, support from the public sector and strategic location, Thailand is well-positioned to become an essential destination for colocation data centers that serve the demand of businesses operating within the Association of Southeast Asian Nations (ASEAN) (Bangkok Post, 2021).

3.7 Indonesia

Indonesia features a one-of-a-kind blend of economic frameworks and geographical specialization. Local enterprises are devoted to both the local and global value chains in terms of specialized operations, including digital technology at various levels of sophistication. As a result, new technologies can be used in various technological domains and sectors (Ministry of Finance. Indonesia, 2020).

According to President Joko Widodo, incremental increases in trade flow are expected to result in more significant foreign direct investment (Arianto & Ira, 2020). In addition, rapid advancements in various technology sectors are attracting much attention to the policy agendas of economies all over the world. A survey shows that the 65% of Indonesian respondents have changed their corporate strategies in reaction to the crisis. On the other hand, global numbers are substantially higher with 77% of respondents agreeing. Furthermore, during the epidemic 68% of worldwide and Indonesian companies are using a crisis response strategy (PwC Research, 2021).

Indonesia promotes "manufacturing 4.0," The Ministry of Industry has identified five key technologies that support the fourth industrial revolution's implementation: the Internet, artificial intelligence, human-machine collaboration, robotics and scanning and additive manufacturing. These technologies will also help Indonesia become more advanced and creative, hoping that technology will speed up industrialization and lead to a globally competitive manufacturing industry (TIER, 2021).

3.8 Malaysia

In Malaysia, the policy on Industry 4.0 emphasizes the application of intelligent machinery for digital transformation of the manufacturing and service industries, which in turn accelerates the industrial restructuring process. In addition, additive manufacturing is identified in the policy as a critical element of such technologies. Companies intending to adopt additive manufacturing technologies will benefit from utilizing the Readiness Assessment (RA) or Domestic Investment-Specific Fund (DISF) (Malaysian Investment Development Authority [MIDA], 2021).

The cost and price pressures are increasingly a concern continue to for 2022. All firms are feeling cost pressure from all prospects. Firms are struggling to manage the cost and overheads with less revenue. Firms have been faced the pandemic-inflicted supply chain disruptions and supply constrictions, inflated shipping, and logistics costs, rising cost of raw materials, higher energy costs and commodity prices, weak domestic currency, a shortage of workers. It shows that these factors will become persistent seriously to feed into inflation expectation and induce self-sustaining inflationary dynamics. Balancing inflation is key to economic recovery. Too much inflation and not-well anchored inflation expectations can be harmful to the economic recovery (MIDA, 2021).

Malaysia's Digital Economy Blueprint (2021 - 2030) was launched by the government on 19 February 2021 - a new and comprehensive strategy aimed at anchoring Malaysia's digital economy by 2030. Through MyDigital, Malaysia is expected to become a digitally driven, high-income economy and a regional leader in the digital economy. It will empower Malaysians from Perlis to Sabah, rural towns are being improved in every aspect, including digital literacy, high-income jobs, improved banking and finances and better digital access to education and health care. With MyDigital, Malaysia sets the tone for its digital future. As part of a comprehensive study, the Economic Planning Unit (EPU) led the development of the Blueprint with active participation from various agencies and ministries, including MIDA, private companies and civil society organizations (27 Group 2021). By implementing MyDigital, Malaysians will enjoy improved living and well-being standards, businesses will enjoy more significant opportunities to expand their operations and market and government services will be more efficient and effective. Malaysia expects domestic and foreign investment to amount to RM70 billion through this Blueprint in ten years. Furthermore, the Malaysian government has taken proactive measures to speed up the roll-out of the 5G

network, making Malaysia one of Southeast Asia's early adopters of 5G internet and cloud services (MIDA e-Newsletter April 2021).

4. Policy Recommendations

It has been well known that supply chain vulnerability implies the global disruptions on key industries and geographies. Thus, we had better made more effort to deal with the following key issues: supply chain crisis forced lots of business owners to rethink a reconfiguring of business operations and trade and investment flows; confronting the challenge of streamlining and securing their supply chains; many economies are re-thinking and taking more localization; and the effective policy implementation to build up STI capability, especially industrial revolution IV. It is necessary to build a resilient supply chain through science technology innovation. Its guidelines are: analyze and define the development benefits of STI translate directly into the daily lives of the people in the region: policymaking resources allocation to close the gaps on good health, well-being; and inclusive economy, setting development priority of the technologies and their applications; such as the education platform, bio tech, information, communication, data, AI, autonomous related services and technologies; and risk assessment, management on frontier technology cooperation, development, demonstration, and implementation, domestic STI connectivity for policy bench marking, dialogue, platform development, workshop, and continue improvement (Shu, 2022).

Furthermore, we will propose the policies based on the macro and micro prospects. The macro prospect will focus on establishing digital supply network ecosystems. As for the micro prospect, the guidelines of organizational resilience and the prototype of forecasting model are proposed.

4.1 Macro Framework of Policy Recommendation

A macro framework of policy recommendation to enhance the supply chain resilience is demonstrated in Figure 1. It consists of three dimensions: STI capacity building which is the fundamental techniques to facilitate policy recommendations for achieving resilience; policy recommendations which is related to the actions should be conducted to achieve supply chain resilience; supply chain resilience which is related to the resilience goals achieved by implementing the policy recommendations and STI Capacity Building.

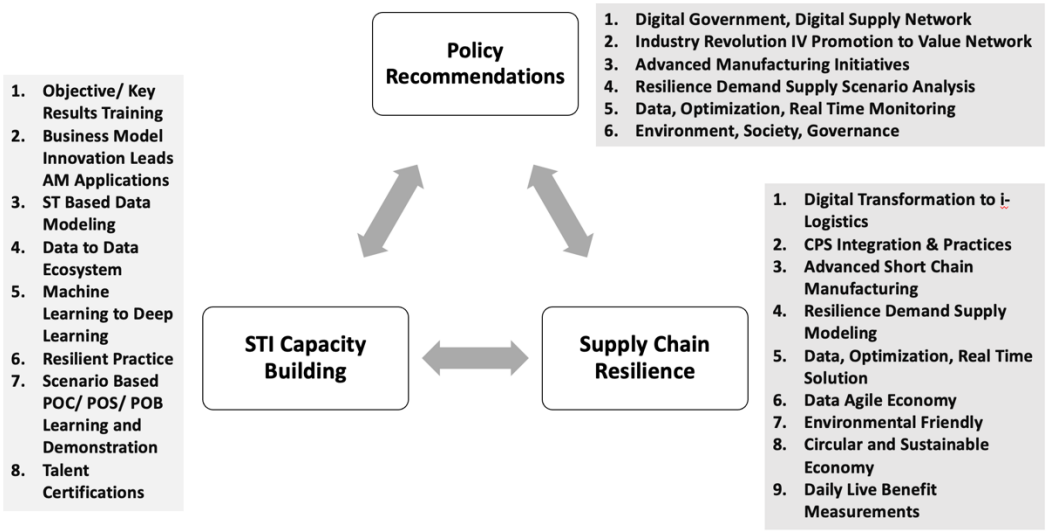

Figure 1. Marco Framework of Policy Recommendation (Revised from Shu, 2022).

More detailed discussion for the important factors among three dimensions of the policy recommendation framework are as follows.

The role of the government

To keep economic growth momentum, the government should pay attention to longer-term development and handling emergent issues. Significantly, the government should play as a dominator to allocate resources to develop the digital supply network ecosystem. Following are the policy recommendations for government to handle emergencies as considering advanced short-chain manufacturing policies and to create longer-term digital manufacturing environment such as, setting the priority of industry development, defining the players in the ecosystem, facilitating collaboration based on trust, investing in digital manufacturing assets, i-Logistic, and talent development.

Consider advanced short chain manufacturing policies

Facing the impact of supply chain disruption, the government can consider the following policies: 1) reshoring, the government hopes to achieve independence of domestic industries and protecting critical industries, thus encouraging firms reshoring to increase the dependence on local supply chain; 2) regionalization, it is essential to develop the model of the domestic manufacturing center by purchasing locally and manufacturing regionally to make sure in the output is closer to customers; 3) replication, as the fast development of digital manufacturing technologies, replication has become a supply chain model with both characteristics of closing to the customer end and diversifying the over-concentrated production risk.

Set priority of industry development

APEC economies should prioritize industry development and develop tailor-made promotion schemes for large-scale firms and SMEs. (e.g., semiconductor, healthcare, aerospace, automotive, defense, agriculture, food, etc.) Set up different incremental digital transformation plans according to the characteristics of various industries.

Define the players in ecosystem

The government should play an effective moderator role to accelerate the development of the digital manufacturing environment, formulating resources allocation policy to close the gaps, such as providing incentives, stimulating demand, fostering public-private partnerships.

Facilitate a trust-based collaboration

APEC members could collaborate with allies and partners across different sectors and economies to mitigate the disruption in the global supply chain. The issue of partner selection lies just not only on the complementarity of capabilities, but also on the alignment of objectives and values. When economies cooperate based on trust, like-minded partners with similar ideas can form a trustworthy network and then share value, including protecting intellectual property rights and guaranteeing business operation norms.

Invest Digital manufacturing Infrastructure

Under the influence of the epidemic, the government has to promote the acceptance of digital manufacturing by companies. In addition, economic policy should invest and develop incentives for industries to input digital infrastructure domestically to narrow the gaps blocking the industrial supply chains.

Invest digital manufacturing assets

The severe epidemic has caused supply chain disruptions so enterprises urgently need a digital environment. Governments should assess the current status of digital manufacturing infrastructure and largely invest in a broad mobile bandwidth, optical fiber broad bandwidth, robots, automation, IOT and data center to fill up the gaps. The government should set an appropriate regulatory framework with digital manufacturing technology adoption incentives. Enterprises could consider building redundancy to invest in the digital manufacturing capacity of both home and host economies.

Talent development

Digital transformation is not exclusively concentrating on applying digitization in the

supply chain; instead, it puts more emphasis on the cogitation of adaption toward the digital environment. Hence, human resources education and training strategy stand as a critical matter in which two significant activities should be concentrated: talent cultivation and academia-industrial collaboration. In talent cultivation, digital technology improvement ensures successful data analysis tailored to focal contexts in sourcing, producing and integrating, which intends the manufacturers to narrow down their talent gaps in specific techniques, such as the know-how gap between senior and junior engineers. Apparently, it is necessary to assist digital manufacturing programs in universities, expand the cultivation of multidisciplinary digital manufacturing talents, exchange technical techniques with other economies for a more advanced improvement and collaborate with industry to support training and education. The aforementioned extends to concentrating on academia-industry collaboration, which has high importance to promoting socioeconomic development (Liu et al., 2017).

Digital Manufacturing

Enterprises should play a pivotal role in the stages of digital manufacturing, ecosystem development both in the hardware as establishing infrastructure, equipment and in the software as building knowledge and capabilities. The following are policy recommendations for enterprises such as, defining the players in the ecosystem, facilitating collaboration based on trust, developing business model, advocating digital transformation, investing in digital manufacturing assets, building digital manufacturing capabilities, building a system of real-time monitoring, analysis and decision making, sourcing, manufacturing, i-Logistic, shaping corporate culture with Environment, Social Responsibility and Corporate Governance (ESG) DNA.

Definition of the players in ecosystem

The ecosystem consists of an orchestrator and complementary players such as equipment providers, raw material suppliers, engineering and software services, output service (3D printing) bureaus, and end customers. A high level of modularity is created by flexibly combining components provided by various players and the integration of components entails low transaction costs; raising the awareness of digital manufacturing (3D printing) and the potential possibilities in productivity by reducing tooling costs, cutting the lead time for machine setup and trimming raw material waste; and differentiation by customization and design flexibility.

Facilitate collaboration based on trust

Enterprises can form a strategic alliance with a business operation based on the laws and regulations. Achieving objectives that maximize the benefits of the end

customer, such as production flexibility and customization, the orchestrators (leading players) need to propose cooperation and coordination strategies to address the interfaces between components with not fully standardized. The ecosystem can build and enhance the relationship and trust among the partners through information transparency and knowledge sharing. The orchestrator and leading players should establish a governance model defining the rules of access, participation and commitment for the existing or potential players.

Develop a business model

An ecosystem should design incentive strategies that focus to encourage the players' participation, thus fostering network effects. The partners within the ecosystem can co-create and share the value by asking following questions: what should the ecosystem charge for? who should the ecosystem charge? how much should it charge? The AM ecosystem could benchmark best practices and experiment with more innovative approaches other manufacturing industries have employed, e.g., pay per use and data sharing.

Advocate digital transformation

Enterprises could evaluate three stages of digital transformation: (1) digitalization – improve the quality and quantity of digital information in the works, digitalize the documents and pictures with original hardcopy; (2) optimization - implement digital technologies such as Big Data, IOT, AI to develop innovation, integrate digital tools with the operational process; (3) digital transformation - combining horizontally with strong partners or integration of upstream and downstream partners in the supply chain. Ultimately, enterprises can broadly utilize the above-mentioned digital tools and the talents with digital thinking to further assist in various aspects of product development, product value provision, business models and organizational processes.

Invest digital manufacturing assets

Enterprises could consider building redundancy to invest the digital manufacturing capacity of both home and host economies.

Additive manufacturing ecosystem

An ecosystem should require coordination among industries, academia and R&D specialists, to jointly develop products with a particular service model (Liu et al., 2017). With the conclusion of several interviews from industries and advisors and secondary data, it is suggested to establish an additive manufacturing ecosystem (Please see Figure 2.), including additive manufacturing OIP (Open Innovation Platform), AM center,

engineering design parties and academia, cloud technology parties, manufacturers, users/customers and external assistance–government policy. Additive manufacturing OIP is an exhaustive design technology infrastructure that encloses all critical implementation domains to reduce design obstacles and improve operational success. Accordingly, AM center demonstrates as the orchestrator of the ecosystem, while the others (engineering design parties and academia, cloud technology parties, manufacturers, users/customers, and government policy) respond as the complementors. Within the collaboration among the ecosystem, manufacturers could benefit by shortening the time in designing models or prototypes, enhancing productivity and quality and approaching a more flexible production scheduling, which improves inventory management performance. In summary, the additive manufacturing ecosystem would eventually enable companies to easily stretch into localization manufacturing and enlarge the capability of prevention from supply chain disruption.

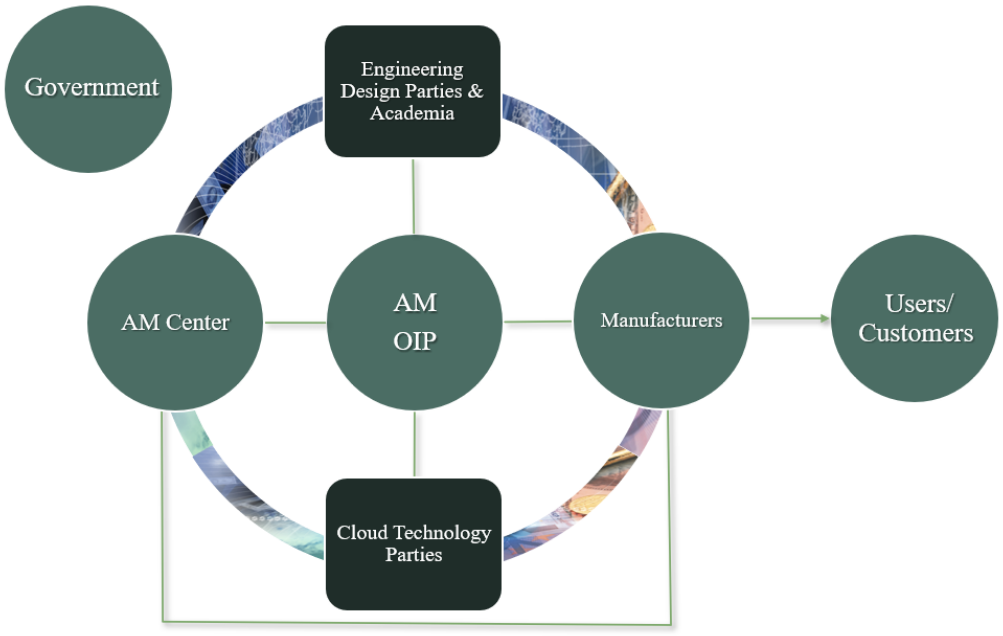

Figure 2. Additive manufacturing ecosystem framework

Build Capabilities of Digital Manufacturing

The business model with cyber-physical integration and the establishment of work capabilities will become the new normal in the post-epidemic. Therefore, enterprises should build capabilities of developing and applying the digital manufacturing tools, such as Big Data, AI, Cloud, AM (3D printing).

Build a system of real-time monitoring, analysis, and decision making

Enterprises should develop and implement methods of data collection that are

comprehensive and accurate, including further utilizing such data to conduct resilient demand-supply scenario analysis. Institutes or large-scale corporations could establish a digital innovation center providing the services of one-stop shops to promote the digital transformation for SMEs by providing professional knowledge, test equipment and digital manufacturing solutions. Enterprises could collect and analyze data by digital technologies such as IOT, Big Data, cloud, etc. and make adjustments and responses with an AI model in time according to factors such as inventory, logistics, and market demand.

(1) Sourcing

Enterprises should implement the continuous assessment for the supply chain layout decision and logistics risk by collecting data, including procurement source, production process carbon footprint tracking, labor condition inspection, connecting to the material network platform, tracking goods and forecasting demand. See the prototype model for focusing on the micro policy section (Figure 3).

(2) Manufacturing

Enterprises could apply additive manufacturing as well as IoT, AI, remote sensing technologies for different phases of product development, including prototypes for verification and validation, molds and specific tools for pilot production and parts and components for mass production. Leading companies in the ecosystem should invest in R&D and skill training, applying materials and mastering the interplay between these two in the closed or open system. They also value investment in high-tech/automation and collaboration between firms and universities. They can be beneficial in building integrity and sustainability in the ecosystem to increase visibility, traceability, inclusion and trust between large businesses and SMEs.

(3) i-Logistic

It is vital to collect data from real-time environmental monitoring, such as earthquakes, floods, extreme weather and pandemics. Using the following data, develop and implement methodologies for analyzing and dealing with emergent transportation difficulties. The intelligent logistics distribution management system created can efficiently solve traditional logistics distribution management difficulties. For example, in logistics distribution, visual sensor image processing technology can not only complete the acquisition and analysis of the target image, but also track and monitor it effectively (Miao & Lan, 2021). Using the Internet of Things as a foundation to raise the degree of intelligent logistics management may help a firm develop a good corporate image and increase its competitiveness and professionalism (Lei, 2022).

Shape corporate culture with ESG DNA

Environment friendly, socially responsive, circular and sustainable economies are all aspects of ESG DNA that may be used to shape business culture. Improve supply chain resilience by collaborating with customers' green transformation requirements, employing green power and environmental friendly products and via invention, development and implementation of clean energy technology. Daily live benefit measurement is also available. Defining and analyzing the benefits of digital manufacturing directly to people's everyday lives in the region, especially ESG issues, such as environment, social stakeholder and corporate governance, by collecting and analyzing daily production data such as raw materials consumption, greenhouse gas emissions, wasted water disposal, employees and labor recruitment and defining and exploring the benefits of digital manufacturing directly to people's daily lives in the region, especially ESG issues, such as environment, social stakeholder, and corporate governance.

4.2 Micro Prospect of Policy Recommendation

In micro policy recommendation, companies with organizational resilience embedded in their DNA may emerge stronger from a crisis, which is ready to seize new opportunities and take on whatever comes next. First, companies with a strategic crisis response strategy can mobilize faster, stabilize company operations and respond more effectively to disruptive shockwaves. Companies should appoint a crisis response team to effectively lead the effort, develop a crisis response plan linking to their strategy, goals and purpose and focus on continuous improvement and developing an integrated resilience program to prepare for the next unavoidable disruption. Second, an integrated response is required to implement an effective crisis management program and create resilience. Companies should be able to communicate and collaborate effectively. Third, organizational resilience is essential just not for success, but also for survival. The company should elevate resilience within the organization, take a snapshot of crisis management structure, foster a culture of resilience throughout the enterprise, and examine crisis response strategies.

Company prospect

To gain a beneficial return on the investment, the company should concentrate organizational resilience on the following below: (PwC Research, 2021)

(1) A boost of ability to anticipate and identify threats

(2) Quick response activation

(3) Clarity of roles and plans

(4) Access to critical data and insights
(5) Reinforce the purpose and values of the supply chain
(6) Enhancement of trust with stakeholders
(7) Ability to emerge stronger

A prototype of forecasting model

As previously stated, companies need to develop a prototype of the forecasting system that monitors, inputs and scans data based on previous experience and freshly obtained data to recommend relevant crisis risk reduction activities. In the long term, the forecasting model, which continuously collects data and knowledge, will help the company to build resilience for the next normal.

Companies can establish a forecasting model (See Figure 3.) for forecasting future events to reduce future risk. In which numerous mathematical algorithms (i.e., clerical operations research, classical statistic, and AI) can be applied to recognize and implement the model in practice.

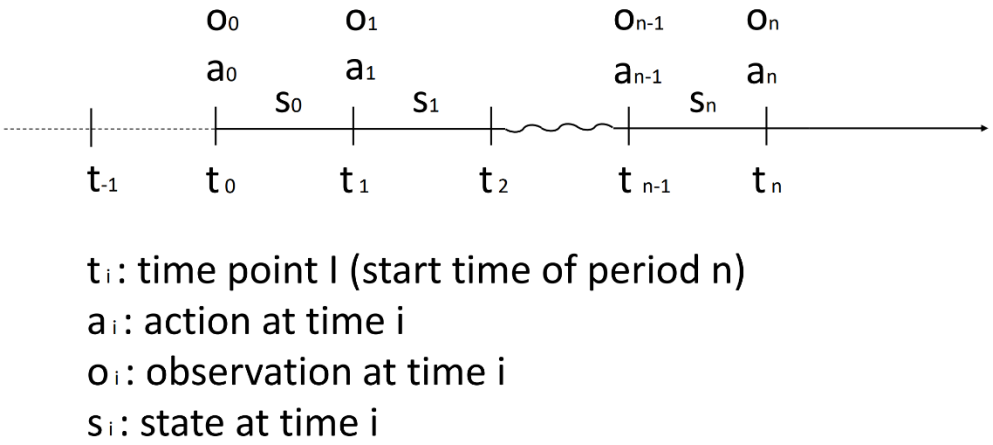

Figure 3. A prototype of forecasting model

In Figure 3. At time point t_n, based on state (defined by s_{n-1}) at the period n, we realize once we perceive an observation (o_n), we will decide to implement the action (a_n). In practice, it is difficult to completely catch the s_{n-1}, and o_n is a function based on a_{n-1}, o_{n-1}, and s_{n-1}. The relationships can be modeled by Markov chain decision process. Furthermore, it can be defined $a_n$as expected award function depending on different states and actions. The normal network (Rodriguez, Parr, and Koller, 1999) with a heuristic approach (Cassandra, 1998) can be used to derive the optimal solution.

It can also be solved by Deep Q-Learning Network (Mnih et al., 2015; Van Hasselt, Guez and Silver; 2017). Furthermore, a knowledge graph developed by Amazon, Facebook, Google, can be inserted into the model to derive the appropriate action based on all collected knowledge (Noy et al., 2019; Hogan et al., 2021).

5. Reference

1. 27 Group (2021). What is MyDigital Initiative & Digital Nasional Berhad about? Retrieved from: https://27.group/what-is- MyDigital-initiative-digital-nasional-berhad-about/ (Mar 31, 2021).
2. Asia News Network. (2022). Export opportunities abound for Vietnam.
3. Aylor, B., Datta, B., DeFauw, M., Gilbert, M., Knizek C., and McAdoo, M. Designing Resilience into Global Supply Chains. Retrieved from: https://www.bcg.com/publications/2020/resilience-in-global-supply-chains (Aug 3, 2020).
4. Bangkok Post (2021). Thailand's Digital Transformation Boosts Data Industry. Retrieved from: https://www.bangkokpost.com/business/2142475/thailands-digital-transformation-boosts-data-industry (Jul 2, 2021)
5. Chang M.F., Lin C., Shen C.H., Wang S.W., Chang K.C., Chang R. and Yeh W.K. (2021). The role of government policy in the building of a global semiconductor industry. Nat Electron 4, 230–233.
6. Clochet A. (2021). Using real-time data analytics to achieve manufacturing excellence. PEX Network & Matics.
7. Common Wealth Magazine. (2022). Chinese Taipei -wide supply chain survey, industry faces vary challenge, how to predict the need of talent gap?
8. Cooper, R. (2022). How engineers can help build smarter, more resilient supply chains. Create Digital. Retrieved from: https://createdigital.org.au/how-engineers-can-help-build-smarter-more-resilient-supply-chains/ (Jan 20, 2022)
9. Department of Industry Science Energy and Resources. (2018). Australia's Tech Future: digital technologies will deliver benefits across the economy and society. Australia Government.
10. Digital Agency. (2022). Priority Policy Program for Realizing Digital Society. Retrieved from: https://www.digital.go.jp/policies/priority-policy-program (Dec 24, 2021)
11. Duanadee V. (2022). In Thailand, business feel economic shock of Ukraine war. Retrieved from: https://www.aljazeera.com/economy/2022/3/9/in-thailand-businesses-feel-economic-shock-of-ukraine-war (Mar 9, 2022)
12. Fox, B. (2020). Scaling Australian Manufacturing Through Digital Platforms. The Royal Society of Victoria. Retrieved from: https://rsv.org.au/events/industry-4-0/ (Dec 10, 2020).
13. Gil, E. (2021). Strengthening Korea's Position as a Manufacturing Powerhouse through the Introduction of Smart Factories. Industry Trends. Retrieved from: https://www.investkorea.org/ik-en/bbs/i-308/detail.do?ntt_sn=490753 (Mar 4,

2021).
14. Goto, S. (2021). Can semiconductors be Japan's new auto industry? Wilson Center: Asia Dispatches.
15. International Institute for Management Development (IMD). (2020). The Localization of Global Supply Chains amid the Pandemic.
16. Jackson, B., and Morrow, D. (2020) Coronavirus and the localization of supply chains. Retrieved from: https://www.sustainalytics.com/esg-research/resource/investors-esg-blog/coronavirus-and-the-localization-of-supply-chains (Apr 9, 2020).
17. Lee, H. G. (2022) Cover story: weathering the perfect storm of supply chain disruptions, The Edge Malaysia Weekly.
18. Lee, J. (2022). Borneo Bulletin Online. ASEAN poised for post-pandemic inclusive growth.
19. Lee, J. M. (2020). *Recent changes in the trade environment and GVC reorganization trends: examples of global companies*. Retrieved from: https://news.kotra.or.kr/user/reports/kotranews/20/usrReportsView.do?reportsIdx=11805 (Sep 25, 2020).
20. Lee, Y. C. (2021). Observe the opportunity of Chinese Taipei's manufacturing industry: The discussion on digital transformation. Market Intelligence & Consulting Institute. Retrieved from: https://mic.iii.org.tw/industry.aspx?id=409&list=5 (Feb 7,2021)
21. Linkov, I., Carluccio, S., Pritchard, O., Ní Bhreasail, Á., Galaitsi, S., Sarkis, J. and Keisler, J.M. (2020), "The case for value chain resilience", Management Research Review, Vol. 43 No. 12, doi: 10.1108/MRR-08-2019-0353.
22. McKinsey & Company (2021). Japan Digital Agenda 2030: Big moves to restore digital competitiveness and productivity.
23. Mehri, B. (2021). Resilience, not decoupling: Critical supply chains in China-Japan relationship. Institut Montaigne.
24. MIDA e-Newsletter April 2021. MALAYSIA'S JOURNEY IN THE DIGITAL AGE. Retrieved from: https://www.mida.gov.my/malaysias-journey-in-the-digital-age/.
25. Ministry of Economic Affairs/ Taipei Economic and Cultural Office in Ho Chi Minh City (2021). The Vietnamese government is committed to national digital transformation. Viet Nam Business News. Retrieved from: https://www.trademag.org.tw/page/newsid1/?id=7851382&iz=1 (Oct 26, 2021).
26. Newswires. (2022). Siemens helps Vietnams customers unlock potential of digitalization.
27. Palit, A. (2020). The Resilient Supply Chain Initiative: Reshaping Economics

Through Geopolitics. The Diplomat. Retrieved from https://thediplomat.com/2020/09/the-resilient-supply-chain-initiative-reshaping-economics-through-geopolitics/ (Sep 10, 2020).

28. PwC Research. (2021). Global Crisis Survey 2021: Building resilience for the future.
29. Remko, vH. (2020), "Research opportunities for a more resilient post-COVID-19 supply chain – closing the gap between research findings and industry practice", International Journal of Operations & Production Management, Vol. 40 No. 4, pp. 341- 355, doi: 10.1108/IJOPM-03-2020-0165.
30. Sher, D. (2020) Japanese additive manufacturing is rising. 3D printing media network. Retrieved from https://www.3dprintingmedia.network/japanese-additive-manufacturing-is-rising/ (Dec 7, 2020)
31. Song, S. (2019) Korean manufacturing's digital transformation must escape 'pilot purgatory'. McKinsey & Company. Retrieved from https://www.mckinsey.com/featured-insights/asia-pacific/korean-manufacturings-digital-transformation-must-escape-pilot-purgatory (Aug 8, 2019).
32. Taiwan Aerospace Additive Manufacturing Industry Association (2019). 3D printing to focus on three key areas. Premier says public will see results. Retrieved from http://www.taamia.org.tw/taamia_en/xmdoc/cont?xsmsid=0I165381441548018933&sid=0J247355933363303233 (Sep 4, 2019).
33. Taiwan External Trade Development Council (TAITRA), (2021). Roadmap to Resilient Supply Chains. TAITRA
34. Taiwan Institute of Economic Research (TIER), (2021 Oct). 2021 Year-end Review and 2022 vision.
35. Tan, W. (2022). South Korean trade minister says Russia-Ukraine crisis could disrupt supply chains, Asian Economy.
36. Thai PBS World's Business Desk. (2022). Five key economic challenges of 2022. Retrieved from: https://www.thaipbsworld.com/five-key-economic-challenges-of-2022/ (Jan 13, 2022)
37. The Nation (2019). Thailand a rising star in ASEAN's additive manufacturing scene. Retrieved from https://www.nationthailand.com/business/30374659 (Aug 13, 2019)
38. The World Bank. (2021). The World Bank In Thailand. Retrieved from: https://www.worldbank.org/en/country/thailand/overview#1 (Oct 31, 2021)
39. Tillmann, B., James, A., Neil, T. and Robert H. (2021). Covid-19 response of an additive manufacturing cluster in Australia. An international Journal, Vol. 26 No. 6, pp. 767-784.
40. Cassandra, A. R. (1998). *Exact and approximate algorithms for partially*

observable Markov decision processes. Brown University.

41. Rodrıguez, A., Parr, R., & Koller, D. (1999). Reinforcement learning using approximate belief states. *Advances in Neural Information Processing Systems, 12*, 1036-1042.
42. Noy, N., Gao, Y., Jain, A., Narayanan, A., Patterson, A., & Taylor, J. (2019). Industry-scale knowledge graphs: lessons and challenges. *Communications of the ACM, 62*(8), 36-43.
43. Hogan, A., Blomqvist, E., Cochez, M., d'Amato, C., Melo, G. d., Gutierrez, C., Kirrane, S., Gayo, J. E. L., Navigli, R., & Neumaier, S. (2021). Knowledge graphs. Synthesis Lectures on Data, Semantics, and Knowledge, 12(2), 1-257.
44. Van Hasselt, H., Guez, A., & Silver, D. (2016, March). Deep reinforcement learning with double q-learning. In *Proceedings of the AAAI conference on artificial intelligence* (Vol. 30, No. 1).
45. Mnih, V., Kavukcuoglu, K., Silver, D., Rusu, A. A., Veness, J., Bellemare, M. G., Graves, A., Riedmiller, M., Fidjeland, A. K., & Ostrovski, G. (2015). Human-level control through deep reinforcement learning. nature, 518(7540), 529-533.
46. PwC Research. (2021). Global Crisis Survey 2021: Building resilience for the future.
47. Miao, J., & Lan, S. (2021). Application of Visual Sensing Image Processing Technology under Digital Twins to the Intelligent Logistics System. Advances in Civil Engineering, 2021.
48. Rong, T., & Hulin, Z. (2021, April). Construction of Intelligent Logistics System Based on Internet of Things Technology. In Journal of Physics: Conference Series (Vol. 1883, No. 1, p. 012095). IOP Publishing.
49. Lei, N. (2022). Intelligent logistics scheduling model and algorithm based on internet of things technology. Alexandria Engineering Journal, 61(1), 893-903.
50. Liu, X., Schwaag Serger, S., Tagscherer, U. and Chang, A.Y. (2017), “Beyond catch-up – can a new innovation policy help China overcome the middle income trap?”, Science and Public Policy, Vol. 44 No. 5, pp. 656-669.
51. P.H. Shu, J.P.H., (2022). Concluding Remarks, APEC Workshop on Digital Manufacturing for Supply Chain Resilience, Taipei.