SMART CITY TRANSFORMATION: A LESSON LEARNT FROM A DEVELOPING ECONOMY

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Abstract

The transformation from a rural to an urban economy has resulted in modifications to population structure, manufacturing processes, and the social and political environment (Ritchie & Roser, 2019). To address urbanisation-related issues, the push toward smart cities has been accelerated (Adiyarta et al., 2020). To turn Pathum Thani, Thailand, into a smart city promptly, a number of problems must be resolved. This research aims to assess the strengths and shortcomings of Pathum Thani's efforts to become a smart city and to rate the importance of each application domain for smart cities. A representative sample of Pathum Thani locals was examined. For data analysis, the 5-point Likert scale and the priority needs index (PNI) were implemented. The findings show that Pathum Thani's potential to become a smart city is highest in the field of smart energy and weakest in all other areas. When ranking the significance of the seven application domains, it was crucial to build smart governance first. The findings imply that government agencies should set guidelines for urgent development projects and provide a transparent and sufficient digital infrastructure to facilitate the expansion of business activities in the city.

Keywords: ICT, Internet of Things, Smart City, Urbanisation

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1. INTRODUCTION

The population is projected to increase more in urban regions than in rural ones in the foreseeable future. In 2021, 4.46 billion people resided in metropolitan regions, compared to 3.42 billion in rural areas. The urban population of the world has increased fast, from 751 million in 1950 to 4.46 billion in 2021, and will reach 6.68 billion by 2050. Therefore, over 2.22 billion more people will reside in urban areas between 2021 and 2050, with 90% of the predicted worldwide urban population expansion occurring in Asia and Africa. Since 1950, the global rural population has risen steadily. It was predicted to peak in 2021, then decline to 3.09 billion people by 2050 (Ritchie & Roser, 2019). There is a significant correlation between the rise in

urban populations and the establishment of new megacities. During the period between 2020 and 2035, Asia-Pacific and Africa will be among the leading areas in terms of population growth and the establishment of new megacities, whereas eastern Europe, Latin America, and the Caribbean will have lower rates of megacity formation. The United Nations Human Settlements Programme (UN-Habitat, 2020) estimated that there would be 1,934 metropolises with more than 300,000 residents in 2020, representing around 60% of the world's urban population. When a region urbanizes, there are modifications to its demographic structure, production processes, social and political environment, and a shift from a rural to an urban economy (Li et al., 2019). Economically, urbanization is driven by an increase in demand caused by the area's population and wealth (Anser et al., 2020). As the city expands, new issues arise, such as traffic congestion, trash management, pollution, and parking allocation, and resources become limited (Camero & Alba, 2019; Khuan-arch & Thinphanga, 2013). This situation demands an appropriate approach. Consequently, several smart city models have been established for the urban development of a country (Amado et al., 2018; Bifulco et al., 2016; Bıyık, 2019).

Recent global trends have seen the rise of smart cities as a solution to a variety of urban complexities (Adiyarta et al., 2020). The term "smart city" is generated from the development and application of mobile computing systems through realistic data management networks across all city components and levels (Gavalas et al., 2017). With the usage of data management networks, such as the Internet of Things (IoT), big data, and cloud computing, cities are focusing more on being smarter. In the smart city, these data management systems improve many operations and organizations, such as traffic control, sustainable resource management, quality of life, and infrastructure (Ismagilova et al., 2019). Several scholars have offered distinct formal definitions of a smart city from diverse angles. According to Harrison et al. (2010), the smart city is the requirement for a connection between physical, social, business, and information and communication technology (ICT) infrastructure in order to enhance the smartness of an urban region. The Telecommunication Standardization Sector of the International Telecommunication Union (2015) describes it as a contemporary city that must apply ICT to enhance the quality of life and urban services for its residents. These two definitions illustrate that a smart city is a smart urban environment equipped with ICT technologies to improve the operations and performance of individuals' day-to-day city life (Silva et al., 2018). Several smart city ideas and themes should leverage data management technology to build a profound link between each component and layer of a city as a result of the development of ICT technologies (Kirimtat et al., 2020). Current literature contains studies on a variety of smart components, including smart people, smart economy, smart governance, smart mobility, smart environment, and smart living. However, many of these concepts are described in a lot of articles, and their components vary based on preferences (Silva et al., 2018).

Thailand likewise placed a high priority on smart city development. The Thai government has made the construction of smart cities a top priority on its national agenda. In 2017, the Smart City Office was established, and the Smart City Development Driving Committee was assigned to work on proposing a draught smart city development strategy and master plan that must be in line with the country's development plan, called Thailand 4.0. The development of Thailand's smart cities has been driven by seven application domains — smart environment, smart mobility, smart living, smart people, smart energy, smart economy, and smart governance (Digital Economy Promotion Agency [DEPA], n.d.-b). Since the smart city idea is a new trend in urban development and Pathum Thani is one of the cities designated as a smart city promotion zone, it is intriguing to examine the components that might propel this city's transformation into a smart city. This research aims to determine Pathum Thani's strengths and weaknesses in becoming a smart city and to rank each component according to the necessities that must be prioritized in order to reach this objective. Two primary quantitative approaches, the 5-point Likert scale and the priority needs index (PNI), were employed for data analysis. The tests were conducted on a sample of Pathum Thani residents. In this study, seven domains (smart environment, smart mobility, smart living, smart people, smart energy, smart economy, and smart governance), identified by the Digital Economy Promotion Agency (DEPA), are used to evaluate the smartness of Pathum Thani. The findings indicate that Pathum Thani's potential to become a smart city is strongest in the area of smart energy, while its weakest points are in the areas of smart environment, smart mobility, smart living, smart people, smart economy, and smart governance. It was important to establish smart governance first, followed by smart economy, smart mobility, smart energy, smart living, smart people, and smart environment, when prioritizing the importance of these seven domains. The research findings may be implemented by policymakers and relevant sectors to facilitate further planning for the development of smart cities across Thailand, adopting these supplementary indicators to fulfil the country's objectives.

To provide an overview of the study, the article is divided into six sections. The introduction comprises Section 1. Section 2 is a review of the literature. Section 3 explains the research methodology. Section 4 presents the findings of the study, while Section 5 is a discussion of the results. The last Section 6 includes the study's findings, limitations, implications, and suggestions for further research.

2. LITERATURE REVIEW

2.1. Definition of a smart city

While the term "smart city" is gaining popularity, the concept is considered to be still a work-in progress (Albino et al., 2015). The concept of a smart city is widely used, but is differently understood and different meanings are given by different researchers. There is no consensus on the concept of a smart city as the same approach is not adopted.

However, it can be said that public sector researchers, and even the general public, agree that the main components of a smart city are information and communication technologies (Adiyarta et al., 2020).

The concept of urban development first appeared in 1997 with the term "virtual city", which arose from urban crises in Western countries. Economic growth has clearly resulted in inequality among people in cities. This includes disparities in access to basic technological services such as phones, computers, and telecommunication services. The virtual city concept was born with the aim of solving this inequality using advances in technology at the time (Benkő et al., 2021). For example, a local telecommunication network could be operated using the Internet connection system to develop a community in the form of a virtual city. Smart cities have been defined in a variety of academic and institutional publications. Washburn et al. (2010) define a smart city as a city that applies smart computing technologies to develop the critical infrastructure of the city and improve the services available to its citizens. DEPA (n.d.-b) defines a smart city as a city that leverages smart and modern technologies and innovations to enhance the efficiency and management of city services and reduce the cost and resource usage of the city and population. It emphasizes good design and the involvement of businesses and citizens in urban development. The Organization for Economic Co-operation and Development (OECD, 2019) states that a smart city is a concept or guideline for each country. Different meanings are given according to the needs of each city on the basis of regional or country differences. International organizations and other relevant organizations have different definitions. It can be said that although a city operates in a way that means it is known as a smart city, the meanings, objectives and algorithms for each smart city are different. That is, smart cities have different goals, outputs and outcomes as well. Chaiyakam and Wongthanavasu (2020) define a smart city as a city that applies technology and digital technology to the basic structure and services of society, to develop a city that is sustainable and suitable for living, to optimize the city's efficiency, to provide convenience, to connect travel, work, and the safety of the city, and to improve the quality of life. Petrova-Antonova and Ilieva (2018) explored the efficiency and sustainability indicators of smart cities and collected 183 research findings. They found that as many as 1,152 smart city indicators have been defined. They classify the characteristics of the development of a smart city into six dimensions: nature, living, mobility, governance, people and economy. They found that most of the indicators, accounting for 34%, related to nature, followed by those for living and mobility, which accounted for 16% each.

From the definitions of a smart city mentioned above, it can be seen that there are various scopes and approaches. There is no single definition that can give a comprehensive meaning for cities around the world. The definition will vary depending on the context of each city in each country. It will depend on the level of the city's development, the technology used, the necessary dimensions of urban development, and the readiness and participation of the people in the city.

2.2. Policy framework for developing smart cities in Thailand

Thailand places a high priority on smart city development. This is evident from the establishment of a framework for developing smart cities from the plan of Level 1, which is the "*National Strategy 2018–2037*", to the transfer of the goals, indicators, and strategic issues to the plans of Levels 2 and 3 in order to provide a unified picture of smart city development. The strategy establishes two ambitious targets for the future: by 2032, Thailand will be the center of smart city development in the Association of Southeast Asian Nations (ASEAN), and by 2036, Thailand will be ranked in the top ten smart cities in the world (Prathombutr, n.d.). The *National Strategy 2018–2037* is a national development plan that has set the direction for smart city development in its Strategy 4, which relates to creating opportunities and social equality and the issue of the centralization of economic, social and technological prosperity. The strategy is to organize a city system that is conducive to creating a high quality and safe life and society that can respond to the aging society and future urbanization trends. The strategy broadly defines the guidelines for the development of smart cities: "Technology development to manage the city and the provision of facilities to be a smart, safe, convenient city for all groups of people and environmentally friendly" (National Strategy Secretariat Office, Office of the National Economic and Social Development Board, n.d., pp. 10–11). The master plan under the *National Strategy 2018–2037* is a crucial part of the transfer of the goals and strategic issues of the national strategy into different levels of plans. It sets out guidelines for the development of smart cities, which aim to develop centres of economic and social prosperity in all regions of the country to spread economic and social prosperity. It aims to develop habitable cities in all regions of the country that have efficient urban management systems and facilities that cater to the needs of all groups of people. Such cities combine good environmental management and resilience, so that they can adapt to changes in the economy, society, environment and technology. The Digital Development Policy for Economy and Society is to be carried out through two types of plans:

1. The national policies and plans on digital development for the economy and society (2018–2037) (*National Strategy 2018–2037*) are the main policies driving Thai society towards a digital economy over the next 20 years and driving the implementation of policies and plans. These visions, goals, and long-term strategies are transformed into a concrete framework of action in the short term.

2. *The 5-Year of Digital Parliament Development Plan (2018–2022)* (Parliament of Thailand, n.d.) sets out guidelines for the development of smart cities in its "Strategy 1: Develop high-performance digital infrastructure to cover the whole country in terms of building a quality society to increase the quality of life, access to health services and access to professional skills and knowledge". The *Digital Economy Promotion Master Plan 2018–2022* (DEPA, n.d.-b) is a framework for promoting and supporting

the development of digital industry and innovation, and promoting the adoption of digital technology for the benefit of the economy, society, culture and national security. It serves as a framework, in conjunction with national policies and plans on digital development for the economy and society. The Digital Economy and Society Development Fund has set the direction for smart city development in its "Strategy 4: Develop infrastructure for digital innovation — Infrastructure and facilities". This includes the legal, regulatory and environmental infrastructure that facilitates innovation and digital technology, the creation of information platforms, and the promotion of cybersecurity.

2.3. Application-domain taxonomies for smart cities

A smart city is formed of many sectors in which the advent of ICTs has induced a radical shift. Giffinger and Gudrun (2010) define the smartness of a smart city with six criteria in which the city should perform well and which may be regarded as typical application domains for smart cities. These six domains are smart economy, smart citizen, smart governance, smart mobility, smart environment, and smart living. Liu and Peng (2014) divide smart city applications into three categories: life enhancement (residence, community, medical services, and education), public administration and service (public security supervision, food safety supervision, smart traffic, and environmental protection), and large-scale resource management (water, electricity, and agriculture). Their strategy is based on their concept of a smart city, which they define as one that enhances the lives of its residents, improves urban administration and industry, and protects the environment. Lombardi et al. (2012) collected 60 indicators from two focus groups. These indicators are grouped into the following five categories: smart governance, smart economy, smart human capital, smart living, and smart environment. Albino et al. (2015) modified the later taxonomy and linked each group to a perspective of urban life: smart economies to industry, smart people to education, smart governance to e-democracy, smart mobility to logistics and infrastructures, smart environments to efficiency and sustainability, and smart living to efficiency and sustainability. Gharaibeh et al. (2017) provide a taxonomy that includes smart lighting, smart traffic management, smart grid, smart emergency, and smart health.

Despite the fact that several authors describe identical application domains, they create subdomains with extremely restricted scopes and lengthy descriptions. This may provide a difficulty for applications. As Thailand has just recently introduced and implemented the smart city concepts, it may not be appropriate to employ subdomain specificity in this study. To evaluate smart city in Thailand, thus, more basic domains and subdomains or indicators are required. Therefore, this study employed the Smart City Office's simple application domains for Thailand's smart city plan, including smart environment, smart mobility, smart living, smart people, smart energy, smart economics, and smart governance (DEPA, n.d.-b). Definitions of each domain are as follows:

Smart environment

Smart environments, such as air quality, green and water spaces, pollution monitoring, trash management, energy efficiency, and monitoring of city trees, have gained popularity with the assistance of researchers and are one of the most important elements of smart cities (An et al., 2019). This indicator emphasizes resource management sustainability. A smart city with a smart environment is a city that prioritizes quality, efficiency, and effectiveness in environmental management, as well as systematic monitoring of the environment and resources, such as water management, climate care, and disaster surveillance, as well as increasing public participation in natural resource conservation (DEPA, n.d.-b).

Smart mobility

Smart mobility or smart transportation focuses on intelligent transportation systems that handle the intensity of vehicle capacity based on urban congestion, which is today one of the most significant problems confronting cities (Adart et al., 2017). Internet of Vehicles (IoV) has evolved as a solution by playing a significant role in intelligent transportation systems to increase traffic safety efficiency (Chen et al., 2015).

Smart living

Smart living (smart building and quality of life) involves smart buildings for education, tourism, healthcare, and public safety, and these characteristics have the potential to enhance the quality of life for residents. Public safety as it relates to the urbanisation of emerging economies is one of the primary problems of smart living (An et al., 2019).

Smart people

Since humans are the primary users of smart devices and services, improving the living environment and enhancing the quality of life are two important objectives of smart cities. Therefore, it is essential to adequately plan and create these services (Yeh, 2017). A smart city with smart people is a city that focuses on educating and empowering its residents to employ technology for economic and societal gains. The city must develop an environment that encourages creativity and informal learning among its residents, as well as promote social cohesion (DEPA, n.d.-b).

Smart energy

A smart city with smart energy is a city that may increase its energy efficiency or employ clean energy (renewable energy) alternatives, such as biomass fuel, electricity from renewable energy, and power from other green energies (DEPA, n.d.-b).

Smart economics

Within the context of the smart city, a smart economy is also associated with smart business and mobile commerce (Johnson et al., 2014). This domain focuses on enhancing the efficiency and manoeuvrability of operation of the company, fostering business partnerships and collaboration, and implementing innovation in economic growth, such as smart agricultural cities and smart tourism cities (DEPA, n.d.-b).

Smart governance

Providing residents with city services, channels, smart mobile services, and network integration is crucial to the success of the government in smart

cities (Cledou et al., 2018). Moreover, smart governments must not only be progressive in their pursuit of technical advancements, but they must also have smart management and regulations that allow citizens to be incorporated into the processes (An et al., 2019).

3. RESEARCH METHODOLOGY

Based on the research objectives, this study is divided into two parts: Part 1 identifies Pathum Thani's strengths and weaknesses in becoming a smart city, and Part 2 ranks each domain of applications by its priority for becoming a smart city. The data was gathered via an online survey from 452 residents of Pathum Thani through non-probability sampling and incidental sampling. In this study, smart environment, smart mobility, smart living, smart people, smart energy, smart economy, and smart governance are application domains of Pathum Thani becoming a smart city based on DEPA guidelines to drive and develop proposals for smart city development plans, including the "*Smart City Plan Assessment Criteria Guide*" and the "*Seven Smart City Indicators*" (DEPA, n.d.-b). For data analysis, the 5-point Likert scale and the PNI served as the two key quantitative methods.

3.1. Part 1: Strengths and weaknesses in becoming a smart city of Pathum Thani

Respondents were asked to rate each subdomain or indicator under each application domain using a 5-point Likert scale. The questions were divided into seven sections according to seven domains (smart environment, smart mobility, smart living, smart people, smart energy, smart economics, and smart governance), with three indicators in each domain, totalling 21 indicators in this study. Each section was divided into two scorings: "current performance" and "expected performance". Respondents needed to rate 1–5 for each indicator based on their perceptions. The meanings of rating intervals are as follows:

- 4.50–5.00 means the "Highest" level of opinion;
- 3.50–4.49 means a "High" level of opinion;
- 2.50–3.49 means a "Moderate" level of opinion;
- 1.50–2.49 means a "Low" level of opinion;
- 1.00–1.49 means the "Lowest" level of opinion.

3.2. Part 2: Priority of components in transforming Pathum Thani into a smart city

The modified priority needs index ($PNI_{modified}$) was used to rank all seven domains. An equation is as follows:

$$PNI_{modified} = (I - D)/D \quad (1)$$

where, $PNI_{modified}$ = priority needs index; I (importance) = Mean ($\bar{x}$) of expected performance; D (degree of success) = Mean ($\bar{x}$) of current performance.

3.3. Alternative method

To investigate things in greater depth, an in-depth interview may be conducted. As a community is comprised of a wide range of demographic characteristics, it may be beneficial to investigate the perspectives of specialists from other disciplines in order to comprehend how to construct a smart city in a specific location. Adopting the ideas of people from diverse backgrounds may result in the most ideal smart city for all local residents.

4. RESEARCH RESULTS

4.1. Part 1: Strengths and weaknesses in becoming a smart city of Pathum Thani

The mean and standard deviation for seven application domains of smart city were calculated for the current performance and the expected performance, and the results are shown in Table 1. When considering the indicators of each domain, the current performance of Pathum Thani becoming a smart city is at a moderate level for all seven domains, with an overall average score of 2.95. Smart energy earns the highest score (3.01), followed by smart environment (2.99), smart people (2.98), smart economy (2.97), smart living (2.96), smart mobility (2.88), while smart governance obtains the lowest score (2.87). In contrast, the overall picture of expected performance is at a high level, with an average score of 3.74. Smart governance earns the highest score (3.95), followed by smart economy (3.84), smart energy (3.77), smart people (3.71), smart living (3.68), smart mobility (3.64), whereas smart environment obtains the lowest score (3.60).

Table 1. Mean and standard deviation for domains and indicators in transforming Pathum Thani to be a smart city (Part 1)

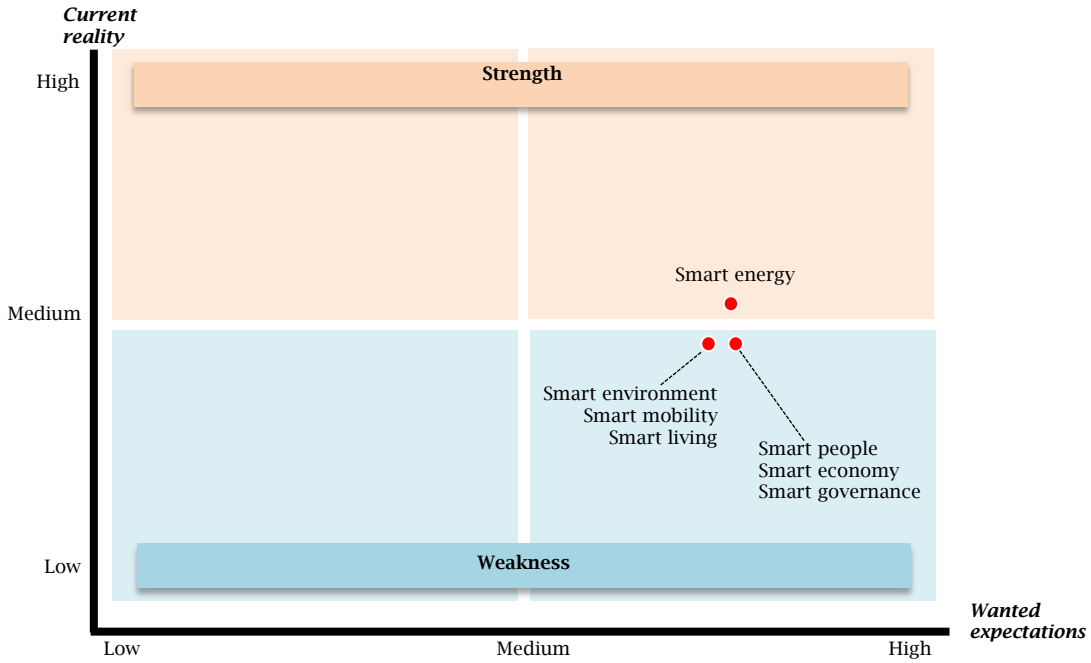
Domains and indicators	*Expected performance*			*Current performance*		
	$\bar{x}$	*S.D.*	*Level*	$\bar{x}$	*S.D.*	*Level*
Smart environment	**3.60**	**1.05**	**high**	**2.99**	**0.78**	**moderate**
Comprehensive community solid waste management	3.48	1.21	moderate	2.81	1.15	moderate
Adequate clean water for consumption	3.66	1.11	high	3.13	1.01	moderate
Sufficient green areas	3.65	1.21	high	3.01	1.03	moderate
Smart mobility	**3.64**	**1.05**	**high**	**2.88**	**1.00**	**moderate**
Providing information to passengers	3.63	1.21	high	2.92	1.16	moderate
Parking management	3.67	1.12	high	2.92	1.11	moderate
Utilization of energy-saving and low-emission vehicles	3.63	1.17	high	2.81	1.21	moderate
Smart living	**3.68**	**0.95**	**high**	**2.96**	**0.95**	**moderate**
Provide opportunities for people to access comprehensive health information	3.62	1.05	high	3.11	1.06	moderate
Comprehensive service systems	3.67	1.19	high	2.94	1.10	moderate
Development of tourist attractions in the area	3.75	1.06	high	2.81	1.13	moderate

Table 1. Mean and standard deviation for domains and indicators in transforming Pathum Thani to be a smart city (Part 2)

Domains and indicators	*Expected performance*			*Current performance*		
	$\bar{x}$	*S.D.*	*Level*	$\bar{x}$	*S.D.*	*Level*
Smart people	**3.71**	**0.81**	**high**	**2.98**	**0.78**	**moderate**
Citizens have the knowledge and skills to enter a high-quality workforce system	3.60	1.09	high	3.08	1.13	moderate
Creating an environment and continuously improving learning methods	3.77	1.02	high	2.81	0.95	moderate
Creating an environment conducive to coexistence between people in society	3.75	1.08	high	3.06	0.99	moderate
Smart energy	**3.77**	**0.90**	**high**	**3.01**	**0.96**	**moderate**
The importance of renewable energy production	3.81	1.06	high	2.98	1.23	moderate
Promoting the use of vehicles that are environmentally friendly	3.78	1.05	high	3.09	1.15	moderate
Managing local energy consumption with the lowest cost in mind	3.72	1.07	high	2.94	1.08	moderate
Smart economy	**3.84**	**0.98**	**high**	**2.97**	**0.95**	**moderate**
Promotion of new business expansion	3.73	1.14	high	2.90	1.19	moderate
Digital infrastructure sufficient for urban expansion	3.92	1.08	high	2.94	1.10	moderate
Creation of highly skilled work	3.86	1.09	high	3.06	1.15	moderate
Smart governance	**3.95**	**0.80**	**high**	**2.87**	**1.06**	**moderate**
Promoting access to government services through a One Stop Service	3.92	0.96	high	2.81	1.37	moderate
Government agencies adopting digital technology for quick service	3.76	1.11	high	2.90	1.14	moderate
Promoting the good governance of the government sector	4.16	0.85	high	2.90	1.17	moderate
Average scores	**3.74**	**0.14**	**high**	**2.95**	**0.10**	**moderate**

According to the average scores, the seven domains for both expected and current performance are plotted in Figure 1. The matrix illustrates the two-dimensional relationship between reality and expectations. The graph is divided into four quadrants to reflect the strengths and weaknesses of Pathum Thani. Figure 1 shows that the strength of Pathum Thani as a smart city lies in the area of smart energy. This indicates that the population of Pathum Thani has relatively high expectations for the city's energy operations and the city is more active in this area than in the others. The figure reflects the fact that Pathum Thani's smart city energy performance is at a good level. In contrast, the domains in the third quadrant (smart environment, smart mobility, smart living, smart people, smart economy, and smart governance), are the weaknesses of Pathum Thani as a smart city. This means that the population of Pathum Thani has relatively high expectations for environment, mobility, living, people, economy, and governance, but the current conditions are far below the target. This reflects the fact that the performance in the aforementioned areas has not been successful and must be greatly improved.

Figure 1. Strengths and weaknesses in becoming a smart city of Pathum Thani



4.2. Part 2: Priority of components in transforming Pathum Thani into a smart city

The analysis of what is needed to become a smart city based on the assessment of 21 indicators of seven criteria was performed using the priority needs index ($PNI_{modified}$). The calculation was performed using the means ($\bar{x}$) of the current performance and expected performance (the degree of success (*D*) and the importance (*I*), respectively), and arranging the data priorities according to the above index values as detailed in Table 2.

Table 2. Priority ranking of domains and indicators in transforming Pathum Thani into a smart city

Domains and indicators	*I*	*D*	$PNI_{modified}$	*Order*
Smart environment	**3.60**	**2.99**	**0.205**	**(7)**
Comprehensive community solid waste management	3.48	2.81	0.238	1
Adequate clean water for consumption	3.66	3.13	0.169	3
Sufficient green areas	3.65	3.01	0.213	2
Smart mobility	**3.64**	**2.88**	**0.263**	**(3)**
Providing information to passengers	3.63	2.92	0.243	3
Parking management	3.67	2.92	0.257	2
Utilization of energy-saving and low-emission vehicles	3.63	2.81	0.292	1
Smart living	**3.68**	**2.96**	**0.246**	**(5)**
Provide opportunities for people to access thorough health information	3.62	3.11	0.164	3
Comprehensive healthcare service systems	3.67	2.94	0.248	2
Development of tourist attractions in the area	3.75	2.81	0.335	1
Smart people	**3.71**	**2.98**	**0.242**	**(6)**
Citizens have the knowledge and skills to enter a high-quality workforce system	3.60	3.08	0.169	3
Creating an environment and continuously improving learning methods	3.77	2.81	0.342	1
Creating an environment conducive to coexistence between people in society	3.75	3.06	0.225	2
Smart energy	**3.77**	**3.01**	**0.254**	**(4)**
The importance of renewable energy production	3.81	2.98	0.279	1
Promoting the use of vehicles that are environmentally friendly	3.78	3.09	0.223	3
Managing local energy consumption with the lowest cost in mind	3.72	2.94	0.265	2
Smart economy	**3.84**	**2.97**	**0.293**	**(2)**
Promotion of new business expansion	3.73	2.90	0.286	2
Digital infrastructure sufficient for urban expansion	3.92	2.94	0.333	1
Creation of highly skilled work	3.86	3.06	0.261	3
Smart governance	**3.95**	**2.87**	**0.375**	**(1)**
Promoting access to government services through a One Stop Service	3.92	2.81	0.395	2
Government agencies adopting digital technology for quick service	3.76	2.90	0.297	3
Promoting the good governance of the government sector	4.16	2.90	0.434	1

According to Table 2, the priority needs index is highest for smart governance (0.375), followed by smart economy (0.293), smart mobility (0.263), smart energy (0.254), smart living (0.246), smart people (0.242), and smart environment (0.205). When considering the $PNI_{modified}$ of each indicator in each domain, the priority needs index of Pathum Thani to become a smart city, can be arranged in descending order:

Table 3. Smart city's domains

Domains	*Priority needs index of each indicator and descriptions*
1) Smart governance	The corruption indicator, referring to promoting the good governance of the government sector, had the highest priority needs index. The second highest was the promotion of access to government services through a One Stop Service and the adoption by government agencies of digital technology for quick service. The $PNI_{modified}$ values were 0.434, 0.395 and 0.297, respectively.
2) Smart economy	The indicator referring to digital infrastructure sufficient for urban expansion had the highest need priority index, and this was followed by the promotion of the expansion of new businesses and the creation of highly skilled work. The $PNI_{modified}$ values were 0.333, 0.286 and 0.261, respectively.
3) Smart mobility	The indicator for energy-saving and low-emission vehicle utilization had the highest priority needs index, followed by parking management and passenger information. The $PNI_{modified}$ values were 0.292, 0.257 and 0.243, respectively.
4) Smart energy	The indicator for the importance of renewable energy production to reduce the environmental impact had the highest priority needs index, followed by the management of local energy consumption with the lowest cost in mind, and the promotion of the use of vehicles that are environmentally friendly. The $PNI_{modified}$ values were 0.279, 0.265 and 0.223, respectively.
5) Smart living	The indicator for the development of tourist attractions in the area had the highest priority needs index, followed by comprehensive healthcare service systems and the provision of opportunities for people to access thorough health information. The $PNI_{modified}$ values were 0.335, 0.248 and 0.164, respectively.
6) Smart people	The indicator for creating an environment and continuously improving learning methods had the highest priority needs index, followed by the creation of an environment conducive to coexistence between people in society and citizens having knowledge and skills to allow them to enter a high-quality workforce system. The $PNI_{modified}$ values were 0.342, 0.225 and 0.169, respectively.
7) Smart environment	The indicator for comprehensive community solid waste management had the highest priority needs index, followed by sufficient green areas and adequate clean water for consumption. The $PNI_{modified}$ values were 0.238, 0.213 and 0.169, respectively.

5. DISCUSSION

Pathum Thani has not yet been designated a smart city by DEPA as of August 5, 2022; only 30 cities have been thus designated as of that date. It remains in the promotion zone and is making progress toward meeting the DEPA's core key performance indicators (KPIs) (DEPA, n.d.-b). If all requirements have been met, Pathum Thani will be designated as a smart city. Pathum Thani citizens ranked "smart governance" as the application domain with the lowest score for the Pathum Thani smart city, and this domain has the highest PNI, indicating that it must be pushed as the top priority issue to achieve smart city success. Smart city implementation is heavily reliant on contexts such as nations and governments (Fu & Peng, 2014). Governance is one of the primary problems in establishing an effective network for smart cities. Thus, there is a greater need for improved governance to efficiently manage several city activities (Rana et al., 2019). From the aspect of information technology (IT) management, the indicators promoting access to government services through one-stop services and government agencies adopting digital technology for quick service may be viewed. In a smart city environment, according to Chourabi et al. (2012), the integration of IT with development initiatives is vital. Electronic government (e-government) is the use of electronic communications devices, computers, and the Internet to offer public services to residents and other individuals in a country or region. E-government can contribute to a smart city's smart governance. Beyond e-government, Bernardo (2019) and Pereira et al. (2018) introduce the notion of "smart governance". This refers to a style of governance that enables municipal stakeholders, especially residents, to engage in decision-making processes that enhance the quality of life in cities.

The "smart economy" earns the second highest PNI among the sectors to be considered for Pathum Thani to become a smart city; however, the performance in this domain ranks fourth. This means that the importance of smart economy is high despite the fact that Pathum Thani's performance in smart economy has a moderate score. According to Rana et al. (2019), smart cities would necessitate a gigantic infrastructure, cutting-edge technology, and linked networks of sensors, displays, cameras, smart devices, smart grid, etc., in order to analyse data and/or information, along with a substantial budget. Chourabi et al. (2012) define the economy as a development engine for smart cities since it not only provides economic prosperity but also stimulates job creation and enhances the quality of life for its residents.

The PNI of "smart mobility" ranks third, while the performance in this sector is in the sixth place. This means that the significance of smart mobility among Pathum Thani residents is pretty high since the performance of Pathum Thani in smart mobility is relevant poor so. In this study, smart mobility includes providing ease and facilities to commuters and using energy-saving and green energy vehicles. However, the paradigm of smart mobility extends far beyond the solution of urbanisation issues such as the need for new routes, traffic congestion, and inadequate optimization of logistic operations, since future contributions are anticipated to represent really differentiated and inventive solutions (Gouveia et al., 2016). In the following years, smart mobility should have an emphasis on the sustainability of the solutions produced, active transportation, the use of ecologically friendly fuels, and involvement with residents. Thus, the impacted dimensions will increase and encompass sustainability, economy, and quality of life, which will have direct effects on residents and government institutions (Paiva et al., 2021).

Even though Pathum Thani's performance in "smart energy" is ranked first, demonstrating the best performance across all other categories, people are nevertheless significantly concerned about this issue due to its fourth-ranked PNI. According to Wang et al. (2020), a smart city with smart energy is based on the life cycle of energy in the city, which entails the connectivity and exchange of information about objects. It implements the Internet of Energy (IoE) as its foundation and is built on a new business model and company structure with many parties as its pillars. It focuses on fostering the establishment of a shared energy platform and seeks to realise a low-carbon and efficient energy economy as well as accessible and convenient energy services. Smart energy is a crucial component of smart cities. The implementation of smart energy is an effective driver of the energy revolution, which will immediately lower the cost of urban energy consumption, secure the fundamental safety of energy consumption, and make the energy consumption environment more sustainable. It will indirectly result in high-quality, sustainable urban development. In addition, the nation is making attempts to construct smart cities.

Both the smart living PNI and Pathum Thani's smart living performance are placed fifth. This indicates that the priority and effectiveness of smart living are moderate. Smart living, which is motivated by the use of intelligent networking by humans, businesses, and communities and is built on immersive information and data, is not a straightforward phenomenon for all residents (Chourabi et al., 2012). Smart living is not restricted to the smart lifestyle made possible by smart technology but also focuses on the life quality given by the independent deployment of smart technology in sustainable settings. In other words, human existence can only be directed by a human being, regardless of how clever the technology may be (Han & Kim, 2021). The domain "smart living" encompasses smart buildings for education, tourism, healthcare, and public security, and these characteristics might enhance the quality of life for humans (An et al., 2019).

The PNI of "smart people" ranks sixth, while the performance in this sector is in third place. This means that the priority of smart people among Pathum Thani residents is low, while the city's performance in this regard is average. Since humans are the primary users of smart products and services, improving the living environment and enhancing the quality of life are two important objectives of smart cities (Yeh, 2017). Therefore, it is essential to adequately plan and create these services. People in smart cities should interact and communicate with one another in order to share common and essential online social experiences and

physical space (Sun & Poole, 2010). According to An et al. (2019), smart citizens should not only engage via services but also offer data for these services. As they are the core of smart cities, smart people should also be open-minded, easily adaptable to changing environmental conditions, and innovative. Citizens should participate in each alteration of the city since they are the ones developing it, and they should consider what sort of city they desire. People should be informed of the rules and regulations governing the information processing environment. In addition, social networking sites should educate users about information-providing smart city technologies and services.

Pathum Thani's "smart environment" has the lowest PNI, and its performance in this domain ranks second. Assuming Pathum Thani's performance in a smart environment is acceptable, the priority of this domain may be of the least concern. One of the most significant aspects of smart cities is their smart environments, which have recently gained popularity. Many studies have looked at the elements of a smart environment, such as air quality, green and water areas, pollution monitoring, waste management, energy efficiency, and monitoring of city trees (Corbett & Mellouli, 2017; Niforatos et al., 2017; Zhang et al., 2017).

6. CONCLUSION

Thailand has set guidelines to become a smart city into seven application domains: smart environment, smart mobility, smart living, smart people, smart energy, smart economics, and smart governance. In order to consider the development of Pathum Thani as a smart city according to these criteria, 21 subdomains or indicators were included in this study. The assessment of current performance and the expected performance of Pathum Thani becoming a smart city indicates that the strength of the city is "smart energy", while the weaknesses are all the rest domains: smart environment, smart mobility, smart living, smart people, smart economy, and smart governance. The priority needs index shows that "smart governance" is the first priority that Pathum Thani needs to be achieved in order to accomplish the goal of becoming a smart city, followed by smart economy, smart mobility, smart energy, smart living, smart people, and smart environment. In order to achieve the goal of becoming a smart city, the following suggestions are recommended: DEPA, the Department of Local Administration (DLA), and local government agencies should establish guidelines or policies for urgent development projects to assist Pathum Thani's local government agencies and relevant organisations in achieving the smart city KPIs. This is because Pathum Thani has the poorest performance in smart government and this is the top priority concern of Pathum Thani's residents. In order to accelerate the fulfillment of the smart city concept, these steps should improve access to government services in the region through clear approaches. In addition, government agencies should have a transparent and adequate digital infrastructure to enable the development of economic activity in the city. This will support the formation of new companies and the creation of highly skilled employment opportunities. This study has limitations by the fact that the participants are representative of the general public, who may have limited knowledge and expertise with smart cities and associated technology. Therefore, in order to study topics in more detail, specialists from a variety of fields may conduct an in-depth interview. In order to grasp how to develop a smart city in a particular location, it may be advantageous to explore the opinions of experts from different fields, given that a community is formed of diverse demographic traits. Adopting the ideas of people from varied backgrounds may result in the smart city that is most desirable for all local citizens. This study's findings may be useful for Pathum Thani's local administration agencies and related sectors in planning the city's transformation into a smart city. This study may also be used by local government agencies and organisations from other regions to aid their cities in achieving smart city status.

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