Article

Infrastructure-driven growth of a coastal tourist city: A case study of Pattaya, Thailand

Suwadee T. Hansasooksin[1], Nij Tontisirin[1], Sutee Anantsuksomsri[2,*]

[1] Faculty of Architecture and Planning, Thammasat University, Pathumthani 12121, Thailand
[2] Regional, Urban, & Built Environmental Analytics (RUBEA), Faculty of Architecture, Chulalongkorn University, Bangkok 10330, Thailand
*** Corresponding author:** Sutee Anantsuksomsri, sutee.a@chula.ac.th

CITATION

Hansasooksin ST, Tontisirin N, Anantsuksomsri S. (2024). Infrastructure-driven growth of a coastal tourist city: A case study of Pattaya, Thailand. Journal of Infrastructure, Policy and Development. 8(9): 8141. https://doi.org/10.24294/jipd.v8i9.8141

ARTICLE INFO

Received: 26 July 2024
Accepted: 19 August 2024
Available online: 6 September 2024

Abstract: Pattaya City is a well-known tourist destination in Thailand, famous for its beautiful beachfront, lively nightlife, and stunning natural scenery. Since 2019, the Eastern Special Development Zone Act, the so-called EEC (Eastern Economic Corridor), has positioned the city as a focal point for Meetings, Incentives, Conferences, and Exhibitions (MICE), boosting its tourism-driven economy. Infrastructure improvements in the region have accelerated urban development over the past decade. However, it is uncertain whether this growth primarily comes from development within existing areas or the expansion of urban boundaries and what direction future growth may take. To investigate this, research using the Cellular Automata-Markov model has been conducted to analyze land use changes and urban growth patterns in Pattaya, using land use data from the Department of Land for 2013 and 2017. The findings suggest an upcoming city expansion along the motorway, indicating that infrastructure improvements could drive rapid urbanization in coastal areas. This urban expansion emphasizes the need for urban management and strategic land use planning in coastal cities.

Keywords: urban growth; land use change; infrastructure; coastal city; Thailand

1. Introduction

Research on urban growth patterns, encompassing both compact and sprawling developments, has received considerable attention. However, coastal cities, characterized by diverse socioeconomic and geographic features, have been relatively understudied in this regard (Jabareen, 2006; Jenks, 2000; Schneider and Woodcock, 2008). Particularly in Thailand, research has predominantly focused on land use changes and management. For instance, Senawongse and Eiumnoh (2019) investigated the dynamics of land use change in Chonburi province, highlighting the considerable conflicts arising from high land demand between public and private sectors. Similarly, Wang et al. (2022) identified tourism as one of the main drivers of land use and land cover change (LULC) in Thailand from 2000 to 2020. There are many major coastal hubs in Thailand, for example, Pattaya, Hua-Hin, and Phuket, located in the eastern, western, and southern parts of the country, respectively. However, Pattaya stands out as a leading tourist destination in Thailand, having aggressive marketing strategies, coupled with its diverse attractions and ongoing development projects (Maneethorn et al., 2023). As of 2024, the city has set an ambitious target to attract 27 million tourists and is expected to generate 3.5 trillion baht, making it one of the top destinations in Thailand. This figure is driven by both international and domestic tourism, with Pattaya playing a crucial role due to its vibrant nightlife, beaches, and cultural events. Against this backdrop, this research paper aims to explore the urban growth patterns of Pattaya City, a prominent coastal tourism destination in Thailand.

Historical evidence recorded by Pattaya city indicated that the city was originally a small fishing village until the late 1950s. In 1959, during the Vietnam War, American servicemen stationed nearby discovered its beautiful beaches and began visiting for relaxation and recreation. This marked the beginning of Pattaya's transformation into a tourist destination. The Vietnam War brought an influx of tourism and development to Pattaya. With its proximity to U-Tapao Royal Thai Navy Airfield, which was used by the United States Air Force, Pattaya became a popular rest and recreation spot for American soldiers. Throughout several past decades, Pattaya has continued to experience significant growth in both construction activity and population movement, mainly because more tourists started coming and businesses started investing there. Pattaya is one of Thailand's top spots for beach vacations, attracting millions of visitors every year. The city provides a wide range of activities, including nightlife, shows, hotels, dining, shopping, water activities, and cultural sites.

Between 2008 and 2019, the number of tourists in Pattaya grew significantly, with an average annual increase of 13% (The Ministry of Tourism and Sports, 2019). By the end of 2019, Pattaya had welcomed 14.6 million visitors. The city is ranked 15th among the top global destination cities, attracting international tourists primarily from China, Russia, and South Korea (Mastercard Global Destination Cities Index, 2019). However, when the COVID-19 pandemic hit, the number of tourists dropped sharply to 2.8 million, mostly Thai people. By 2022, Pattaya's tourism had started to recover, with 16.6 million tourists returning. On average, tourists stayed for about 2.4 to 4.1 days. Moreover, the amount of money tourists spent also went up significantly, from 102.7 billion THB in 2014 to 265.9 billion THB in 2019. Compared to other seaside cities, Pattaya's growth rate was higher, around 17.20%. The increase in spending was higher for tourists from other countries (6.10%) than for local Thais (4.60%). On average, foreign tourists spent 5561 THB per day, while Thai tourists spent 3836 THB per day.

Pattaya's advantageous location in the eastern region of Thailand has established a well-connected land transportation network, facilitating easy access to Bangkok. Recently, Pattaya city and other provinces in the eastern region, including Chachoengsao, Chonburi, and Rayong, have undergone rapid development as a part of the Eastern Economic Corridor (EEC) project, which was established in 2019. The EEC project encompasses six infrastructure projects linking Pattaya to neighboring cities, including U-Tapao International Airport, the Bangkok-Rayong High-Speed Rail, a double-track railway, the Pattaya to U-Tapao motorway (Route 7), the Map Ta Put deep seaport, and the Laem Chabang commercial port (Hiratsuka, 2018) as shown in **Figure 1**. This regional strategy promotes economic specialization within each main city of the respective provinces, bolstering overall regional growth. These provinces not only serve as residential areas but also act as hubs for commercial and industrial investments. Pattaya, in particular, has been earmarked as a key area for tourism businesses and for accommodating long-term visits by overseas expatriates. Hence, the major cities and hinterlands in the region are well connected, fostering a systematic approach to development.

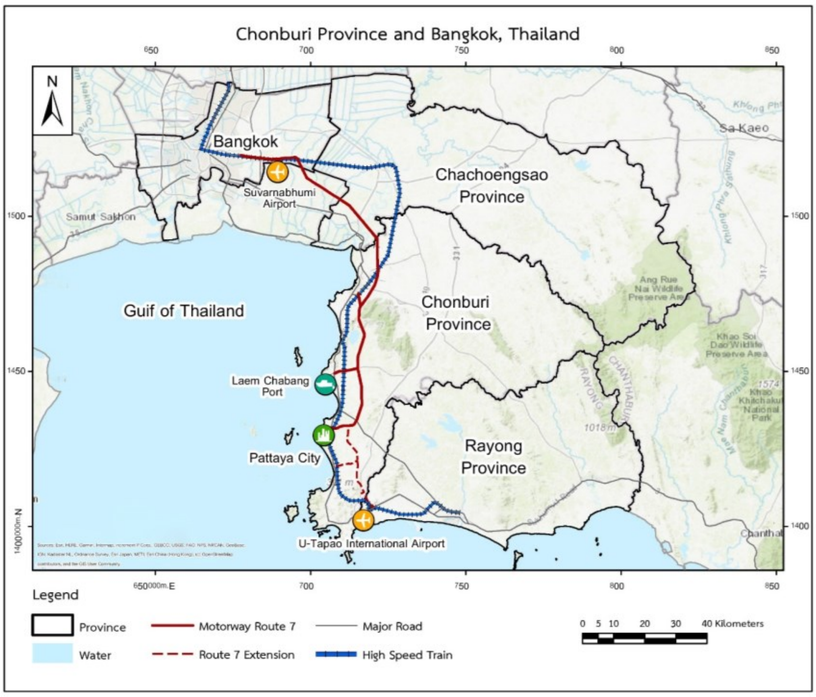

Figure 1. Pattaya City, Chonburi Province, Thailand.

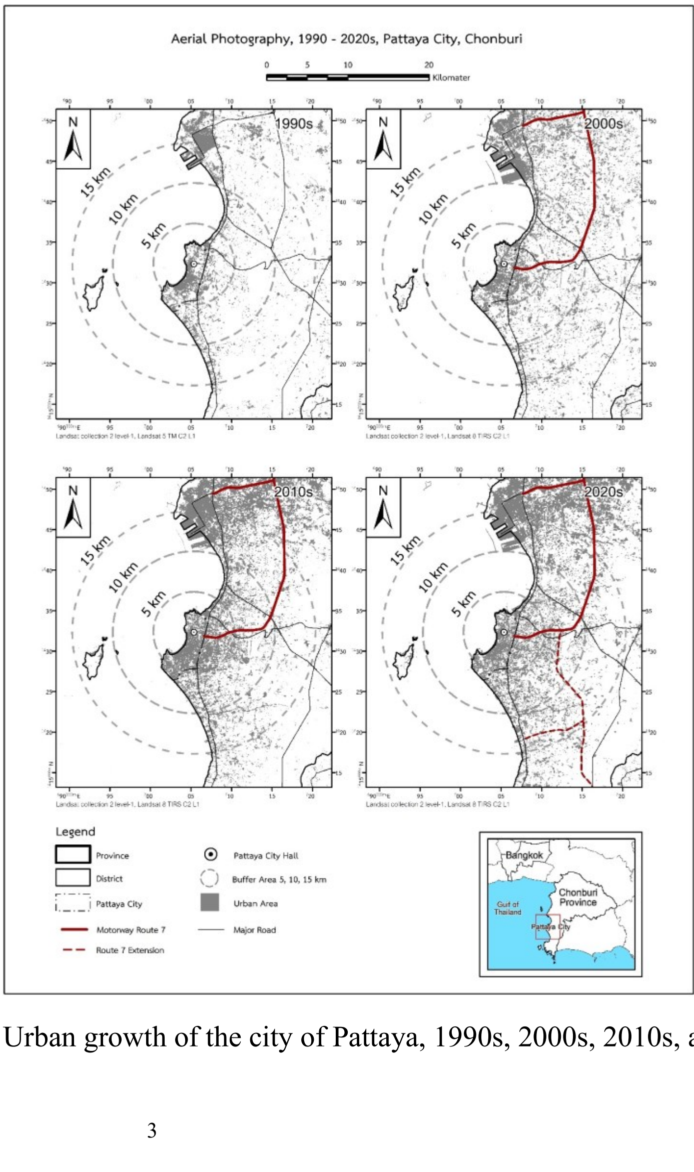

Figure 2. Urban growth of the city of Pattaya, 1990s, 2000s, 2010s, and 2020s.

The transportation infrastructure has played a significant role in shaping the urban development of Pattaya. The central area of the city is characterized by dense urban development along the coast, particularly along the major roads that follow the beachfront (**Figure 2**). In the 1990s, a highway served as the main access route in central Pattaya, where hotels, shopping centers, entertainment venues, and services were concentrated. Moving away from these central roads towards the eastern part of the city, the density of settlement gradually decreases, and there is a shift in land use from mainly commercial to residential. With the opening of motorway Route 7 in the early 2000s, residential areas for the local population and those working in the tourism sector are spread out along the city's outskirts (Hansasooksin and Tontisirin, 2021). Consequently, the growth pattern of Pattaya City also shows signs of sprawl as it expands eastward toward newly established transportation infrastructure.

The urban landscape described above has drawn attention from both researchers and policymakers, particularly regarding the impact of regional development policies such as the EEC on changes in land use. While much research has explored urban growth in general, there is less focus on how specific infrastructure projects influence the spatial patterns of urban expansion. Pattaya is an ideal location for this study due to its rapid urban expansion driven by significant infrastructure development, particularly following the EEC project. This demonstrates how infrastructure investments shape urban growth in coastal regions. The city's diverse land use patterns provide a rich context for analyzing the impacts of infrastructure on urbanization. The growth patterns observed in Pattaya City can offer insights into general trends in land development in coastal cities.

This paper aims to gain insight into Thai coastal development, with a focus on Pattaya, in order to analyze the urban expansion pattern and predict the future growth of Pattaya City. It contributes to a better understanding of the unique challenges and opportunities presented by coastal urban growth.

2. Review of literature

The literature review can be broadly divided into two parts: existing studies on coastal growth and methods for studying land use change. The first part describes research that monitors the urban expansion of coastal areas, while the second part explains the technical methods used to examine land use changes.

2.1. Coastal growth

Coastal regions are essential environments shaped by geographical, socioeconomic, and land use factors. Coastal cities, which are home to approximately 70% of the global population, are experiencing rapid growth and extensive development due to high population density and commercial activities (Huang, 2016). Lagarias et al. (2023) state that coastal regions now face significant conflicts between development and urban expansion. The landscape in these areas is being heavily transformed, with mass tourism development making natural and man-made ecosystems more vulnerable to disasters. Therefore, studying the growth of coastal urban areas is of great interest. This research focuses on the spatial growth patterns and the factors driving expansion in coastal cities.

Yılmaz and Terzi (2021) also examine coastal growth in Mediterranean cities influenced by coastal use and urban planning policies, typically expanding along motorways, coastlines, and low-density sprawl areas. They point out that coastal cities are vital economic hubs owing to their high population density and commercial activities. The cities face unique growth pressures driven by economic, social, and cultural factors, often resulting in linear expansion along coastlines. Such expansion triggers diverse land use changes, including edge-expansion, infilling, and leapfrogging, altering the city's spatial structure and geographical thresholds. Edge-expansion is the continuation of existing growth within spatio-temporal limits (Bhatta, 2010); infill development is defined as growth into the gaps that remain within the urban area; and leapfrog development refers to construction done without continuity (Bhatta, 2010; Harvey and Clark, 1965; Wilson et al., 2003). They found a shift in growth dynamics from coastal areas to inland regions along roads as coastal linear expansion saturates. Some cities at higher socioeconomic levels, like Izmir, Kocaeli, and Antalya, show stabilized effects and expand inland over time, driven by geographical location and historical processes. Contrarily, some cities, like Çanakkale, Sinop, Tekirdağ, and Giresun, exhibit unique growth patterns due to specific geographical characteristics.

Similarly, Zhang et al. (2019) point out that the expansion of construction land in Ningbo, China, is driven by marketization, globalization, and decentralization. Marketization increases demand for construction land, driven by private enterprise growth and population influxes, while globalization intensifies competition for foreign investment, leading to the establishment of development zones and further expansion of construction land. Decentralization empowers local governments to lease land for industrial, residential, and commercial purposes, contributing to urban expansion and economic growth. Such findings underscore the complex interplay between economic, social, and geographical factors influencing urban spatial growth patterns in coastal cities globally.

However, it seems that coastal growth is generally found in the form of urban expansion led by infrastructure development. Steven (2020) defined such growth as an 'ocean sprawl,' a proliferation of infrastructure expanding along coastlines, near-shore waters, and offshore areas. Though infrastructure offers economic, social, and ecological benefits, it displaces natural habitats and alters environmental conditions, particularly affecting downstream coastal ecosystems. Garcia-López (2012) also underlines infrastructure as a major factor encouraging sprawling expansion. He examines the influence of transportation enhancements on population distribution in metropolitan Barcelona (1991–2006). Using detailed census tract data and considering various city areas and transportation infrastructure types, the research employs instrumental variable techniques to reveal transportation's impact on suburbanization. Results indicate that highway and railroad improvements encourage suburban population growth, while transit systems affect the distribution of the central business district (CBD).

The research conducted by Tian and Chen (2022) identifies three primary categories of suburban development scenarios: economic development, population settlement, and suburban sprawl. Economic development orientation involves the concentration of industries in suburban areas, while population settlement orientation focuses on urbanization and migration-induced population growth in suburbs. Suburban sprawl, on the other hand, encompasses areas experiencing an increase in construction land without significant economic or population concentration (Tian and Chen, 2022). The study reveals the ecological landscape impacts of suburban expansion and sprawl with distinct characteristics and impacts on ecological landscapes.

2.2. Land use change model

There are three main types of land use change models, according to Osman et al. (2018). The first type is statistical models, which use mathematical equations to show how key variables affect changes in land use. The second type is Cellular Automata (CA) and Markov Chain models, which are spatially explicit. The third type is agent-based models, which consider interactions between agents and their environment. A systematic review of these models shows that the first two types are commonly used to analyze and predict future land uses (Gaur and Singh, 2023).

Since their increased use, spatially explicit models of urban growth and sprawl, like CA-Markov, have become increasingly popular. These models usually employ remote sensing and Geographic Information Systems (GIS) techniques to analyze land use changes. Most previous studies focus on understanding the spatiotemporal patterns of land use changes within their respective study areas.

CA-Markov model of land use change combines spatial and temporal changes in land use over time. A CA-Markov model integrates the effects of spatial neighbors found in a Cellular Automata model with the temporal transitioning characteristic of a Markov model. The CA-Markov model is based on von Neumann's concept of spatial structure, so spatial dimensions are depicted through a two-dimensional grid of cells. The attributes of these cells can vary in each iteration based on specific transition rules set within the model (White and Engelen, 1993). Thus, a CA-Markov model is capable of reflecting changes across both spatial and temporal dimensions.

In a CA model process, the attributes may change based on the neighborhood effects (Batty, 1997). The status of a cell depends on the status of its adjacent neighbor cells, which could be defined as the Moore neighborhood or the von Neumann neighborhood (Tontisirin and Anantsuksomsri, 2021). In a Markov process, a cell's characteristics in one period are determined by its characteristics in the previous period, and the temporal change is defined by a transition probability matrix. For a technical description of the CA-Markov model, see the work of Sang et al. (2011).

Since the 1960s, the CA-Markov model has become a popular tool in land use studies due to its simplicity and lack of theoretical assumptions (Batty, 2007). One practical advantage of CA-Markov is that it requires only two time periods, making it ideal for areas where land use data is not frequently available. However, the CA-Markov model assumes that future land use changes will follow historical patterns. This assumption may not hold if new policies or external factors significantly alter land use dynamics. Therefore, the model's predictions may be limited in scenarios where there are unexpected changes in economic, social, or environmental conditions. As such, it is suitable for short-term land use predictions that are likely to follow historical trends.

There are many versatile applications of CA-Markov models. Some examples of the topics covered in the existing literature include monitoring urban growth, environmental monitoring, and urban heat islands. The CA-Markov models have been used to monitor urban expansion in various areas such as Bangkok and its surroundings (Losiri et al., 2016) and Hua Hin (Kityuttachai et al., 2013). Tontisirin and Anantsuksomsri (2021) also examined changes in land use in the eastern region of Thailand at the regional level. Thus, the method of analyzing land use changes in this study is Cellular Automata-Markov (CA-Markov).

3. The city of Pattaya

Pattaya, situated in Chonburi province, is located about 180 km from Bangkok by road. Once a peaceful seaside village of fishermen, Pattaya City has become a bustling tourist destination since the 1950s as a vacation beach town for the American military, who came for the international friendship between Thailand and the United States. Since then, the city has been established as the center of tourism-based activities, with a specialization in entertainment, medical services and meetings, incentives, conferences, and exhibitions (MICE) businesses. Tourism has been a significant driver of Pattaya's growth, increasing income, employment opportunities, and urban development through place-making (Hansasooksin and Tontisirin, 2021; Mansury et al., 2021). Socially, tourism has contributed to the modernization and cultural diversification of Pattaya. The influx of international visitors has led to a blending of cultures and has spurred the development of amenities and services that cater to a global clientele. Pattaya has become a popular area for real estate investments, particularly in high-rise condominiums, for both Thais and foreigners (Pongpisitkul and Khumpaisal, 2021). This is because the nature of the city potentially serves various hospitality venues, such as hotels, resorts, bungalows, and entertainment and recreational places, such as restaurants and bars.

The rapid urbanized growth based on tourism economy proved too complex for a small local government unit to handle. In response, in 1978, Pattaya City's governance was established as a special administrative entity under the Pattaya City Administration Act. Functioning akin to a city municipality, Pattaya is overseen by a city manager vested with the authority to organize, plan, and manage city resources. Consequently, it became the second special form of local government organization in Thailand, following Bangkok. What sets Pattaya City apart from other local government organizations is its special powers to regulate and promote tourism activities, a jurisdiction not granted to the Provincial Administrative Organization or the Bangkok Metropolitan Administration.

Figure 3 delineates the boundary of Pattaya City and eight current municipalities within a 15-kilometer radius around it, illustrating Pattaya's role as the primary center of urban development. To the north of Pattaya, four municipalities—Laem Chabang, Chao Phraya Surasak, Bang Lamung, and Takhian Tia—are home to deep-sea ports and industrial estates. Conversely, the eastern area of Pattaya, consisting of Nong Prue, Nong Chak, and Huai Yai, remains predominantly agricultural land with resident populations. Na Chom Thian, located to the south, has transitioned into a low-density settlement serving as accommodations and facilities for tourists.

Longjit and Pearce (2013) examined destination management practices in Pattaya, revealing the involvement of multiple agencies in managing the city's tourism sector. Consequently, the challenges of managing urban areas in Pattaya become more pronounced as urban growth extends beyond the boundaries of municipalities, as depicted in **Figure 3**. Not all areas fall under municipal coverage, and infrastructure developments often struggle to keep pace with population growth. Despite these challenges, the municipalities have operated independently, without the presence of a formal regional governing body.

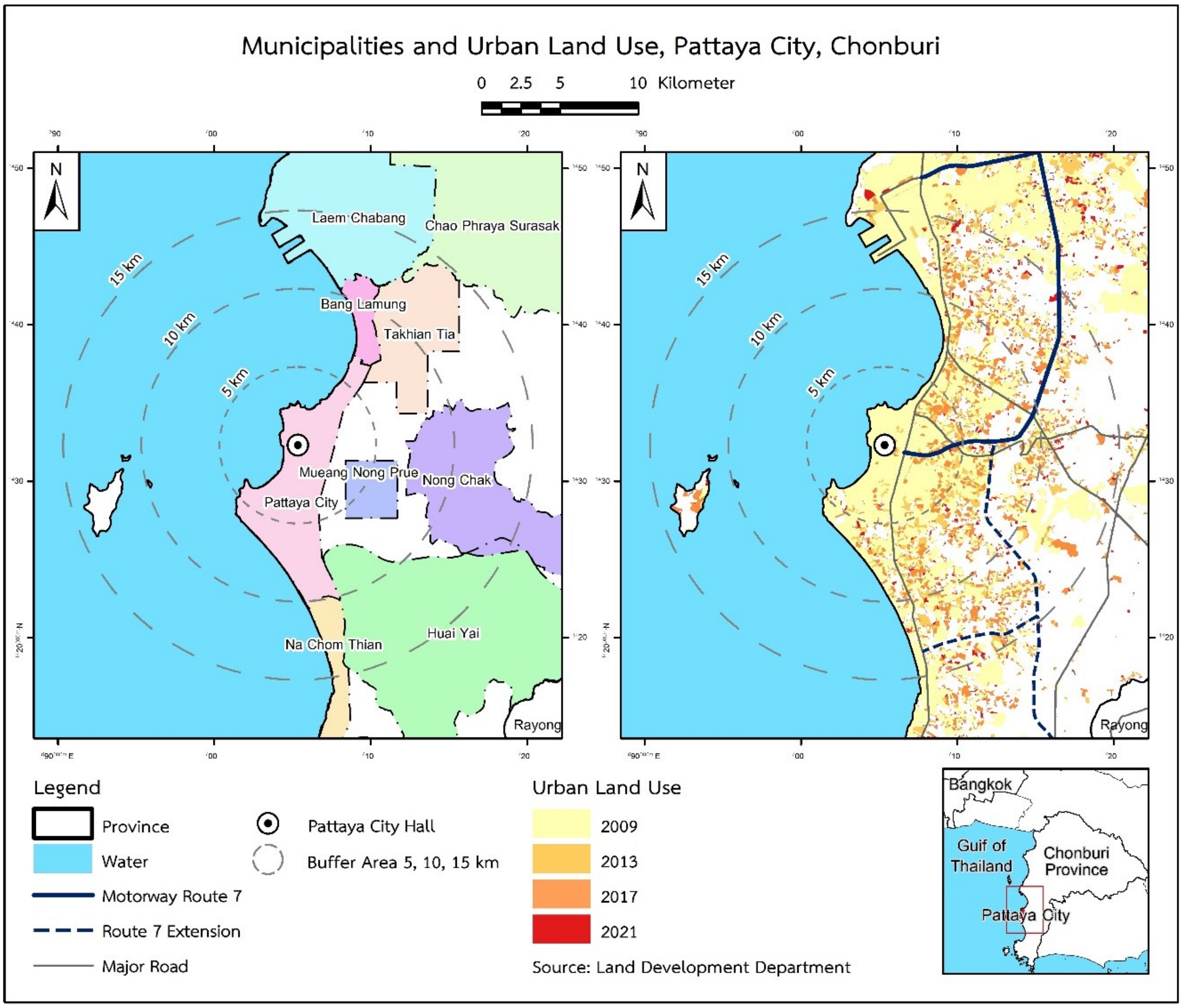

Figure 3. Municipalities and urban land use, Pattaya city.

In 2019, the EEC project was enacted through the Eastern Special Development Zone Act. This regional development policy aims to transform the region, comprising of Chachoengsao, Rayong, and Chonburi province, into an area characterized by systematic economic, social, and environmental development, as well as establishing efficient infrastructure and public utilities. Moreover, the region is positioned to gear Thailand's economy into a value-based, innovation-driven industry, positioning the region as a leading economic zone in ASEAN. The management of this development plan falls under the purview of not only the Board of the EEC Policy Committee, headed by the Prime Minister and consisting of 14 relevant ministers, but also the Eastern Economic Corridor Office of Thailand.

The EEC region has a comprehensive land use plan developed through collaboration between the Office of EEC Policy and the Department of Town and Country Planning (DTP). The objective is to promote and develop the economy, society, and public utilities; while ensuring transportation, resource management, nature, and environmental considerations are consistent and suitable for the area's potential, supporting future city and community development. The area is delineated as follows: urban area 13.23%, industry 5.12%, agriculture 58.51%, conservation of natural resources and environment 20.25%, and other areas 2.89%.

With the EEC project, this regional corridor is supported by three interconnected transportation channels: land, air, and sea. These channels encompass six infrastructure projects linking Pattaya to neighboring cities, including U-Tapao airport, the Bangkok-Rayong High-Speed Rail, a double-track railway, the Pattaya to U-Tapao motorway, the Map Ta Put deep seaport, and the Laem Chabang commercial port (Hiratsuka, 2018) as shown in **Figure 1**. Those aforementioned infrastructural projects highlight Pattaya City as one of the economic hubs attracting new settlements and investments.

Motorway, particularly Route 7, is one major road connecting Pattaya city with Bangkok and other cities in the EEC region. This strategic route serves the logistics businesses of many industrial estates and facilitates the flow of tourists visiting Thailand's east coast. Originally constructed in 1998 as a limited-access expressway, Route 7 stretched 100 km from Bangkok to Chonburi. The second phase, extending 20 km towards Pattaya, was opened in 2010. In 2020, an expansion project was undertaken, extending the route from Pattaya to Map Ta Put, Rayong, covering an additional 31 km. The motorway is considered a factor that generates city growth and forms the basis for the analysis in this paper. It aims to examine the extent to which infrastructure-led development contributes to the coastal growth of the City of Pattaya.

4. Methodology

This paper employs the CA-Markov modeling procedure for analyzing and predicting land use changes. Land use in the Geographic Information Systems (GIS), publicly available upon request from the Department of Land, Ministry of Agriculture and Cooperatives (https://dinonline.ldd.go.th/), is selected.

4.1. Modeling procedure

Figure 4 presents the CA-Markov modeling procedure. The model initialization input data are GIS land use data for 2013 and 2017, denoted as LU 2013 and LU 2017, respectively. These datasets have similar land use classifications, and the time interval between them is reasonable because the second phase of limited access motorway Route 7 (Chonburi-Pattaya) opened in 2010, so the interval between 2013 and 2017 reflects the effect of the motorway operation on land use. The land use analysis covers Chonburi Province, reflecting that land use regulation is typically governed at the provincial level. The software used in this process is TerrSet Geospatial Monitoring and Modeling Software.

The changes in land use over time are studied using a Markovian process, which examines the transition between different land use classifications from one time period to another. Suppose P_{ij} represents the probability of transitioning from one land use status i to another status j. This probability has certain properties:

$$\sum_{j=1} P_{ij} = 1 \quad (1)$$

$$0 \leq P_{ij} \leq 1 \quad (2)$$

A Markov model has the following properties:

$$P_{(n)} = P_{(n-1)} P_{ij} = P_{(0)} P_{ij}^{n} \quad (3)$$

where $P_{(n)}$ denotes a probability in period n, and $P_{(0)}$ denotes a probability from the land use data. With these properties of the probability transition matrix, a Markov model can be used to predict future land uses from the current ones (Hyandye and Martz, 2017). In other words, future land use patterns are based on change patterns in the past.

Based on changes in land use in 2013 and 2107, the initial model is built and validated by comparing the predicted land use in 2021 (Predicted LU 2021) with actual land use (LU 2021). The statistical test to validate the model is the cross-tabulation analysis. A Chi-square test and Cramer's V are used to assess the interdependence between observed and predicted land uses at the grid level. The value of Cramer's V is acceptable when it is above 0.5. Additionally, the Overall Kappa is utilized for proportional cross-tabulation to validate model predictions of land use changes (Hamad et al., 2018; Mondul et al., 2016; Pontius and Schneider, 2001). The Overall Kappa is acceptable when it is above 0.8.

The outputs are a transition matrix and predicted land uses in the short term. The validated model is used to forecast future land use in the short-term and medium-term. The temporal interval of data is four years. Thus, the four-year interval is used to predict future land use. The predicted land uses are short-term, namely 2025, 2029, and 2033.

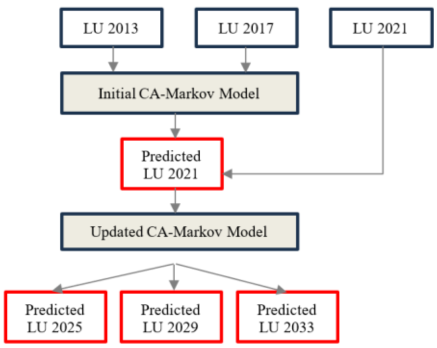

Figure 4. Overview of CA-Markov procedure.

4.2. Data

The land use data are available at the provincial level in multiple years, namely 2009, 2013, 2017, and 2021. There are five primary land use categories: agriculture, forest, miscellaneous, urban and built-up, and water bodies. Urban and built-up encompasses residential, commercial, industrial lands, transportation, communications, utilities, golf courses, and governmental and institutional establishments. Miscellaneous are undeveloped lands, including marsh, swamp, rangeland, scrub, and garbage dump. **Table 1** shows the detailed land use categories within each classification.

Table 1. Land use classification.

Class	Land use	Land Use Category
1	Agricultural land	Paddy field Field crop Perennial Horticulture Orchard Swidden cultivation Pasture and farmhouse Aquatic plant Aquacultural land Integrated farm
2	Forest land	Evergreen forest Deciduous forest Mangrove forest Swamp forest Forest plantation Agro-forestry Beach forest
3	Miscellaneous land	Rangeland and scrub Marsh and swamp Mine and pit Other miscellaneous land Salt flat Beach Garbage dump
4	Urban and Built-up land	Urban and commercial area Residential area Governmental and institutional land Transportation, communication, and utilities Industrial land Other built-up land Golf course
5	Water body	Natural water body Artificial water body

Source: Author's modification from the department of land, ministry of agriculture and cooperatives.

5. Results and discussion

Figure 5 shows land use data for 2013 and 2017 as inputs to the CA-Markov model. **Table 2** displays the transition matrix of land use in Chonburi Province between 2013 and 2017. The diagonal cells in the table show the probability of land use remaining the same in 2013 and 2017. For instance, there is a 90.22% chance that agricultural land will remain agricultural land in 2017. Among the five land use categories, forest land is likely to stay the same, while miscellaneous land is the least likely to remain the same, with probabilities of 0.9725 and 0.687, respectively.

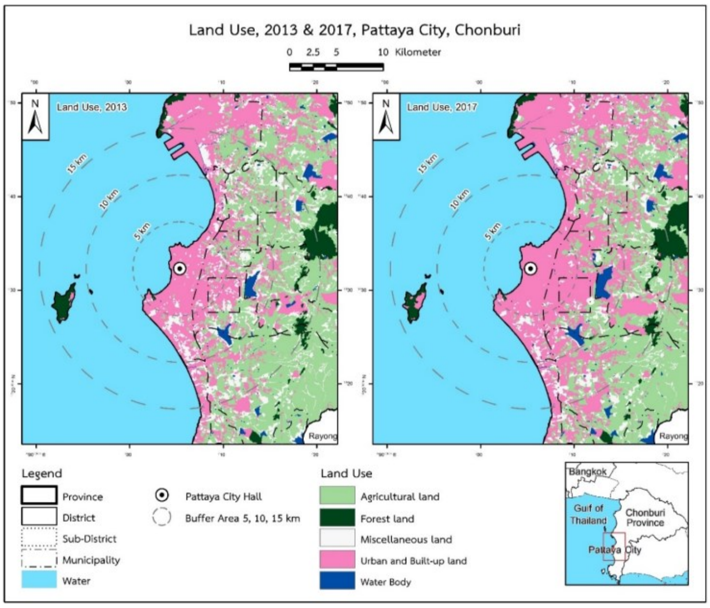

Figure 5. Land use, Pattaya city, 2013 and 2017.

Table 2. Probability transition matrix of land use change, 2013 and 2017.

Probabilities of being a land use class		2017				
		Agricultural land	Forest land	Miscellaneous land	Urban and Built-up land	Water Body
2013	Agricultural land	0.9022	0.0046	0.0276	0.0539	0.0116
	Forest land	0.0139	0.9725	0.0031	0.0093	0.0012
	Miscellaneous land	0.1022	0.0227	0.687	0.1651	0.023
	Urban and Built-up land	0.0473	0.0034	0.0232	0.9221	0.0041
	Water Body	0.0547	0.0059	0.0208	0.037	0.8816

Cramer's V: 0.8956; Overall Kappa: 0.9528.

The results also indicate that numerous miscellaneous lands were likely to be converted into urban or agricultural lands, with probabilities of 0.1651 and 0.1022, respectively. The findings further reveal that agricultural land use is more likely to be converted to urban land use, with a probability of 0.0539. These results imply that urban expansion results in the expense of decreased agricultural and miscellaneous lands. **Figure 6** illustrates the actual land use distribution and the predicted land uses for 2021, showing a similar urban land use pattern between the actual and predicted land use.

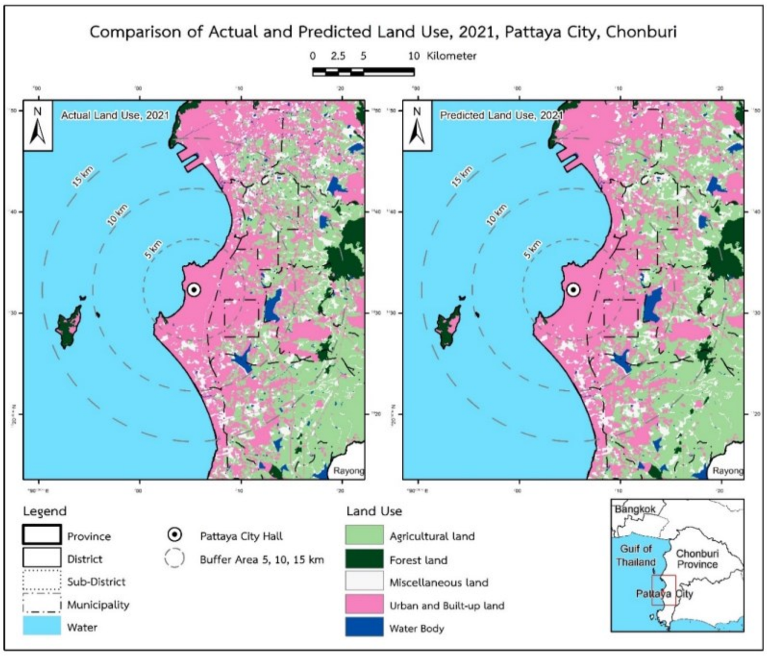

Figure 6. Comparison of actual (left) and predicted (right) land use.

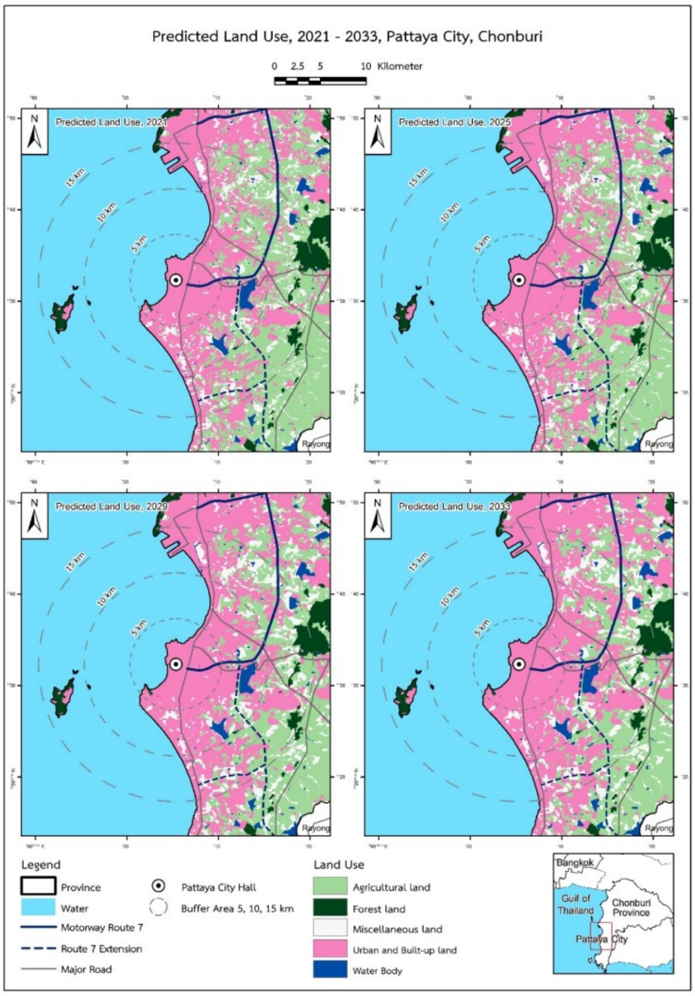

Figure 7. Predicted land use, 2021, 2025, 2029, and 2033.

The maps of predicted land use for 2021, 2025, 2029, and 2033 are shown in **Figure 7**. The maps illustrate both urban infill developments and sprawl patterns in Pattaya City. The urban growth pattern is expected to expand toward the motorway Route 7.

In the model, Cramer's V is 0.8956 with a Chi-square of 55047712 (df = 25, P-Level = 0.0000). Overall Kappa is 0.9528. The tests indicate the reliability of the CA-Markov model.

To demonstrate the changes in urban land use around Pattaya City, we have analyzed three radii from the city center, which are 5, 10, and 15 km away. **Table 3** displays the changes in urban land use within these radii. Overall, urban areas around the city have increased from 135.54 sq.km. in 2013, accounting for 39% of the total land area within the radii, to 204.70 sq.km. or 59% of the total land area in 2033. Urban areas are expected to growth at a rate of 2.55 percent annually. Among these radii, the 10-to-15-kilometer ring has witnessed the most significant expansion of urban land; urban land has increased from 49.24 sq.km. in 2013 to 84.56 sq.km. in 2033, accounting for 71.73 percent growth or 3.59 percent annual growth. These results highlight the sprawling urban expansion of Pattaya City.

Table 3. Urban land use changes of Pattaya city.

Radius from City Center	Total area (sq.km.)	2013		2017		2021		2025P		2029P		2033P		Avg. Annual Growth (%)
		sq.km.	%	sq.km.	%	sq.km.	%	sq.km.	%	sq.km.	%	sq.km.	%	
5 km	47.13	40.00	85%	44.76	95%	44.22	94%	45.20	96%	45.67	97%	45.82	97%	0.73%
5–10 km	108.45	46.30	43%	63.95	59%	62.57	58%	66.81	62%	72.24	67%	74.32	69%	3.03%
10–15 km	192.86	49.24	26%	69.75	36%	71.16	37%	74.55	39%	80.74	42%	84.56	44%	3.59%
Grand Total	348.44	135.54	39%	178.46	51%	177.95	51%	186.55	54%	198.65	57%	204.70	59%	2.55%

Note: P denoted predicted values. Source: Author's calculations from land use data of the department of land.

On the other hand, the area within a 5-kilometer radius, which is the most urbanized among the three, has experienced the smallest growth, with around 0.73 percent of annual growth. It suggests that infill urban development has taken place within the city center but at a much lower rate than in the outer areas of the city. Within a 5–10-kilometer radius, urban lands are expected to grow from 46.30 sq.km. in 2013 to 74.32 sq.km. in 2033, or around 3.03 percent annual growth.

6. Discussions

Although Pattaya was originally a coastal tourism-based city, its major growth has been driven by infrastructure and guided by policy. Based on patterns of land use changes between 2013 and 2017, the expansion of urban areas is expected to grow toward inland transportation infrastructure, especially along local roads that follow the beachfront. The EEC development plan also positions the city as an economic hub and integrates it into a transportation network linking the east coastal region, known as the EEC, with Bangkok. In particular, the motorway serves as a crucial route for both travel and logistics, significantly enhancing accessibility to Pattaya's hinterland and stimulating land development.

To monitor and manage the growth of the city, planning in terms of comprehensive plans or master guidelines for land utilization is considered less efficient. Such future land use plans often struggle to cope with urban sprawl, a well-accepted phenomenon following urban expansion. Sprawl makes the city fragmented and less sustainable, as expansion exceeds the city's capacity, resulting in a significant cost of urban investment. Commuting under such circumstances requires both time and energy consumption.

Growth management strategies, particularly those centered on incentive measures rather than prohibitive approaches, have demonstrated greater efficacy compared to traditional land use planning methodologies. In the context of Pattaya City, the implementation of incentive-based measures is paramount to fostering sustainable urban development. Firstly, the designation of Pattaya as investment zones should be prioritized, offering attractive incentives such as Floor Area Ratio (FAR) bonuses or allowances for high-density construction. By incentivizing compact and mixed land use patterns, this approach promotes efficient land utilization and urban consolidation.

Secondly, financial incentives, such as reductions in land and building taxes, should be tailored to zones earmarked for intensive investment. By alleviating financial burdens on developers and investors within these zones, this strategy encourages the concentration of economic activities and facilitates the realization of urban development objectives.

Moreover, effective regional management to address issues of suburbanization and land use spillover beyond administrative municipalities is imperative. The Eastern Economic Corridor Office of Thailand, given its overarching authority and resources, is ideally positioned to undertake this responsibility. Given the seamless nature of urban boundaries, comprehensive regional management becomes essential for addressing multifaceted challenges such as resource management, population dynamics, and transportation infrastructure planning. Through coordinated efforts at the regional level, these challenges can be effectively addressed, fostering sustainable urban growth and development in Pattaya City and its surrounding areas.

7. Conclusion

Urban expansion of coastal cities exhibits a unique pattern, especially when new transportation infrastructure like a highway is developed. This study examines the growth of urban areas of the City of Pattaya, a well-known tourist spot in Thailand, using the CA-Markov model of land use change between 2013 and 2017 as a basis. This temporal framework allows for the effect of the new limited-access motorway that started operating in 2010. There are five land use categories: agriculture, forest, miscellaneous, urban and built-up, and water bodies. The model also predicts short-term land use changes in 2025, 2029, and 2033.

The results show that urban areas in Chonburi Province were likely to be converted from miscellaneous and agricultural lands. Particularly, Pattaya City is expected to experience sprawling development more than infill development in the city center. The annual growth rate of urban land use change in the 5-kilometer radius of the city center is predicted to be 0.73 percent, while the growth rate of 5-10- and 10-15-kilometer radius are 3.03 and 3.59 percent, respectively. The predicted urban growth suggests that urban expansion is beyond one administrative boundary, and urban management and land use planning can be critical issues.

The analysis inherits several limitations. First, the CA-Markov model assumes that future land use changes will follow historical patterns, but this may not hold if new policies or external factors significantly alter land use dynamics. This limitation impacts the model's predictions in scenarios involving unexpected changes in economic, social, or environmental conditions. Secondly, the analysis did not take into account the change in land prices that may come into play with urban growth and development. Thirdly, input land use data are pre-classified secondary data from the Department of Land. It is possible that there are some differences from the primary ground-truth data. In addition, the data does not consider the density in urban areas, or the detailed classification of urban land uses, such as residential or commercial uses. Urban growth is monitored at the regional level instead of focusing solely on the city center, which may overlook important local variations in urban development. This regional focus might miss critical insights into how different areas within the city or smaller neighborhoods contribute to overall urban sprawl or infill development. Future studies could emphasize urban land use in the city center in much more detailed classifications.

Author contributions: Conceptualization, NT, SA and STH; methodology, NT; software, NT; validation, NT and SA; formal analysis, NT; investigation, NT and STH; resources, NT and SA; data curation, NT and SA; writing—original draft preparation, NT and STH; writing—review and editing, NT, SA and STH; visualization, NT; supervision, NT; project administration, NT; funding acquisition, NT. All authors have read and agreed to the published version of the manuscript.

Acknowledgments: The authors would like to acknowledge the land use data from the Department of Land. The authors wish to express gratitude to the research assistants of this project, namely, Korrakot Positlimpakul and Areen Phuntarakit.

Funding: This work was supported by the Thailand Science Research and Innovation Fundamental Fund fiscal year 2023 (contract number TUFF 03/2566).

Conflict of interest: The authors declare no conflict of interest.

References

Arsanjani, J. J., Kainz, W., & Mousivand, A. J. (2011). Tracking dynamic land-use change using spatially explicit Markov Chain based on cellular automata: the case of Tehran. International Journal of Image and Data Fusion, 2(4), 329–345. https://doi.org/10.1080/19479832.2011.605397

Batty, M. (1997). Cellular Automata and Urban Form: A Primer. Journal of the American Planning Association, 63(2), 266–274. https://doi.org/10.1080/01944369708975918

Bhatta, B. (2010). Analysis of Urban Growth and Sprawl from Remote Sensing Data. In: Advances in Geographic Information Science. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-05299-6

CLARK LABS. (n.d.). TerrSet Geospatial Monitoring and Modeling Software. Available online: https://clarklabs.org/terrset/ (accessed on 20 February 2024).

Dadashpoor, H., & Hasankhani, Z. (2022). Exploring patterns and consequences of land consumption in a coastal city-region. Ecological Processes, 11(1). https://doi.org/10.1186/s13717-022-00391-z

Garcia-López, M.-À. (2012). Urban spatial structure, suburbanization and transportation in Barcelona. Journal of Urban Economics, 72(2–3), 176–190. https://doi.org/10.1016/j.jue.2012.05.003

Gaur, S., & Singh, R. (2023). A Comprehensive Review on Land Use/Land Cover (LULC) Change Modeling for Urban Development: Current Status and Future Prospects. Sustainability, 15(2), 903. https://doi.org/10.3390/su15020903

Gervasi, O., Murgante, B., Rocha, A. M. A. C., et al. (2023). Lecture Notes in Computer Science. In: Computational Science and Its Applications – ICCSA 2023 Workshops. Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-37123-3

Hamad, R., Balzter, H., & Kolo, K. (2018). Predicting Land Use/Land Cover Changes Using a CA-Markov Model under Two Different Scenarios. Sustainability, 10(10), 3421. https://doi.org/10.3390/su10103421

Han, Y., Zhu, J., Wei, D., et al. (2022). Spatial-Temporal Effect of Sea–Land Gradient on Land Use Change in Coastal Zone: A Case Study of Dalian City. Land, 11(8), 1302. https://doi.org/10.3390/land11081302

Hansasooksin, S. T., & Tontisirin, N. (2018). Applying the Analytical Hierarchy Process (AHP) Approach to Assess an Area-Based Innovation System in Thailand. Nakhara : Journal of Environmental Design and Planning, 15, 63–76. https://doi.org/10.54028/nj2018156376

Hansasooksin, S. T., & Tontisirin, N. (2021). Placemaking as an urban development strategy for making the Pattaya Innovation District. Regional Science Policy & Practice, 13(6), 1930–1951. https://doi.org/10.1111/rsp3.12400

Harvey, R. O., & Clark, W. A. V. (1965). The Nature and Economics of Urban Sprawl. Land Economics, 41(1), 1. https://doi.org/10.2307/3144884

Huang, Y. (2016). Understanding China's Belt & Road Initiative: Motivation, framework and assessment. China Economic Review, 40, 314–321. https://doi.org/10.1016/j.chieco.2016.07.007

Hyandye, C., & Martz, L. W. (2016). A Markovian and cellular automata land-use change predictive model of the Usangu Catchment. International Journal of Remote Sensing, 38(1), 64–81. https://doi.org/10.1080/01431161.2016.1259675

Jabareen, Y. (2006). Sustainable urban form: their typologies, models, and concept. Journal of Planning Education and Research, 26(1), 38-52. https://doi.org/10.1177/0739456X0528511

Jenks, M. (2000). The acceptability of urban intensification. In: Williams, K., Burton. E., & Jenks, M., (editors). Achieving Sustainable Urban Form. E & FN Spon. pp. 242-250.

Lagarias, A., & Stratigea, A. (2023). Coastalization patterns in the Mediterranean: a spatiotemporal analysis of coastal urban sprawl in tourism destination areas. GeoJournal, 88, 2529–2552. https://doi.org/10.1007/s10708-022-10756-8

Longjit, C., & Pearce, D. G. (2013). Managing a mature coastal destination: Pattaya, Thailand. Journal of Destination Marketing & Management, 2(3), 165–175. https://doi.org/10.1016/j.jdmm.2013.05.002

Maneethorn, E., Rugchoochip, K., Sangsunt, Y., et al. (2023). Innovation Application Toward Strategic Development of Pattaya City Administration from Viewpoints of Visitors Visiting Pattaya City, Chonburi Province, Thailand. International Journal of Sustainable Development and Planning, 18(6), 1813–1821. https://doi.org/10.18280/ijsdp.180616

Mansury, Y., Anantsuksomsri, S., & Tontisirin, N. (2021). New landscape of data and sustainable development in Asia. Regional Science Policy & Practice, 13(6), 1724–1728. https://doi.org/10.1111/rsp3.12487

Mathanraj, S., Rusli, N., & Ling, G. H. T. (2021). Applicability of the CA-Markov Model in Land-use/Land cover Change Prediction for Urban Sprawling in Batticaloa Municipal Council, Sri Lanka. IOP Conference Series: Earth and Environmental Science, 620, 012015. https://doi.org/10.1088/1755-1315/620/1/012015

Ministry of Tourism & Sports. (2019). Domestic Tourism Statistics Q1-Q4 (Classify by region and province). Available online: https://www.mots.go.th/news/category/618 (accessed on 10 December 2023).

Mondal, M. S., Sharma, N., Garg, P. K., et al. (2016). Statistical independence test and validation of CA Markov land use land cover (LULC) prediction results. The Egyptian Journal of Remote Sensing and Space Science, 19(2), 259–272. https://doi.org/10.1016/j.ejrs.2016.08.001

Osman, T., Shaw, D., & Kenawy, E. (2018). An integrated land use change model to simulate and predict the future of greater Cairo metropolitan region. Journal of Land Use Science, 13(6), 565–584. https://doi.org/10.1080/1747423x.2019.1581849

Pawlukiewicz, M., Gupta, P. K., & Koelbel, C. (2007). Ten Principles for Coastal Development. ULI-the Urban Land Institute.

Pongpisitkul, P. & Khumpaisal, S. (2021). A Development of Design and Management Guidelines for Condominium Projects to Enhance the Decision Making of the Investors: Case Studies of Pattaya City. Journal of Architectural/Planning Research and Studies (JARS), 18(2), 71–86. https://doi.org/10.56261/jars.v18i2.240132

Pontius, R. G., & Schneider, L. (2001). Land-cover change model validation by an ROC method for the Ipswich watershed, Massachusetts, USA. Agriculture, Ecosystems & Environment, 85, 239-248. https://doi.org/10.1016/S0167-8809(01)00187-6

Robino, D. M. (2019). Global Destination Cities Index. Available online: https://www.mastercard.com/news/media/wexffu4b/gdci-global-report-final-1.pdf (accessed on 10 December 2023).

Sang, L., Zhang, C., Yang, J., et al. (2011). Simulation of land use spatial pattern of towns and villages based on CA–Markov model. Mathematical and Computer Modelling, 54(3–4), 938–943. https://doi.org/10.1016/j.mcm.2010.11.019

Schneider, A., & Woodcock, C. E. (2008). Compact, Dispersed, Fragmented, Extensive? A Comparison of Urban Growth in Twenty-five Global Cities using Remotely Sensed Data, Pattern Metrics and Census Information. Urban Studies, 45(3), 659–692. https://doi.org/10.1177/0042098007087340

Senawongse, P., & Eiumnoh, A. (2019). Decision Support System Module for Sustainable Land Development for Thailand: A Case of Chonburi Province. Journal of Sustainable Development, 12(3), 159. https://doi.org/10.5539/jsd.v12n3p159

Steven, A., Appeaning Addo, K., Llewellyn, G., et al (2020). Coastal Development: Resilience, Restoration and Infrastructure Requirements LEAD AUTHORS About the High-Level Panel for a Sustainable Ocean Economy. Available online: www.oceanpanel.org/blue-papers/coastal-development-resilience-restoration-and-infrastructure- (accessed on 10 December 2023).

Tian, Y., & Chen, J. (2022). Suburban sprawl measurement and landscape analysis of cropland and ecological land: A case study of Jiangsu Province, China. Growth and Change, 53(3), 1282–1305. Portico. https://doi.org/10.1111/grow.12608

Wang, Y., Hu, Y., Niu, X., et al. (2022). Land Use/Cover Change and Its Driving Mechanism in Thailand from 2000 to 2020. Land, 11(12), 2253. https://doi.org/10.3390/land11122253

Wilson, E., Hurd, J., Civco, D., et al. (2003). Development of a geospatial model to quantify, describe and map urban growth. Remote Sensing of Environment, 86(3), 275-285. https://doi.org/10.1016/S0034-4257(03)00074-9

Yi, L., Ma, S., Tao, S., et al. (2022). Coastal landscape pattern optimization based on the spatial distribution heterogeneity of ecological risk. Frontiers in Marine Science, 9. https://doi.org/10.3389/fmars.2022.1003313

Yılmaz, M., & Terzi, F. (2021). Measuring the patterns of urban spatial growth of coastal cities in developing countries by geospatial metrics. Land Use Policy, 107, 105487. https://doi.org/10.1016/j.landusepol.2021.105487

Zhang, C., Zhong, S., Wang, X., et al. (2019). Land Use Change in Coastal Cities during the Rapid Urbanization Period from 1990 to 2016: A Case Study in Ningbo City, China. Sustainability, 11(7), 2122. https://doi.org/10.3390/su11072122