

Paradigm on Internet of AI-Centric (IoAIC) for Thailand Economics Growth Engine

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Abstract— This paper presents an emerging paradigm on Internet of AI-Embedded for fostering Thailand economics growth engine. Since Thailand has long been trapped by middle income, inequality, and imbalance, the roadmap based on “Digital Economy” policy has recently been accelerated towards the 4th industry evolution so called “Thailand 4.0”. While digital technologies have been well developed and highly diversified in various fields, there is, however, no distinct paradigm on technology utilization has been suggested in order to potentially enable a success in digital economy policy under unique challenges in Thai contexts. This paper consequently recommends an emphasis on Internet of AI-Centric (IoAIC) involve three promising features, i.e. physical things, services, and data. Integration on such physical things, services, and data is presented as a straightforward ecosystem to be utilized for implementation of roadmap and strategies of Thailand 4.0. A primary survey companies in Bangkok Metropolitan Region in terms of the need of new IoAIC concepts for applying such to their companies is presented. This paper offers an emerging paradigm on social and economic impacts of Internet of AI-Centric in Thailand as a possibly potential economical country hub in South East Asia region.

Index Terms— Thailand ; Internet of AI-Centric; Economics Growth Engine; Physical Thing; Service; Data; IoAIC

I. Introduction

Thailand is a Southeast Asian country where Bangkok is a capital city, and has been integrated into the Association of Southeast Asian Nations Economic Community (AEC) since the year 2015. Currently, the total population is approximately 68 million people, and the GDP of the first quartile of the year 2017 is 0.4%, expecting to increase to 0.5% and 0.9% in the second and third quartiles, respectively [1]. Over the past decades, Thailand, however, has been trapped in three conditions, including middle income trap, inequality trap, and imbalance trap [2]. Consequently, an acceleration of economic growth through the utilization of digital technologies has been of much interest by both government and private sectors under unique challenges in Thai contexts.

Digital technology must be leveraged in order to address many challenges Thailand, i.e. (i) to raise capacity and competitiveness in all economic sectors, (ii) to develop capacity and prepare both IT and non-IT workforce, (iii) to adapt and seize opportunities from AEC, (iv) to reduce inequality in all aspects, and (v) to eliminate corruption by increasing government transparency and civic engagement. Thailand has been appointed to transform towards digital Thailand, refers to the country’s brilliance in taking full and creative advantage of digital technology to develop infrastructure, innovation, data capability, human capital,

and other resources, thus propelling the country’s economic and social development towards stability, prosperity, and sustainability [3].

Table 1 compares economics growth engines, environments, and technologies of some countries, involving United States of America, United Kingdom, China, Singapore, and South Korea, that have announced a concrete roadmap and strategies with some promising technologies as for economic growth engine. The United States [4] has announced a campaign on “A Nation of Makers” which focuses on a culture of abundance with inclusive community of practice through encouraging connections, broadly sharing resources, facilitating funding opportunities, engaging in policy development, and advocating for the maker movement. On the other hand, United Kingdom [5] has publicized the campaign on “Design in Innovation”. Centers for design excellence have consequently been established in order to achieve greater commercial success through the effective use of early-stage design processes.

Meanwhile, China [6] has clearly announced the theme of “Made in China 2025” as a world manufacturing power in order to promote the integration of informatization and industrialization, to enforce green manufacturing, and to improve international competitiveness. Singapore [7] has already moved forward to “Smart Nation”, stating an outstanding intelligent island for improving the quality of life, strengthening business, and building stronger communities. In addition, South Korea [8] has promoted a policy on

Table 1. Comparisons of economics growth engine, envisions, and selected emerging technologies.

Countries	Economic Policies	Strategies	Selected Emerging Technologies
United States of America [4]	A Nation of Makers: A Culture of abundance with inclusive community of practice	<ul style="list-style-type: none"> • Encouraging connections • Broadly sharing resources • Facilitating funding opportunities • Engaging in policy development • Advocating for the maker movement 	<ul style="list-style-type: none"> • Assistive and Soft Robotics • Bioengineering for Regenerative Medicines • Bioprinting across Technology Sectors • Secured Manufacturing • Chemical and Thermal Process Intensification • Materials for Harsh Service conditions
United Kingdom [5]	Design in Innovation: A centre for design excellence	<ul style="list-style-type: none"> • Fostering better innovative businesses • Growing faster, and achieving greater commercial success through the effective use of early-stage design. 	<ul style="list-style-type: none"> • Infrastructure Systems • Manufacturing and Materials • Health and Life Sciences • Emerging and Enabling Technologies • Open Programme
China [6]	Made in China: A World manufacturing power	<ul style="list-style-type: none"> • Promoting integration of informatization and industrialization. • Enforcing green manufacturing. • Improving international competitiveness. 	<ul style="list-style-type: none"> • High-end numerical control tools and robotics • Oceaneering Equipment and High-Tech Ships • Advance Railway Equipment • Aerospace and Aviation Equipment • Energy Saving and New Energy Vehicles • Medicine and High-Performance Medical Devices
Singapore [7]	Smart Nation: An outstanding intelligent island	<ul style="list-style-type: none"> • Improving the quality of lives • Strengthening business • Building stronger communities 	<ul style="list-style-type: none"> • Homes and Environments • Transportations • Health and Enabled Ageing • Business Productivity • Public Sector Services
South Korea [8]	Creative Economy: A realization of national welfare and new era of hope	<ul style="list-style-type: none"> • Establishing platforms to help commercialize creative ideas • Stimulating ventures and startup ecosystem • Creating new industries, markets, and careers • Supporting startups to the global. 	<ul style="list-style-type: none"> • Wearable Smart Devices • Manufacturing System and Advanced Materials • Offshore Plant in Extreme Environments • Nano Based Bio-artificial Devices • Virtual Training Platforms
Japan [9]	Made by Japan: (An attractive nation in the Twenty-First Century)	<ul style="list-style-type: none"> • Revitalizing society that draws on the talents of all its members and provides a rewarding, liberating environment. 	<ul style="list-style-type: none"> • Information and Communications • Nanotechnology and Materials • Social Infrastructures • Frontier and Environmental Sciences • MONOZDOKURI Philosophy and Technology

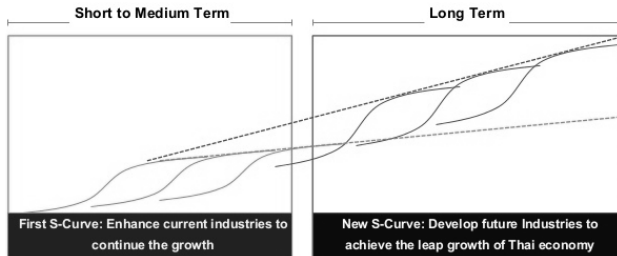


Fig.1 First and Second S-Curve as a mechanism to drive Thailand Digital Economy strategy.

“Creative Economy” based on a concept of a realization of national welfare and new era of hope by establishing platforms to help commercialize creative ideas, stimulating ventures and startup ecosystem, creating new industries, new markets, and startups. Last, Japan [9] has also raised a theme on “Made by Japan”, indicating a vibrant, attractive nation in the Twenty-First century by revitalizing society that draws on the talents of all its members and provides a rewarding environment.

Consideration of economics growth engine and envisions from those countries summarized in Table 1 points to possible and suitable strategies of technology-driven economics growth of Thailand. This paper will present an emerging paradigm on Internet of AI-Centric for fostering Thailand economics growth engine. An emphasis on Internet of AI-Centric framework, which focuses on three promising features, i.e. physical things, services, and data, will, be described. Integration of such promising features will be proposed in order to provide a perspective on an

opportunity in international trading and investments of Thailand. Current status of available technology and its levels, challenges and some concerns are also presented.

II. Thailand 4.0: Digital Technology Technology-Driven Policy

With reference to Table 1, those countries five countries have apparently been promoting new economic policies and innovation strategies for the 21st century. By turns, Thailand has also continuously been improving economic models. Traditionally, “Thailand1.0” which is a focus on the agricultural sector was an initial economic model, and “Thailand 2.0”, which relates to light industries, involving cheap labor costs and a focus on domestic productions, had lately been realized. Subsequently, a shift to “Thailand 3.0,” was realized, which focused on complex industries to attract foreign investments, leading to Thailand as a production hub for exports. Nonetheless, the country has encountered middle-income trap, growing disparities, and imbalanced development, resulting in a transform of Thailand’s economic model to “Thailand 4.0” [10]. In terms of Economic Freedom Index (EFI), Thailand placed was placed in a rank of 75th among the 178 countries in the year 2015 and increased to the rank of 67th in the year 2016. In particular, Thailand ranks third in ASEAN state members and 11th among 42 countries in the Asia-Pacific Region [11].

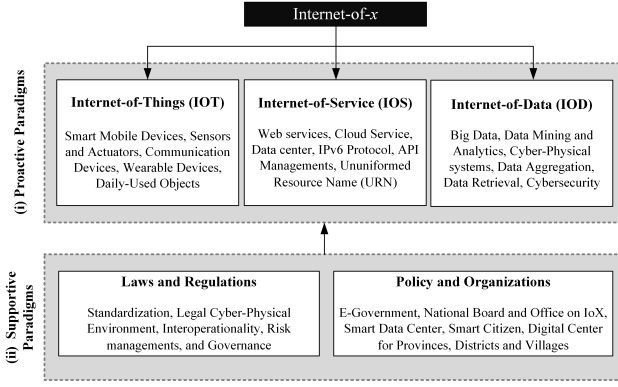


Fig.2 Concepts and framework of Internet-of-x, involving both proactive and supportive paradigms

In accordance to a paradigm shift to transform to Thailand 4.0, a value-based and innovation-driven economy so called “Digital Economy” has becoming major issues through commodities to innovative products and emphasis on promoting technology, creativity, and innovation in focused industries. Fig. 1 shows the first and second S-Curve as a mechanism to drive Thailand Digital Economy strategy. It can be seen from Fig.1 that the 1st S-Curve aims to enhance current five key industries to continue the growth, involving (i) Next-Generation Automotive, (ii) Smart Electronics, (iii) High-Income Tourism and Medical Tourism, (iv) Efficient Agriculture and Biotechnology, and (v) Food Innovation. In addition, five additional growth engines in order to develop and foster future growth in the 2nd S-Curve are Automation and Robotics, Aerospace, Bio-Energy and Bio-chemicals, Digital, and Medical and Healthcare [12]. Although an apparent economics policy has been launched and activated with quick responses from both government and private sectors, digital technology is relatively new for Thai society, starting from digital literacy to high-ended technologies. This paper therefore proposes an emerging paradigm on Internet-of-x concept as an alternative for supporting Thailand digital economy strategy where x represents three promising features, i.e. (i) physical things, (ii) services, and (ii) data. Integration on such physical things, services, and data leads Internet-of-AI-Centric, which is expected to be utilized as a new perspective on influential tool for real implementation of Thailand 4.0.

III. Proposed Primary Internet-of-X Concept

Fig.2 shows the overall architecture of Internet-of-x, where x represents physical things, service, and data. In other words, such a conceptual framework can particularly be classified into three categories, i.e. Internet-of-Things (IoT), Internet-of-Service (IoS), and Internet-of-Data (IoD). Besides, all categories are regulated by laws, and policies. Digital organizations should be established in order to drive the existence and successfulness of Internet-of-x. Proactive and supportive paradigms also offer a systematic perspective on integration, interconnection, and interaction.

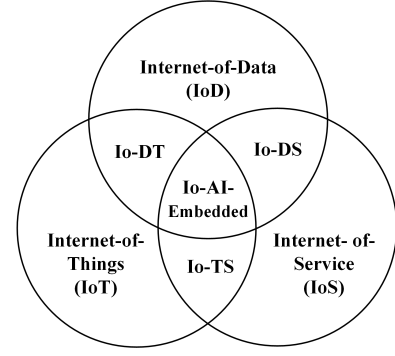


Fig.3 The intersection diagram of proposed Internet-of-AI-Centric.

1) Internet-of-Things (IoT)

The IoT refers to as a physical system in which physical devices, e.g. embedded electronics, are perceived by sensors and controlled through actuators in order to establish interactions to internet via either wired or wireless communication channels, remote collaboration, or real-time localizations. The physical devices can be designed based on specific purposes in particular use such as smart home with lighting, lockers, trackers, or even plugs. Embedded micro-controller technologies have readily been provided for *IoT* implementation such as Raspberry Pi, Arduino, Friendly Arm, STMicroelectronics and BeagleBone Black. Meanwhile, key technologies on communications that potentially enable the success of in Thailand growth engine should emphasize on Radio Frequency Identification (RFID), Near-Field Communication (NFC), Micro-electro-mechanical systems (MEMS), Wireless Sensor Network (WSN), IEEE 802.15.4 Standard and Zigbee, and Bluetooth Low Energy (BLE). Recently, LoRaWAN has been introduced to Thailand as a new promising communication technology. LoRaWAN not only targets to IoT requirements such as secure bi-directional communication, mobility and localization services, but also provides seamless interoperability among smart things [13]. These technologies have enabled and synergized for real applications as mentioned in Fig.2, involving smart mobile devices, sensors and actuators, communication devices, wearable devices, daily-used objects [13-14].

2) Internet-of-Services (IoS)

The *IoS* is referred to a global communication network acting as a medium platform for retrieval, combination, and utilization of interoperable resources including website and application services, which are accessed through standardized protocols and expected to be an enabler for the integration of a seamless application-to-application approach. Since the expectation of billions of devices will be connected to the internet, the IPv6 internet protocol and cloud services has gained significant necessity in terms of internet-based services in order to support the successful implementation for *IoT*. Consequently, the role of Data center, API Managements, and Ununiformed Resource Name (URN) will receive more attention in regards to *IoS* platforms [14-16].

3) Internet-of-Data (IoD)

The *IoD* is a concept of an extension of *IoT* since the increase in advanced computational technologies has resulted in enormous data growth in size, complexity, and diversity. Massive data in an internet network has led to

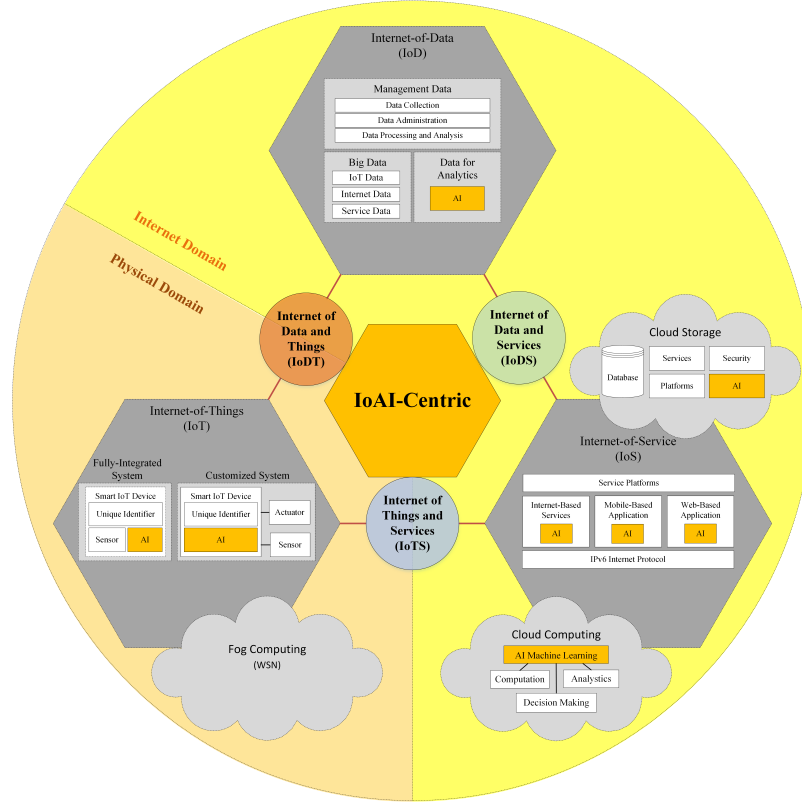


Fig.4 Proposed ecosystem of Internet-of-AI-Centric, revealing that AI is Embedded in both physical and internet domains.

“Big Data”, which typically has seven characteristics (7Vs), including Volume, Velocity, Variety, Veracity, Validity, Volatility, and Value. Besides, the *IOD* is also an emphasis on a management of data produced from transactions and operations of organizations. Data managements generally involve three consequent stages, i.e. (i) data collection, (ii) Data Administration, and (iii) Data processing. First, the data collection is a retrieval of data from physical devices, polymorphism, and rich semantic presentation. Second, data administration deals with data cleaning, designs of flexible database, and effective indexing. Last, data processing is a process for access managements, query optimization, and aggregation [17-18].

IV. Proposed Internet-of-AI-Embedded

Fig.3 depicts the intersection diagram of proposed Internet-of-AI-Embedded. It can be seen from Fig.3 that intersection among IoT, IoD, and IoS, reveals novel three perspectives of internet domains, involving IoDS, IoDT, and IoTS. First, IoDS is a linkage between data and services. First, IoDS is a linkage between data and services, or IoDS can be expressed as internet-based services associating with big data in order to, for instance, systematically manage, create visualization to provide meaningful information, store in the specific database remotely, make a sophisticated computation, or even utilize for analytics in the cloud server hosted on the internet domain. Second, IoDT is a linkage between data and things, where this particular data is both generated and acquired by the physical things interconnected through the internet. Last, IoTS is a linkage between internet-connected things and services that provide

assistance corresponding to those devices for specific purposes such as condition monitoring, current location tracking, or targeted devices controlling.

Fig. 4 illustrates the proposed ecosystem of Internet-of-AI-Centric, revealing that AI is embedded in both physical and internet domains. This paper introduces the term “Internet-of-AI-Centric: IoAIC” as the highest level under a framework of Internet-of-things. In general, an artificial intelligence can be considered as a general term that represent the theory and technology related to simulating intellectual abilities of human being, including the ability to understand and solve problems. A typical process of AI comprises perception, cognition, decision-making, strategy execution, and strategy optimization. A particular case of

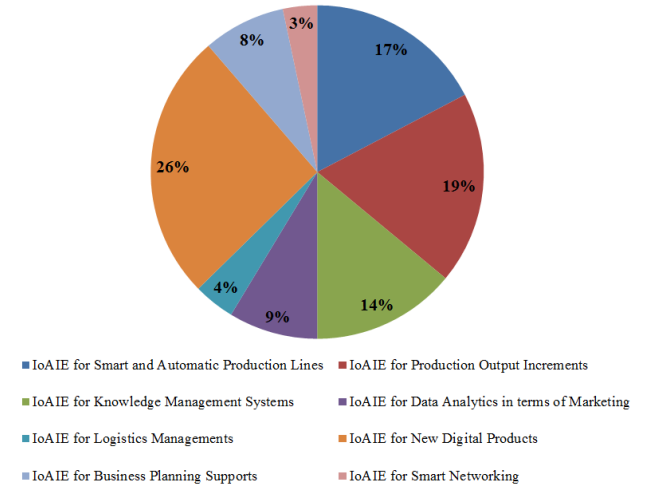


Fig.5 Results of the need of new IoAIE concept for 150 SMES and Startup companies in Bangkok Metropolitan Region

Needs of *IoAIE* for 1st S-Curve Growth Engine in Thai Context

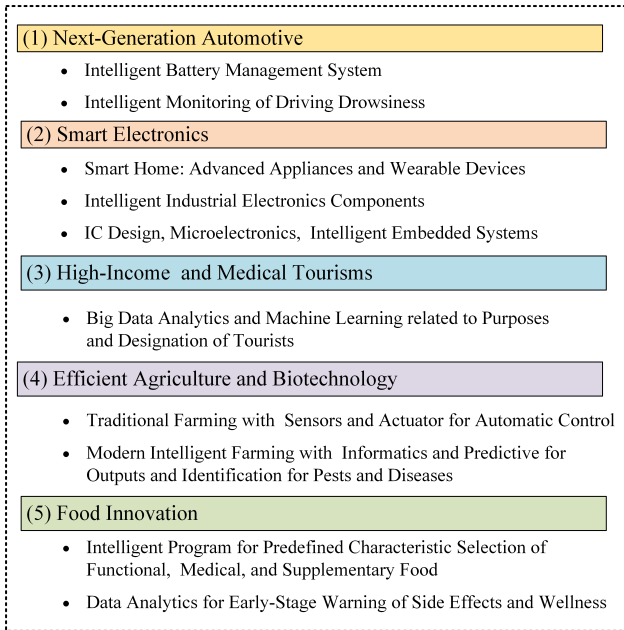


Fig.6 Major technologies and applications of *IoAIE* for 1st S-Curve Growth Engine in Thai Contexts.

“AI-Centric” means that AI should be considered as a center of designing a smart machine or algorithm in all parts of system architecture. AI can also provide the framework and tools to move beyond trivial real-time decision and automation. As depicted in Fig.4, the AI can be embedded in both physical and internet domains. In the case of physical domain, AI can be Embedded in fully-integrated or customized end-devices such microcontrollers or actuators as a feedback control. In other words, wireless sensor network in fog computing can also realize AI in the design such as Ad Hoc systems. In particular for data managements in IoD and IoS associated with cloud server, AI has played a significant role for big data analytics in order to find patterns or solutions for prediction and recognitions. Much attention paid on AI techniques in Thailand is natural language processing, expert systems, planning and scheduling, knowledge engineering, and human interface. In addition, particular techniques under research and development are artificial neural network, machine learning, and fuzzy logic control.

V. A Survey on the Need of *IOAIE* in Thailand

This paper has also conducted a primary online survey from 150 SMES and Startup companies in Bangkok Metropolitan Region in terms of the need of new *IoAIC* concept for applying such to their companies. All companies are related to 1st S-Curve of Thailand growth engine. Fig 5 shows the results of the survey, indicating that *IoAIC* concept is highly required for new digital products (26%) followed by production output increments (19%), smart and automatic production lines (17%), and knowledge management systems (10%), respectively. Meanwhile, data analytics in terms of marketing (13), business planning supports (12%), logistics managements, (6%), and smart networking and community (5%) are also interested in applying *IoAIC* for their business. It can be considered

that Thai companies have realized the importance of *IoAIC*, especially for new intelligent products, increasing productivity through the use of *IoAIC*, and also intelligent production lines.

VI. Proposed Applications of Internet-of-AI-Centric to Thailand Economics Growth Engine

The realization of *IoAIE* would absolutely enhance the potentiality and competitiveness for the industries, involving in digital technology and, moreover, coping with an emerging challenge in heterogeneity of internet-connected devices caused by the large variation due to the computational and communication capabilities. As mentioned earlier, this paper aims to explore a potential alternative to support five key industries in the 1st S-Curve of Thailand to continue the growth in the next-generation automotive, smart electronics, high-income tourism and medical tourism, efficient agriculture and biotechnology, and food innovation. With reference to the reviews of Thai policy and a focus group discussion among expertise and highly-experience representatives from SMEs and Startup companies, Fig.6 summarizes major technologies and applications Internet-of-AI-Centric (*IoAIC*) for 1st S-Curve Growth Engine in Thai Context. Details of such diagram in Fig.6 are described as follows;

First, the next-generation automotive in Thailand has focused on Electric Vehicles (EVs). Regardless the mechanics of the vehicle body and Lithium-Ion battery, Battery Management System (BMS) has become an important issue since those of conventional power balancing circuits is no longer effective for a large stack of Li-Ion batteries. Therefore, an Intelligent Battery Management System (IBMS) is necessarily required, which can be implemented through intelligent software in industrial-grade microcontroller. In addition to IBMS, *IoAIE* concept can be applied to those cars with built-in antenna and chipset, while tethered connections exploits hardware to allow drivers to connect to the cars via smartphones remotely. Image processing with intelligent monitoring of driving drowsiness is another potential approach required since there has been high rate of accidents.

Second, the smart electronics is one of the main focused industries which can be categorized into three subsections comprised of (1) new product section, e.g. smart home including advanced appliances and wearable devices, (2) current potential product section, e.g. industrial electronics components, and (3) electronics design section, e.g. microelectronics, embedded system, and IC design. With the harmonized combination of the state-of-art artificial intelligence and *IoT* Technologies as mentioned in *IoAIE* concept, regular devices integrated by variety of electronic components deserve a significant enhancement to a whole new higher-level by embedding AI into the system hardware so that such system obtained enhanced abilities to response or adapt themselves to properly suit for the acceptable condition changes. In this way, even the ubiquitous devices in daily life such as common home appliances, wearable devices, and sensors will be transformed into smart

devices, which create a feasible opportunities to successfully implementation of IoT smart home that would be capable of being remotely controlled and monitored through the internet. Moreover, boosting in the needs for smart devices in response the IoT consumer markets would accelerate the growth of both new product and current potential product manufacturing, including the augmented promotion of smart electronics design accordingly.

Third, the high-income tourism and medical tourism are expectedly realized to be ones of potential tourism industries in Thailand, as the concept of medical treatment combined with attractive destinations has recently increased influences on the tourism industry, especially in the Southeast Asia region. In contrary, Thailand's medical tourism has still encountered some drawbacks due to the lack of adequate supports for quality reputation, efficacy to produce more values from tourism resources, and suffice capabilities against global competitiveness. By applying the *IoAIE* concept, data, which are whether from devices linked to the internet or worldwide tourists connecting through social networks, are gathered as big data processed and analyzed by the aid of machine learning in order to discover valuable relational knowledge related to particular purposes expectation, and destination including period of time to stay of targeted tourists, therefore exposing suffice strategies to manage and optimize tourism resources, and strengthen competitiveness. Besides, with the implementation of variety of medical devices embedded with *AI* can lead to a responsive environment which transforms ordinary hospitals into whole new-level intelligent hospitals, consequently, improving quality reputation and creating higher-value added to the tourism market.

Forth, the efficient agriculture and biotechnology is involved with two major concerns, i.e. developing from traditional agriculture towards higher modern agriculture and create more value additive for processed products from natural materials in Thailand. In case of farming, the modern farming can be achieved through the cooperated utilization sensors and actuators, multipurpose drones, and farming robots, in order to operate their tasks in harmony and gather all possible physical information, whether in forms of numerical, linguistic, or images, transmitting to the cloud server embedded with *AI*. The right time to plant, apply fertilizers, and harvests, including identification for pest and disease outbreaks are accordingly predictable, which leads to a holistic smart farm being more efficient, optimal, and economical. A similar approach can also be applied on natural processed products e.g. natural rubber. The natural rubber, which is one type of abundant resources that could be found throughout Thailand, is capable of being processed to not only to a common product such as rubber gloves but also novel smart products such as a piezoelectric energy harvester using natural rubber embedded with *AI*.

Last, the food innovation in Thailand has been focused on producing processed food such as functional food, medical food, and supplementary food. As a one of the main aims in modern food industry is to produce novel high quality foods with consideration of rational use of the food sources and preservation of the natural quality in term of

unchanged nutritive value to the products, thus an innovative technology for both production and preservation is inevitably required to make the products with healthy properties, higher safety, and even longer shelf life. The *AI* with adaptive approach collaborating with *IoT* devices, corresponding to *IoAIC*, may be utilized to predict the expected profile of the foods based on the predefined characteristic selection, e.g. taste and texture and identify changes in sensory profile of the products caused by the variation of additive inputs. Besides, customer's preferences can also be predicted in advance by the use of data analytics in order to assist in producing new foods with certain nutrition and benefits appropriate to a certain group of matching consumers.

VII. Discussion and Conclusions

This paper is the first suggestion of an emerging paradigm on Internet of AI-Centric (*IoAIC*) for fostering Thailand economics growth engine. This paper have also recommended an emphasis on *IoAIC* framework Integration on such physical things, services, and data is presented as a straightforward ecosystem to be utilized for implementation of roadmap and strategies of Thailand 4.0. The new Ecosystem of *IoAIC* has been graphically demonstrated, suggesting that *AI* should be embedded in both physical and internet domains. The results revealed that the realization of *IoAIC* for Thai companies have been be well-informed and become aware of its potentiality, particularly for new intelligent products, increasing productivity through the use of *IoAIC*, and also intelligent production lines. The details of particular technologies of *IoAIC* have ben summarized in comparison of economy policy of other countries. This paper has therefore offered an emerging paradigm on social and economic impacts of *IoAIC* as a support for country policy of Thailand as a future hub in terms of business and investment in South East Asia region.

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