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Evolution of Thailand's Eco-Industrial Towns Development: Challenging and Obstacles

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ABSTRACT

This documentary and observational research presents the recent advancements in the development of Thailand's eco-industrial towns (EIT). Problems and suggestions are included to develop an EIT that is consistent with Thailand's future development. According to Thailand's EIT, sustained growth has resulted in the anticipated extension of the EIT area, with three excellent locations now exhibiting EIT performance close to the highest level. As a result, it is intriguing to see how problems and obstacles will be handled, as well as how the EIT operating plan will match with Thailand's national development goal toward a BCG (Bio-Circular-Green). As a result of the 2020 EIT assessment, it is worth noting that the outstanding EIT areas are influenced by several factors. The pressure for local factories to establish environmental management systems and corporate social responsibility (CSR) initiatives is significant. The authors propose encouraging the private sector to develop the circular economy pattern in any EIT area, as well as relaxing measures that impede EIT development and incentive programs of interest, all of which will eventually result in the development of EIT towards eco-cities or a low-carbon society.

1. INTRODUCTION

Eco-industry concepts proposed by Frosch and Gallopoulos [1] in the early nineties have been a crucial basis for developing environmentally friendly industries in the form of eco-industrial towns (EIT) driven by circular economies. The development of EIT in each area has different origins and contexts. In some areas, starting with a shortage of resources in production, industrial plants need to collaborate to share and circulate production resources to survive and build interconnection in an eco-industrial way. In many areas, the government has played an important role in the development of EIT through projects such as Japan's eco-towns project [2] which is outstanding in waste recycling [3] and promoted interdependence between industry and communities [4]. Some other examples are the Korean National Cleaner Production Center in South Korea which clean technology has been promoted [5], and the development of China's EIT in which the government plays a role in promoting and pushing comprehensively into management [6].

Thailand's EIT development began in 1999 as a result of the government's objective of resolving environmental concerns through the creation of eco-industrial parks by the Industrial Estate Authority of Thailand (IEAT) [7]. Later, the Ministry of Industry adopted the concept of green industry to improve the domestic industry by adopting the original criteria of the IEAT to improve and expand its scope from eco-industrial parks to eco-industrial cities, as well as dividing the level of EIT development into 5 levels to experiment in 9 areas between 2011 and 2013 and continuously expanding the area until it was increased to 18 areas [8]. DIW has reviewed and supported its ongoing EIT operations. Until 2020, with 3 areas successfully meeting the assessment criteria at level 4 (symbiosis) and having the opportunity to further develop into level 5 (livable cities combined with industry).

The idea of establishing most industrial parks in Thailand in the early days brought together the same type of industrial facilities in the same industrial area, which gave them a common advantage in logistics and supply chain. As industry has shifted to eco-industry, various eco-industrial parks have become more diversified, thus allowing for the development of eco-industrial parks through material exchange and recycling processes and linking them into eco-industrial networks. Instead, it has been found that the links between factories and between areas still have a lot of potential for development. Therefore, the concept of industrial symbiosis within the plant should be promoted and extended to the local community [9] for mutual benefit. According to an analysis of EIT performance from 2017 to 2019, there are still five operational barriers: personnel, budget, information, tools, and management.

However, in 2019, there are areas of EIT that have achieved level 4 and have the potential to progress to level 5, where it is necessary to focus on environmental stewardship and the quality of life of the people in the area in order to achieve clear and tangible results. Finally, the authors believe that the empirical successes in EIT development will be recognized by the local public.

2. LITERATURE REVIEW

2.1 Thailand's eco-industrial towns development

Thailand has implemented a national economic and social development plan to overcome poverty issues since 1961 [10].

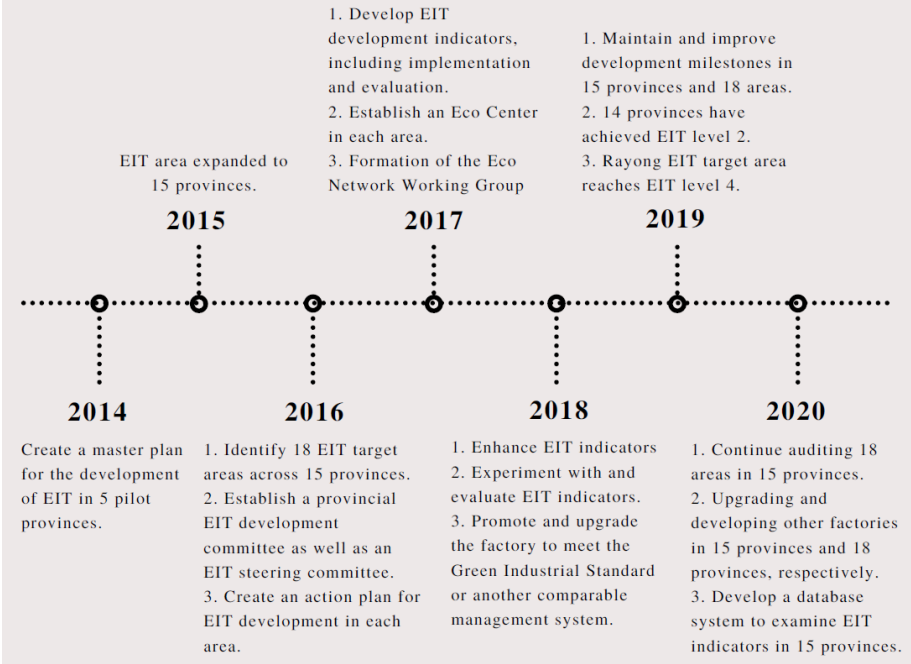

Figure 1. The progress of EIT development in Thailand during 2014-2020 [11]

As a result, the industry plays an important role in driving the country's economy more sequentially. As domestic industrial areas have expanded, environmental problems and impacts on communities surrounding industrial areas have also increased. At that time, the government was interested in developing an eco-industry continuously. The progress of EIT development in Thailand can be divided into three eras, with significant changes as shown in Figure 1.

2.1.1 The First Era: (1999 - 2010) The Beginning of Eco-Industry in Thailand

In 1999, IEAT partnered with Deutsche Gesellschaft Für Technische Zusammenarbeit (GTZ), Germany to develop the eco-industrial Estate & Networks Project (DEE + Net Project) under the concept of promoting the business model that followed the 9-area principles by Cohen-Rosenthal [12] and eco-industrial network creation. In 2004, the IEAT created pilot projects to develop eco-industrial estates in five different contexts, which are (1) organizing eco forums and building an eco-economic industrial network at Map Ta Put Industrial Estate, (2) promoting the Clean and Clear concept at Bangpoo Industrial Estate, (3) comprehensive waste management at Northern Industrial Estates, (4) comprehensive water management at Eastern Seaboard Industrial Estate (Rayong) and (5) skill training and development at Amata Nakorn Industrial Estate [7]. Until 2009, the government assigned the Ministry of Industry (MI) as the main responsible agency for the development of eco-industries under the concept of green industry and driving the development of EIT [8]. Later, a conceptual framework was created and completed in 2010.

2.1.2 The Second Era: (2011 - 2016) Towards green industry

After the EIT conceptual framework and indicators were created and complied with green industry concepts, environmental and energy management systems (ISO 14001 and ISO 50001), and socially responsible projects (so called the White Star Green Flag Project by IEAT and Corporate Social Responsibility, Department of Industrial Works (CSR-DIW) project by Department of Industrial Work (DIW)) have been integrated by green industry guidelines [13]. According to green industry guidelines, the EIT development by DIW was divided into four levels of operation: eco factory / green factory, eco-industrial zone, eco-industrial town, and eco-town as shown in Figure 2.

Figure 2. Levels of EIT development [11]

MOI assigned two major agencies in charge of conducting eco-industrial operations. IEAT is responsible for supervising industrial estates, while outside areas of the industrial estate are under the responsibility of DIW. In 2010, IEAT joined forces with the MOI to expand the eco-industrial park development to EIT. To create EIT characteristics, IEAT defined 24 segments in 5 dimensions as (1) physical dimension, (2) economic dimension, (3) environmental dimension, (4) social dimension, and (5) management dimension, and divided the level of EIT operations into 3 levels: Level 1 "Eco-Champion", Level 2 "Eco-Excellence", and Level 3 "Eco-World Class" [14]. Thailand's EIT criteria and indicators have been regularly revised. Beginning in 2003, the criteria will encompass the EIP, which will subsequently be expanded to include the EIT, and indicators have been modified to match and comply with the EIT development plan. The significant changes as shown in Figure 3.

Initially, in 2015 the target of EIT operation was divided into 5 levels, i.e., law enforcement, environmental and safety standard compilation, resource and energy efficiency, the symbiosis society, and the low carbon society. Later, in 2016 these levels have been revised to engagement, enhancement, resource efficiency, symbiosis, and happiness. The levels'

definition was completed in 2019 as shown in Table 1 the level and definition of EIT. Finally, the EIT features until now are therefore 20 segments in 5 dimensions [15].

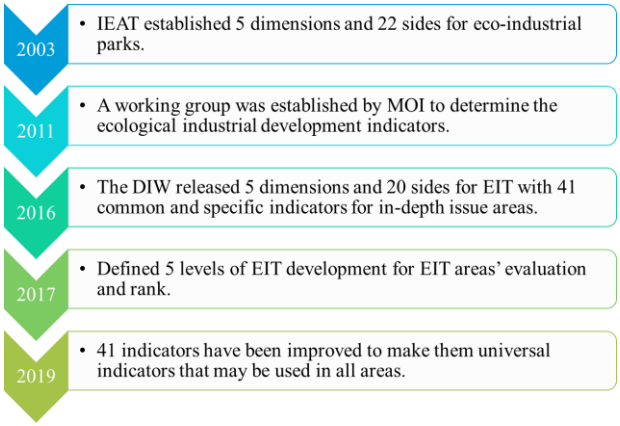

Figure 3. The change of EIT criteria and indicators during 2014-2020 [7, 11, 15]

The development of EIT began after the IEAT defined the first phase of the EIT Development Plan during 2010-2014, formulating an EIT development master plan in 15 industrial estates and expanding to 24 eco-industrial estates nationwide in 2016. The EIT development pilot project was launched for 9 industrial zones in 6 provinces which are Rojana Industrial Zone Ayutthaya, Bangkadi Industrial Park Pathumthani, 304 Industrial Park Prachinburi, Sahapat KabinBuri Industrial Park Prachinburi, Sahapat Sriracha Industrial Park Chonburi, IRPC Rayong Industrial Park, I.P.P. Industrial Communities Rayong, Hemaraj Industrial Estate Rayong, and Hemaraj Industrial Estate Saraburi [8].

Table 1. The level and definition of EIT [15]

Level	Definition
Level 1 Engagement	All stakeholders, which include industrial plants, industrial estates, industrial zones, industrial park, local government agencies, and communities, are to participate in the planning, monitoring, and improvement of the EIT development's action plan.
Level 2 Enhancement	Supporting and encouraging stakeholders concerned with EIT development in the environmental and safety aspects of the targeted areas to meet the standards and goals of EIT development.
Level 3 Resource efficiency	Usage of limited available resources in a way that promotes sustainability by utilizing fewer resources but greater productivity and results or deliver greater value while using fewer inputs to minimize the impact on the environment.
Level 4 Symbiosis	Interaction between agencies, organizations, or people in a particular area fosterages common interest for all parties.
Level 5 Happiness (livable city coupling with industry)	Having a positive emotion, such as happiness or satisfaction, and enjoying life, defines a mental or emotional condition that symbolizes a good life.

2.1.3 The Third Era: (2017 - 2021) EIT development on the path of the 20-year national strategy

According to Thailand's 20-year national strategy framework (2018 - 2037) on October 13, 2018, the fifth strategy mentions the issue of improving environmentally friendly quality of life to achieve sustainable development goals based on a green economic society under environmentally friendly production and consumption. With an emphasis on developing "a livable city with stable rural, sustainable agriculture and combined with eco-industry" [16]. The MOI has issued a 20-year strategy for the development of Thai industry 4.0 from 2017 - 2036 in compliance with the national strategy, focusing on promoting the development of potential industrial clusters to enter the EIT and achieve concrete success [14].

EIT development following green industry guidelines aims to develop cities that are continuously growing while maintaining environmental friendliness. Under an economic system that is based on industrial friendly principles, it is necessary to maintain the environment and improve the quality of life in conformance with sustainable development principles. The stage to EIT development is divided into 3 levels: (1) promoting industrial plants in the form of eco-industrial factories with good operations in terms of safety and environmental management, energy conservation, effective resource consumption, and assistance to surrounding stakeholders. (2) Extending the scope of operation to the industrial zone or industrial estate level to imitate natural ecosystems through matter and energy exchange. (3) Linking activities in the manner of eco-industrial networks supports EIT to develop communities, industrial, agricultural, and others in a balanced way to promote a low-carbon society for a good quality of life and environment (Figure 1).

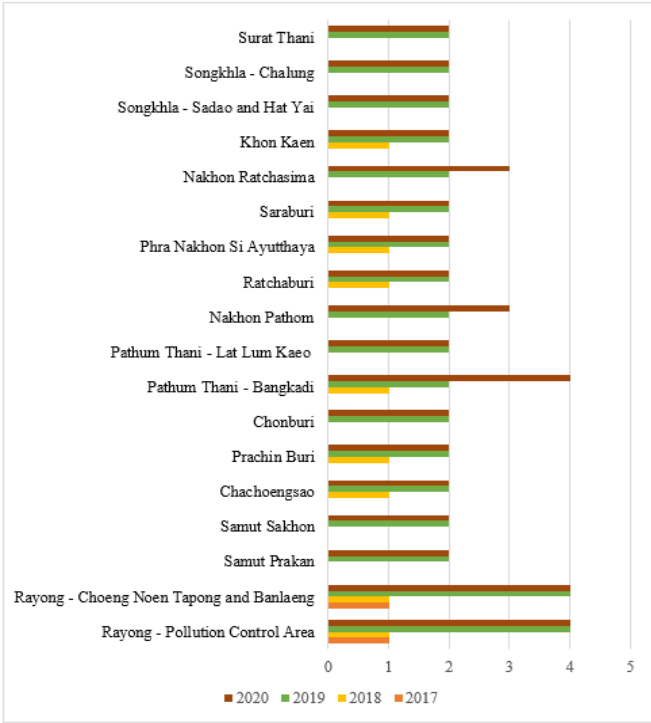

Figure 4. EIT assessment in different areas during 2019-2020 [17, 18]

The DIW has targeted an EIT development plan to achieve at least 40 areas in 37 provinces by 2036 [19], reviewing 41 EIT indicators suitable for the problems and context of each area, covering 20 segments in 5 dimensions, and dividing EIT into five levels (see Table 1) in 2018. Meanwhile, IEAT aims to expand its EIT performance to 34 industrial estates in 2019 and formulate a 5G+ strategy (Growth, Green, Great, Good,

and Global + innovation) to drive the organization to achieve the vision of leading the development of regional integrated industrial estates with innovation to sustainability. The 2020-2022 operational plan aims to meet 24 Eco-Champion, 9 Eco-Excellence, and 3 Eco-World Class industrial estates by 2022 [19].

2.2 The success of Thailand's EIT development

The aim of Thailand's EIT development is to achieve the level 5 of EIT, known as " Happiness (livable city coupling with industry)". The industrial sectors must be able to coexist with communities sustainably and be the main driver to excel the economy in the form of a circular economy, support community economic development, improve quality of life, and take care of the environment in a simultaneous manner [20]. In 2013, the Cabinet passed a resolution to enhance the implementation of EIT to cover industrial areas in other regions.

Figure 4 shows EIT assessment in different areas during 2019-2020. As can be seen, the prominence of EIT development in 3 areas (Rayong – Pollution Control Area, Rayong-Choeng Noen, Tapong and Banlaeng, and Pathum Tani-Bangkadi) is partly due to good cooperation from all relevant sectors. Areas with industrial parks or industrial zones will be an advantage because the presence of industrial plants located in the same area is convenient to promote the EIT development projects consecutively. The implementation of quality and environmental standards of industrial plants in the area promotes EIT operations at level 1-3 of the EIT standard (participation, promotion, and efficient resource utilization). In addition, building good relationships with communities through the social responsibility activities of industrial plants in the area could promote to higher levels.

2.3 EIT problems and obstacles

EIT development indicators have been used to evaluate the success of EIT development. In the past, the EIT development indicators have been continuously reviewed to assist the development of EIT projects to suit the context in each area, resulting in achieving of higher levels of EIT development in many areas. Many recommendations from the conclusion of EIT development from 2017 to 2019 (as stated in Table 2) resulted in the establishment of EIT development centers in the central and provincial areas.

Similarly, the Division of Eco-Industrial Development A review of the EIT area's growth from 2018 to 2020 showed seven challenges and obstacles: ambiguous EIT criteria and indicators, EIT area collaboration, auditor quality, unclear EIT surveillance period, information systems, budgets, and provincial government agencies do not establish EIT KPIs [21].

In 2020, three areas in two provinces passed the EIT assessment at level 4, or the level of symbiosis between industry and communities. The Bangkadi sub-district in Pathum Thani province has improved from level 2 in 2019 to level 4 in 2020. The establishment of eco-industry networks (EIN) in various areas brings cooperation from many sectors in the EIT development, especially in the Rayong Pollution Control Area, which have passed the assessment level 4. The establishment of a Community Partnership Association by a group of large industrial plants in the area streamlines coordination with various agencies and supports the work of the province's EIT development centers. Thus, Rayong Pollution Control Area has gained more database and good coordination. As a result, it achieved better levels of assessment than others.

Table 2. Recommendations from eco-industrial towns development project summary report during 2017 – 2019 [17, 20, 22]

Year	Factor	Recommendations
2017	Personel	1) Adequate manpower. 2) Factories monitor participation.
	Information	1) Enhancement of the digital database system. 2) EIT continuous promotion.
	Law and regulation	Encouraging eco-networks by law improvement.
	Tools	Uncleared assessment indicators and rating measurement.
2018	Personel	1) The relevant authorities should select representatives to attend the EIT meeting and serve as messengers of the meeting's outcomes within the organization. 2) The Eco-Industrial Network (EIN) should be developed through knowledge exchange seminars and provide training on specific areas such as detailed indicators and evaluation criteria. 3) The establishment of a data collection system on the EIT indicators of each agency should clearly determine who is responsible.
	Budget	Insufficient EIT project's budget.
	Information	1) A lack of EIT data sent to the central system by local governments. 2) The EIT communication plan has not been approved by local executives. 3) Establishment of centralized EIT data storage.
	Tools	"Eco-design" should be clarified for easy understanding and practice.
	Management	1) Factories in the EIT area should be encouraged to meet standards such as eco-factory, etc. 2) Consistent and continuous development of EIT indicators by any committee.
2019	Personel	1) Manpower shortages in EIT development centers. 2) Changes and relocation of personnel have resulted in a lack of continuity in the implementation of EIT development.
	Budget	Insufficient budget to carry out EIT activities of EIT centers.
	Information	1) In practice, some indicators are difficult to apply. 2) Each indicator must be improved or standardized in some way. 3) Issues with data import.
	Management	1) Inappropriate EIT target area. 2) It is difficult to gather data from factories outside the industrial estate. 3) Lacks of EIT indicators' understanding. 4) Pre-audit from EIT auditor is required.

Moreover, it has more potential to enhance EIT development up to level 5 which meets the highest assessment criteria (level 5). Promoting careers for local people, air pollution control, reduction of biodiversity threats, and promoting employees' quality of life have been example of their continuous efforts to improve EIT to level 5.

3. METHODOLOGY

3.1 Study area

From 18 areas under the Department of Industrial Works (DIW) EIT promotion program, this study focused on the selected three specific areas base on the top three scores of EIT assessment 2020, which stands out as the following areas:

(1) The Rayong pollution area: according to National Environment Committee Announcement No. 32, the Rayong pollution area includes the Map Ta Phut sub-district and surrounding areas. The Map Ta Phut Industrial Estate, which houses refineries and petrochemical plants, serves as a driving force in the area.

(2) The area around the IRPC industrial zone covers Choeng Noen, Tapong, Banlaeng, Natakwan sub-district, and Rayong Municipality areas. IRPC has an industrial estate with refinery and petrochemical industries that have been operated by IRPC to develop EIT.

(3) The Bangkadi Industrial Zone, which includes 39 factories in the Pathum Thani province's Bangkadi Sub-district, consist of electrical, electronics, and chemical industries.

3.2 Data collection

The primary and secondary data in this study have been collected as shown in the diagram in Figure 5.

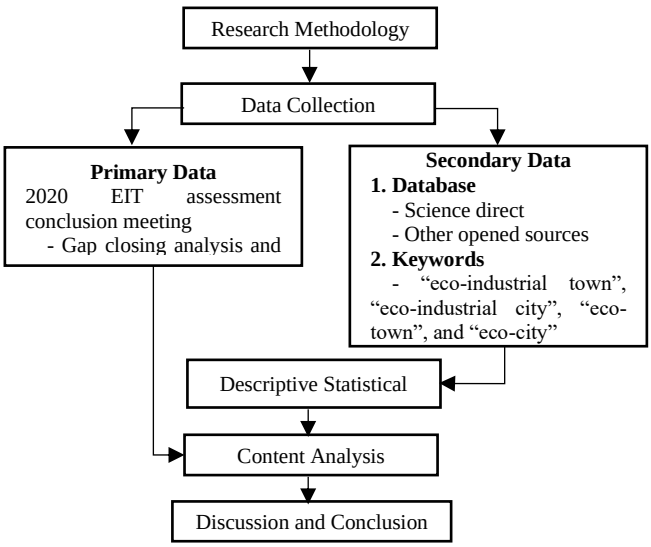

Figure 5. Research methodology

3.2.1 Primary data

We attended and observed the Community Partnership Association (CPA)'s "2020 eco-industrial towns" assessment gap closing meeting in Rayong province on April 4, 2021. Meanwhile, the Pathum Thani Bangkadi area could not be observed due to the COVID-19 pandemic in Thailand from 2020 to 2021. Hence, we selected to interview the Head of Industrial Section, Pathum Thani Provincial Industry Office, instead.

3.2.2 Secondary data

The search was carried out by "eco-industrial towns", "eco-industrial city", "eco-towns", and "eco-city" keyword searches from "science direct" during 2012-2021, which aimed to find relevant journals in which papers were published with open access source.

3.3 Data analysis

3.3.1 Descriptive statistic

The data is analyzed and presented as bar charts to show basic information, relationships, and eco-industry research tendencies each year.

3.3.2 Qualitative analysis

EIT operation data obtained from semi-structural key informant observations and interviews is analyzed with content analysis techniques according to Colaizzi's guidelines [23]. The data gained from observations and interviews is used to sort out important issues and categorize on each of them before checking the consistency compared to the actual phenomena to synthesize the essence that can conclude the actual phenomenon within the research scope.

3.3.3 Content analysis

The data generated from the results of the EIT study, gathered from Thai Journals Online and other Thai databases, will be studied for material relating to EIT development in the areas of management, framework and assessment, indicator improvement, and success factors. Obstacles and improvements identified through gap closing meetings and interviewing to identify development approaches. Thailand's EIT wants to become a low-carbon city powered by a circular economy.

4. RESULTS AND DISCUSSION

4.1 Thailand's EIT development through the perspective of academic research

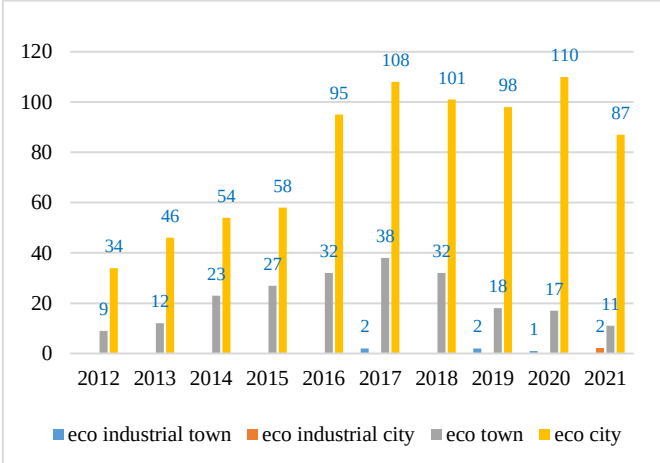

Figure 6. Distribution of publications per year from across "eco-industrial towns", "eco-industrial city", "eco-towns", and "eco-city"

From database available in English language, we found a total of five papers keyworded as "eco-industrial towns" and none of them were open access. Two papers were keyworded as "eco-industrial cities" and accessible. Meanwhile, the "eco-towns" keyword resulted in 219 papers with 32 papers that were open-accessibly. The "eco-city" keyword resulted in 791 papers with 175 papers that were open access, as can be seen in Figure 6.

Meanwhile, Thai Journals Online, and other Thai databases resulted in sixteen papers with "eco-industrial towns" and "eco-industrial city" keywords. Among these papers, four of them proposed the EIT management issues, six studied the EIT framework & assessment, two focused on indicators improvement, and four papers analyzed EIT success factors as described in Table 3.

Table 3. Reviewed papers from Thai Journals Online and other Thai databases

Issues	Technique	Description
Management	In-Depth Interviews	The local community needs EIT development of 5 dimensions (physical, economy, environmental, social, and management) along with the development of local economy, reducing unemployment and poverty [24].
	Face-To-Face Interviews	The EIT development includes management process to balance the economic, social, and environmental contributions [25].
	Focus Group Interviews	The recent EIT operation lacks measures and incentives for the private sectors and other stakeholders. The impact to the affected communities from industries should not be fixed by 5 kilometers radius based on the environmental impact analysis (EIA) report [26].
	Unstructured In-Depth Interviews and Brainstorm	Concerned issues of community environmental plan are urban planning, infrastructure development, community needs, local government empowerment, developing a new generation of community leaders, and common regulations to accommodate relocation from people outside the area [27].
Framework & Assessment	Article Review	The factors of physical greening design are buffer zones, greenbelts, setback, green corridor, green wall, and protection strips along with the Air Pollution Tolerance Index (APTI) measurements [28].
	Geographic Information Systems (GIS)	Seven factors for EIT development are Industrial density, Consolidation of the same industry type, Parks and recreation areas access, Complaints Risks, Main Road access, Environmental standards certified factories, and Natural disasters risk [29].
	Multi-Objective Linear Programming Model	The optimized model can be used to identify and create the material exchanges in the EIT for industrial sustainability [30].
	Geographic Information System (GIS) and Analysis Hierarchy Process (AHP)	The most important indicators for EIT development are environmental standards [31].
	Geographic Information System (GIS) and General Algebraic Modelling System (GAMS)	The integration of industries can improve the profitability of the holistic industry while optimally utilize the availability of energy and materials sharing to their networks and communities via industry symbiosis [32].
	Brainstorming, In-Depth Interviews, and Content Analysis	For EIT development, Laem Chabang Municipality suggested six factors as strictly environmental monitoring, law enforcement, municipality's role, decentralization of power to local government, promoting community networks for environmental monitoring, and establishing a provincial community environmental plan [33].
Indicators	Content Analysis	To have success EIT, all operations should synchronize the laws, regulations, and governmental policies [34].
	In-Depth Interviews and Focus Group Interviews	Key indicators of local government in the EIT development include on-site management, law enforcement, networking information systems, public communication, cognitive development, and participation, combined with improving the quality of life of local people to develop into concrete and sustainable EIT [35].
Success Factors	SWOT Analysis, TOWS Matrix Analysis And Sustainable Balance Scorecards (SBSC)	Four factors to promote the sustainable EIT are stakeholders' capability building, internal processes improvement, focused eco-efficiency concept, and communities' collaboration [36].
	Analytic Hierarchy Process (AHP)	The main support from government should be prioritized in appropriate laws and regulations. This need conforms with the laws and regulations in practices of industrial section [37].
	Exploratory Factorial Analysis (EFA)	Promoting network activities (associations) to find opinions and share important information in all aspects, creating mechanisms of effective collaboration and incentivizing companies about their shared future interests [38].
	Content Analysis	Eight factors for EIT development are participation in public activities, local culture, and environment conservation, potential and vision, participatory management, community self-reliance, learning and sharing experiences, support from government agencies, and networking cooperation [39].

With a circular economy, eco-industry development techniques are a sustainable way for industry to reduce resource, energy, and waste consumption [40]. Over the last ten years, academic study has concentrated on eco-towns and eco-city studies, which more comprehensively represent the holistic development of the city than eco-industrial towns or eco-industrial cities, in order to balance production and consumption for a sustainable eco-footprint. Many discoveries have been made on the dominating character of eco-industry growth in China. The growth of eco-industries under the strong participation of central and local governments in creating policies and encouraging eco-industries brings the design and management of eco-industrial parks under the ideas of industrial symbiosis, clean technology, and waste recycling [41].

Furthermore, the path ahead for EIT growth in Thailand should encourage network (association) activities that are open to hearing perspectives and exchanging critical information across eco-industrial parks. Create effective structures for collaboration between central and local government and educate companies on the long-term advantages [39].

As a result, holistic EIT development must begin with good eco-industrial operations at the factory and industrial park levels in order to build eco-industrial network and eco-industrial town that can be elevated to eco-cities with circular economy concepts, creating economic benefits with a balance of economic, social, and environmental dimensions. As demonstrated by industrialized nations and industry leaders, eco-industrial parks and eco-industry networks have effectively linked community activities with appropriate industrial systems. This may have resulted in an increase in the number of publications on "eco-towns" and "eco-cities" over the last ten years.

4.2 The prominent areas of 2020 Thailand EIT assessment

In 2020, three areas in two provinces passed the assessment at level 4, or the level of symbiosis between industry and communities. These areas are Rayong – Pollution Control Area, Rayong-Choeng Noen, Tapong and Banlaeng, and Pathum Tani-Bangkadi as shown in Figure 7.

The observation and interview in these three areas show that data management based on EIT is a major fundamental issue, as there are various agencies responsible for operating and storing data in each area.

Information obtained from the interview with the Head of Industrial Section, Pathum Thani Provincial Industry Office, found that the problems and obstacles include agents involved in EIT operations lacking knowledge about the eco-industry and EIT indicators, as well as not having an effective data storage system based on indicators. Thus, the Bangkadi Pathum Thani region handled this problem via direct engagement with stakeholders, including industrial plants, community leaders, and local government agencies, who attended the guidelines clarification meeting from the outset. Other major drivers for effectively utilizing their EIT evaluation and upgrading from level 2 in 2019 to level 4 in 2020 are: (1) creating a standard form; (2) ongoing data tracking; and (3) building a standard way to rectify and sort data by indications in all dimensions.

For Choeng Noen, Tapong, and Ban Laeng Rayong areas, the results of an interview with the environmental manager of the IRPC company showed that there are advantages to the fact that various factories located within the IRPC industrial zone are the IRPC's own factories. IRPC has continuously carried out community and social responsibility (CSR) activities to reduce the impacts on surrounding communities and build good relationships with stakeholders, thus maintaining the results of the EIT assessment at level 4 for the second consecutive year.

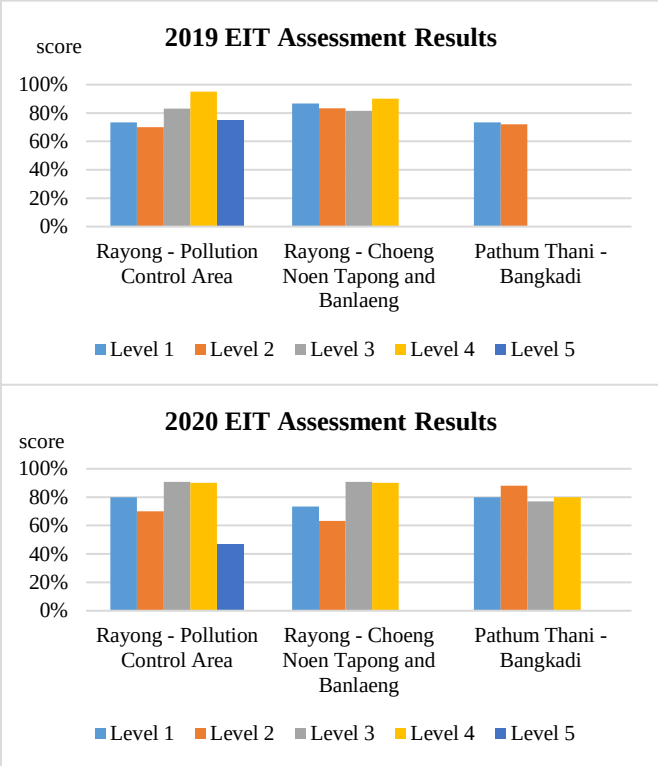

Figure 7. Comparison of EIT assessment results of top three dominant areas between 2019 and 2020 [18, 21]

Meanwhile, the results of an observation workshop on April 4, 2021, organized by the Community Partnership Association (CPA) to analyze EIT 2019 performance in the Map Ta Phut Rayong pollution control area and search for operation gaps showed: Advantages of EIT operations include many industrial plants in the Map Ta Phut Industrial Estate, which has jointly established the CPA by arranging for representatives from various local companies to work together to conduct CSR activities with the surrounding communities and cooperate with local government agencies. This results in the continuous progress of EIT, successfully passing the criteria for EIT assessment at level 4, and being able to meet half the metrics at level 5.

However, developing EIT to meet level 5 is challenging as it is a level where industrial plants must focus on reducing environmental and social impacts, especially on safety and health issues. It is also necessary to support the surrounding communities in improving their career skills and improving quality of life, as well as helping to reduce loss of life and property from disasters, in which both man-made and natural disasters management require industrial cooperation. Government agencies and private sectors are involved, and more importantly, local people's cooperation in monitoring the news and supporting EIT implementation in a participatory manner is critical to balancing sustainable EIT development.

Finally, current EIT operations still focus on fulfilling indicators requirement that cannot measure practical results to reflect the economic and environmental problems, which are

key issues. Therefore, EIT should be developed following its definition and the context of each area to build public confidence and meet sustainable development and national goals.

4.3 Challenging and enhancing to eco-city

DIW and related agencies have been constantly trying to promote EIT development in many areas for more than 10 years. Although obstacles during the EIT development pathway at the beginning of the operation were mainly related to knowledge, communication, and early unclear operational patterns, DIW and related agencies had set the EIT development promotion for years. Their efforts seem to have resulted in the expanding of EIT areas in Thailand constantly according to the EIT roadmap. Nevertheless, in summary, the key issues in EIT's operations during 2017-2019 can be classified into six key aspects as personal, budget, information, laws, tools, and management (Table 2). As a result of the EIT operations gap closing meeting in 2020, inadequate indicators adjustment, data management, and eco-industry project alignment issues have been presented as key issues for finding solutions to achieve better assessment results in the later year.

4.3.1 The inadequate indicators adjustment

The EIT Development Promotion Program, which is set annually by DIW, has resulted in the continuous improvement of activity indicators for EIT operations in various areas. It is evident that the industrial sector in each area continues to focus on adjusting the details and criteria of certain indicators to suit the different contexts of each area. Different audit intensity in each area, as well as incomplete data collection due to personnel shortages in various agencies, are also to key problems.

4.3.2 The data management

Environmental and social data are important information that is required to comply with the EIT level 5. The latest year's results showed that the lack of integration of each agency causes redundant data collection, or some important indicators have never been collected by agencies in the sub-district level. Particularly, environment and social indicators of EIT are not included in the Local Performance Assessment (LPA) indicators of local government officers [42].

4.3.3 The eco-industry projects alignment

Local government organizations in many areas have implemented the "Livable Cities Coupled with Industries" project organized by the Department of Environmental Quality Promotion (DEQP) [43]. Some indicators of the "Livable Cities Coupled with Industries" project are similar to EIT level 5 indicators. Both indicators can be aligned together to reduce workload of local authorities.

Advances in ecological industry research in Thailand still have a pronounced gap compared to the direction of eco-industrial development research in the current trend. International research emphasizes the efforts of leading industrialized countries to become eco-cities, improve the quality of life of communities under the expansion of resource-efficient cities, and reduce their ecological footprint. In our view, the eco-industrial development in Thailand also relies on the industrial sector for an important key role in its performance. There are still opportunities for improvement and strengthening eco-industrial parks and eco-industry networks because the driving forces of eco-industrial development in Thailand are mainly due to environmental problems caused by industrial sectors. The lack of drive forces originating from insufficient resources has resulted in industrial factories not actively collaborating on sharing resources and improving production processes. This makes the industrial symbiosis process inter-firmly linked, which differs from top-down operations through bureaucratic policies and planning, allowing agencies at the workspace level to wait for policies and centralized projects.

Hence, the direction of EIT development project has been driven toward eco-city by target setting while focusing on specific indicators such as ecological efficiency, material recycling rate, greenhouse gas reduction rate, and so on. Ecological efficiency must be encouraged to be effectively used as an evaluation and reporting tool to sustain and enhance the performance of the eco-industrial park to EIT performance [44]. The government should prioritize on improving the ecological efficiency of industrial parks at the same time as EIT development, conducting frequent reviews of industrial park ecological efficiency, and designing appropriate improvement strategies for each park. Furthermore, the creation of circular ecological urban and rural environments necessitates the collaboration of industrial parks and connecting their activities expanding to EIT. The direction of EIT development should pay attention to the participation of all stakeholders, especially local government, and industrial parks to create a circular ecological system in the area [45]. It is interesting how the EIT approach can promote sustainability and what needs to be accelerated in order to successfully implement the EIT operation and enhance the eco-city.

Finally, the EIT operation must adhere to the circular economy, with the industry reducing its environmental footprint through the development of eco-industries in a sustainable way [40]. The challenge of EIT development for decision-makers is to decentralize local governments to establish stakeholder organizations to manage EIT in the area and learn from successful countries and leading developing countries in promoting cleaner production and circular economy. Enhancing EIT to eco-city requires a platform established for information sharing, research, and development (both national and local government level), laws and regulations improvement, and financial incentives [46]. Leveling-up EIT operations requires the transition to be an intermediary linking between EIT and the circular economy to upgrade the operation from EIT to eco-city.

5. CONCLUSION

Thailand's EIT development has progressed steadily, starting with setting environmental standards at the factory level, promoting eco-industrial parks, building eco-industrial networks, and upgrading EIT's operating areas as a result of DIW's efforts to continuously promote EIT. It's particularly challenging because the answer to success lies not in the trophy or reward but in the well-being of the people who live in the area.

This research outlined the problems and obstacles in three dominant areas of EIT operations. EIT to better evaluate. We believe that next year's results will certainly include new EIT areas that have received more EIT assessments that meet the criteria in levels 4 and 5. In addition, the authors propose to establish a strong connection between industry and

community through industrial symbiosis and benefit sharing with an economic mechanism to merge their needs and develop the circular economy pattern. In addition, the main support from the government should be given to appropriate laws and regulations to resolve restrictions on waste exchange activities and provide an interested incentive program to persuade the small and medium-sized factories located outside the industrial estates to participate in or connect to the EIT operation as much as possible.

In terms of Thailand's EIT development, the government and related agencies should accelerate EIT development to make it Thailand's unique eco-city. By linking the prominence of various types of industries such as manufacturing, agriculture, tourism, and culture, it has created a new initiative driven by the BCG (bio-circular-green) economy towards the goal of becoming a low-carbon city, balancing economic growth and livability under sustainable development.

The limitation of this research is collecting secondary data to analyze issues related to industrial ecology that have been studied in various aspects. There is no access to all databases, and we could only access the databases that are available publicly (open access). For further research, gaining access to closed access databases is an important requirement for more complete analysis of EIT development.

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