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Impact of Spatial Configuration on Promoting Lifelong Learning Development in Pathum Thani, Thailand

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Abstract: A "Learning City" uses its resources to enhance learning opportunities for individuals and communities that promote social cohesion, cultural prosperity and economic development. While the UNESCO network of learning cities provides guidelines for measuring social and economic prosperity, there have been no studies examining the current strengths and weaknesses of such cities in Thailand. The purpose of this study was to identify current strengths and opportunities for improvement in the Thanyaburi district of Thailand. We surveyed 400 residents to examine formal and informal learning activities, followed by layering the survey data using geographic information systems, to determine geographic differences in population size, density and transportation access. The findings show that formal and informal learning activities differ by the density and diversity of various geographical locations within the district according to urban centrality scores. The most popular activities were community-based, environmental and educational activities, respectively. However, various municipalities had few learning opportunities for local residents. Promoting lifelong learning opportunities is an essential response to establishing a vibrant environment for individuals, communities and cities and is a key driver to improving economic development (e.g., employment and education) and sustainability.

Keywords: geographic information systems (GIS); learning city; lifelong learning; scalogram analysis; spatial characteristic; urban centrality

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1. Introduction

Urban centrality refers to the capacity of an urban or peri-urban city to provide access to local and nearby services [1]. Urban centrality has typically been measured using spatial modeling to examine the urban structure [2–4] and its interactions with commuting patterns [5], population diversity, density [6], distance from the central business district and attractiveness [7]. In developing countries such as Thailand, urban centrality, with the context of urbanization, has become more challenging and complex, often resulting in urban sprawl with more fragmented areas at the outskirts of cities.

Urbanization is defined as the expansion of cities associated with increasing population densities resulting in land transformation to accommodate residential, commercial and industrial growth [8]. Urban planning is critically important to ensure that infrastructures, facilities and services are implemented to meet growing cities and to ensure its residents have an appropriate quality of life. Adequate urban planning practices can lead to reductions in poverty and inequality by providing better access to housing, employment and education [8]. For example, urban planning activities that developed commercial enterprises from agricultural lands have resulted in additional opportunities for farmers to earn higher incomes while also providing local residents with increased selection of consumer goods and products [9,10].

Urban planning initiatives, however, when implemented poorly, can also result in negative impacts. One issue is that higher income regions may receive additional provisions

and services that improve the economy while lower income regions may not, furthering the divide between high- and low-income areas [11]. This divide is reflected when examining indicators related to population, economic and land developments [12]. Studies show that while urbanization can initially contribute to community improvement through private and commercial development, as cities and communities grow, there is often a lack of planning [9,13–15] to ensure cities and communities have access to important services and amenities [8].

The lack of amenities and services tends to be more pronounced in urban cities in developing countries [16]. For example, in Thailand, cities are growing at a rate much faster than the rate of development [17]. Even in large cities such as Bangkok, this phenomenon has extended beyond the immediate city core to peri-urban areas where population growth is rapidly increasing, including the adjacent provinces of Nakhon Pathom, Pathum Thani, Nonthaburi, Samut Prakan and Samut Sakhon [18,19]. The rapid change associated with urbanization has generated challenges to urban planning developments [20,21], including further increasing socio-economic divisions [22]. As all cities/communities are distinct in social and economic opportunities, urban planners must ensure these cities/communities are interconnected to facilitate opportunities to live, work, play and learn, otherwise known as "learning cities". Incorporating activities related to learning cities will reduce the inequalities between cities and communities and narrow the divide among high- and low-income populations.

Studies show that adopting a "learning city" approach provides employment opportunities regardless of gender, age or socio-economic status, resulting in greater economic benefits [22–24]. This "learning city" initiative has now been adopted by seven cities in Thailand including Chiang Rai, Phuket, Chiang Mai, Chachoengsao, Sukhothai, Phayao and Hat Yai in Songkhla [22]. One of the goals of the learning city initiatives in Thailand is to promote lifelong learning. Lifelong learning promotes continuous learning over a person's lifespan and refers to both formal (e.g., education) and informal (e.g., community participation) activities [22]. Lifelong learning is embedded within the UNESCO Institute for Lifelong Learning's strategy to improve access to information that facilitates learning, skill development and employment opportunities [25–27].

Recent studies have moved towards creating "learning cities" by incorporating existing physical spaces and activities to foster community engagement. For example, Khurana (2022) converted physical spaces into learning spaces which improved accessibility and activity participation among community members [28]. Other studies have noted that lifelong learning through the provision of formal and informal community-based activities is integral to a city and/or communities' development, which can be offered both in-person and virtually [24]. More importantly, the development or re-structuring of physical spaces is important to reduce barriers related to learning opportunities and to improve community integration and wellbeing, which has often been neglected in prior studies and is often influenced by various socio-economic factors [24,28,29]. While prior studies acknowledge the importance of including opportunities for learning, there is a dearth of literature on what activities various cities and communities currently provide and whether they are being accessed.

Studies show that integrating lifelong learning opportunities within cities must be considered with other disciplines including urban planning [24,30], spatial and environmental design [31–33] and inclusive and sustainable development [22,34] to maximize social and economic benefits. However, to better understand how urban planners can contribute to learning cities, a thorough understanding of a city's strengths and weaknesses is critically important to ensure opportunity growth for all residents. We hypothesize that developed urban infrastructures, facilities and services (centrality scores) will be associated with a greater number of learning activities and better activity uptake. The objectives of this paper are to present a case study to (1) examine differences in urban characteristics in Pathum Thani province (urban centrality) and (2) to examine the influences of differences in spatial patterns and urban diversity on participation of learning activities

in Pathum Thani province by focusing on Thanyaburi District. Findings from this study may show how different spatial configurations and urban structures influence the availability and uptake of various learning activities among different geographic regions and population characteristics.

2. Methodology

2.1. Site Selection

Bangkok is the most developed city in Thailand. While city development and expansion in Bangkok have slowed due to limited land space, nearby peri-urban cities such as in Pathum Thani province (north of Bangkok) is growing rapidly [35,36]. This phenomenon of suburbanization in peri-urban areas has resulted in increasing population densities associated with migration. Additionally, as migrants come from various regions of Thailand, these peri-urban areas include diverse cultures and interests, along with varying needs and demands related to employment, housing, facilities and services. However, public investment to develop appropriate infrastructures, facilities and services in peri-urban areas has not kept pace with how quickly they have been growing. The lack of infrastructures, services and facilities, in tandem with mixed cultures and interests, can result in inequalities among its residents with respect to employment opportunities, education, health and housing [36]. Furthermore, the complexity of urban hierarchical systems often results in a lack of inclusivity planning that reduces resident opportunities for housing, employment, education and service needs and does not adequately allow residents opportunities across their lifespan. A learning city for all ages is essential for providing lifelong learning opportunities to ensure residents have greater opportunities that can impact their lifespan. Incorporation of learning activities into peri-urban areas fosters stronger community ties and more educated and potentially more affluent residents. However, data show that the peri-urban area of Pathum Thani province has been overlooked due to its quick development together with ad hoc planning related to both formal and informal learning activities [22,30]. Thus, understanding the formal and informal learning activities residents use is critical to improving access to key activities that may be missing.

The geography of Pathum Thani province includes one major highway that connects to Bangkok, resulting in a large concentration of activities along a single corridor [37]. As shown in Figure 1, the Thanyaburi district of Pathum Thani province is divided into four municipalities—Rangsit city, Bueng Yitho, Thanyaburi and Sanan Rak—and has a total area of 112.124 square kilometers and a population of about 214,091 people [38]. Thanyaburi district has many learning activities and opportunities that include museums, science centers, shops, restaurants, libraries, agriculture and lifestyle learning facilities [30].

2.2. Questionnaire

A questionnaire was created to collect information from residents living in Thanyaburi district from December 2021 to February 2022 (Figure 2). The questionnaire captured information on demographics (e.g., age, gender, education (formal learning) and income) and informal learning activities. Informal learning activities included seven subsets of questions on education, enterprise, community, history, environment, culture, health and wellbeing. The activities were defined as (1) community (learning activities to appreciate the community's way of life); (2) enterprise (activities related to professional skill development); (3) environment (learning activities for environmental preservation); (4) historical (activities for discovering the history of the area); (5) education (e.g., public libraries, museums); (6) cultural (learning activities related to culture, tradition and rituals); and (7) health and wellbeing (learning activities for self and family care, diet, physical activity, hobbies). The inclusion criteria required respondents to (1) be 15 years or older; (2) currently live in Thanyaburi district; and (3) have lived for at least one year in Thanyaburi district.

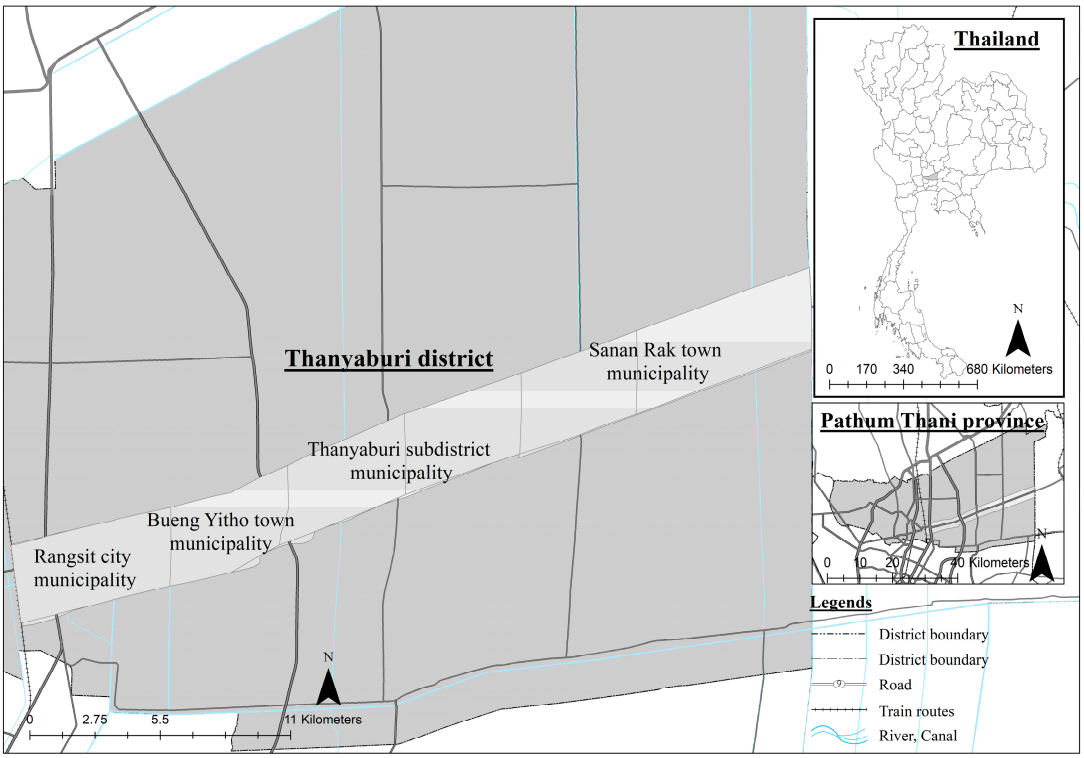


Figure 1. Subdivisions of Thanyaburi district, Pathum Thani.

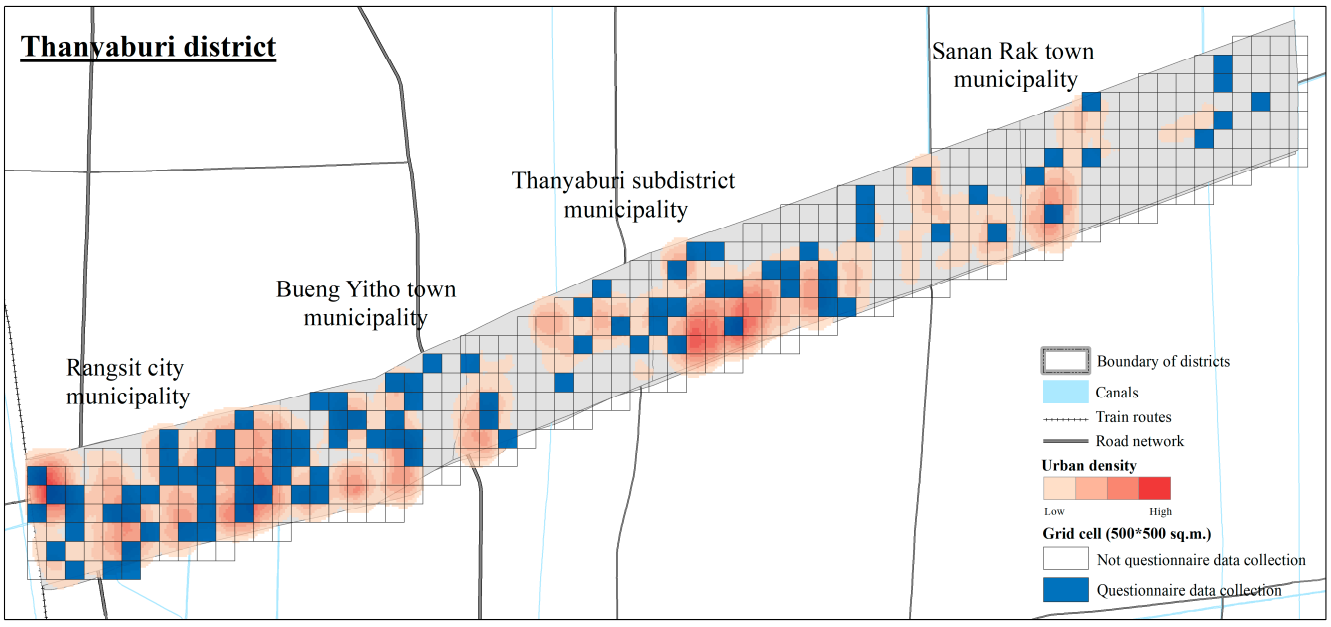


Figure 2. Location of questionnaire respondents by study area.

The questionnaire was disseminated to cover an area of 500 × 500 square meters to ensure data could be used for spatial analyses. The 500 × 500 grid is used for digitizing data and consists of layers from the questionnaire data to produce geographic information system (GIS) maps. This approach provides a method for examining participation in formal and informal activities to better understand usage patterns on a local level. This approach has been used in prior studies to better integrate urban planning with learning activity provisions [24,30–33] consistent with recommendations for inclusive communities and

sustainable development [22,34]. Thus, using a 500 × 500 grid ensures we can capture sufficient information on activity accessibility within geographic areas of interest.

In total, a sample size of 400 was needed to ensure an appropriate representation of residents in Thanyaburi district based on a population size of 215,461 with a power of 80% and a confidence level of 95% [39]. The research team visited various communities in Thanyaburi district to recruit participants. The research team, consisting of 10 staff/student members, walked around the various areas to observe the community focal points (e.g., major intersections, shopping malls, parks). Participants were then approached at these focal points (convenience sampling) to solicit participation. The research team aimed to recruit participants from each community according to the population density distribution, as shown in Figure 2. Thus, there were less participants recruited in lower populated areas and more participants recruited in areas with high population density. The sample included 159 participants from the Rangsit city municipality, 55 from the Bueng Yitho town municipality, 119 from the Thanyaburi subdistrict municipality and 67 from the Sanan Rak town municipality, respectively.

2.3. GIS Modeling

Data from the questionnaire were integrated with spatial mapping using a geographic information system (GIS) to explore characteristics and geographics patterns of formal and informal learning activities in Thanyaburi district. By using GIS, the spatial mapping can uncover differences in geographic characteristics and patterns including diversity and density of activities, population and transportation system. The GIS program can showcase the functional structure of the city to visualize the locations where residents can access learning activities. Additionally, challenges with accessing learning activities (e.g., access to paved roads) and spaces can be observed from the spatial distribution of activities. Thus, spatial differences and accessibility of formal and informal learning in different geographic locations can be easily visualized. Data from the questionnaire were divided into a 500 × 500 sq. kilometer grid, resulting in 479 cells which allowed for visualized comparisons across the four different cities in Thanyaburi district. These visualized comparisons (spatial mapping) provide a better understanding of differences in social, economic and physical characteristics in each district. This approach has been used in prior studies to characterize spatial patterns [40,41].

2.4. Data Analysis

The association between urban centrality and participation in informal learning activities was examined using univariate analysis. SPSS Version 28.0 was used for all statistical analyses; significance level was $p < 0.05$. Questionnaire data on access and participation in informal learning activities using the seven categories (e.g., education, enterprise, community, history, environment, cultural, health and wellbeing) were layered into a spatial map to calculate an urban centrality score (see Figure 3). Spatial analysis was applied to identify patterns of respondents' behavior in participating in learning activities. Then, spatial data were extracted into grid cells with an urban centrality score being calculated for each city in Thanyaburi district. The urban centrality score is used to understand different spatial characteristics related to the informal learning activities within a given area [1].

The urban centrality score counts the number of buildings related to the different informal learning activities. Each building represents possible learning opportunities for residents to access within each area. The urban centrality formula, as shown below, considers whether a defined area is monocentric or polycentric. Scores can range from 0 to 1 where 0 is extreme polycentric and 1 is extreme monocentric.

$$CI_x = \frac{100}{\sum_{i=1}^{n} x}$$

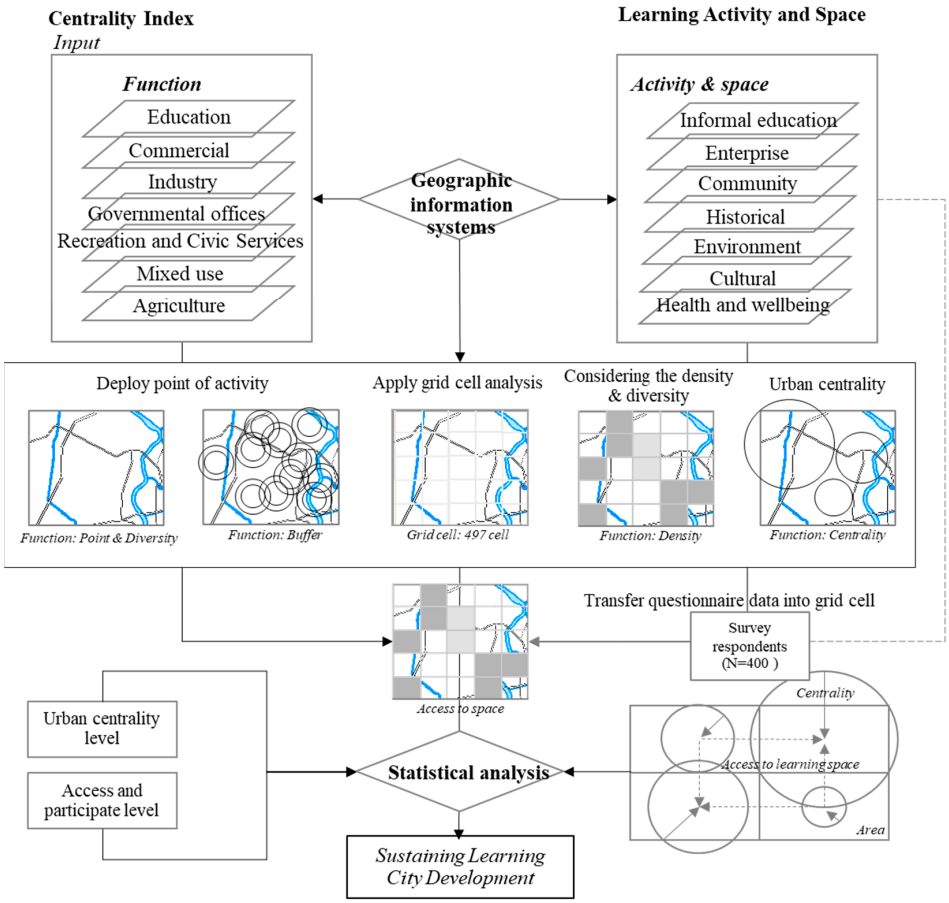


Figure 3. Research framework (source: authors).

Here, CI_x is the centrality index of type x buildings; x is the type of building analyzed; n is the number of unit areas. Based on the centrality index, the diversity and density of each area can be calculated using the presence of city activity and the total number of city activities compared to other cities with the same activity.

In this study, building data were adopted to classify the main building groups into different types of building utilization (e.g., educational, commercial, industrial, governmental, recreation, mixed-use and agricultural). The centrality index was then used to calculate a hierarchy of settlement (*HS*) score:

$$HS_i = \sum_{i=1}^{n} CI_i$$

where HS_n is the hierarchy of settlement of cities I; CI_i is the centrality index of the function I; n is the number of cities analyzed.

The centrality index can measure the urbanization process from increasing density and population metrics of different districts. The centrality scores can be validated and confirmed through the counting of observed learning activities. Furthermore, the multifaceted functions of centrality scores can produce and compare information on how sub-districts are spatially arranged in terms of infrastructures, services and facilities. This allows for a comparison of spatial arrangements by sub-district. By understanding the location of local learning activities together with migration patterns, we can uncover the urban structures through a spatio-functional process and make assumptions about the socio-economic impacts.

3. Results

3.1. Sample Description

The sample consisted of 400 respondents from Thanyaburi district. Tables 1–3 show the data related to social, economic and the built environment, respectively. As shown in Table 1, there were more men who completed the questionnaire than women (52.3% vs. 44.5%). The mean age was 38 ± 12.3 years (range 19 to 83); almost a third were between the ages of 22 and 25 years (30.86%). Most respondents were Buddhist (95.25%), and just over half were married (53.5%).

As shown in Table 2, just over half of the workforce are women (52.69%). The average income is THB 39,506.99, with approximately THB 31,639.92 being spent on daily needs. Just over half had a bachelor's degree; over a fifth of respondents reported they had their own personal business; income ranged from THB 15,001–20,000 (21.5%).

As shown in Table 3, most land is considered agricultural land, followed by residential areas. The average number of years respondents lived in their homes was 1–10 years (48%), followed by 10–20 years (26.5%).

3.2. Urban Centrality

As shown in Figure 4, the density and types of activities among the four municipalities in Thanyaburi district are different. More than a third of the activities across all districts were mixed-use (38.45%) and commercial (35.96%). These activities primarily took place along the main road. The highest density and activities were in Rangsit city (49.3 percent), followed by Bueng Yitho (19.6 percent), Thanyaburi subdistrict (18.89 percent) and Sanan Rak (12.15 percent), respectively. The data show that central areas are denser than areas further away from the city centers.

Figure 5 describes the urban centrality scores of the various cities within Thanyaburi district. The lowest urban centrality score is 0.32, while the highest is 122.05. These scores are then divided by the size of the city center. The city center is divided into three levels: small (0–10), medium (11–40) and significant (over 40). According to the grid-by-grid data (Figure 4a), urbanized areas are concentrated in areas with high activity density (Figure 4b). The municipality with the highest urban center value was Rangsit municipality (18.13), followed by Thanyaburi subdistrict (6.50), Bueng Yitho (5.25) and Sanan Rak (5.21).

When examining grid data by city boundaries, Rangsit city municipality had the area with the highest density of activities, including access to transportation (e.g., Sky Train), large department stores and a hospital. As for the Thanyaburi subdistrict municipality, although the municipality is at the sub-district level, there are educational institutions (e.g., universities) in the area, making it a source of residential activities and mixed utilization. The other cities/districts have lower scores, which can be attributed to a lack of amenities and activities.

3.3. Urban Centrality, Accessibility and Participation in Learning Activities

The questionnaire data were used to examine the various types of activities residents have access to (e.g., education, enterprise, community, historical, environment, cultural, health and wellbeing) in Thanyaburi district, as shown in Figure 6. The most popular learning activities were related to "ways of living" ($\overline{x}$ = 1.44), followed by activities related to advancing careers and skill development ($\overline{x}$ = 1.40) and environmental conservation activities ($\overline{x}$ = 1.34), respectively.

Table 1. Social aspect at the municipality level, district level and provincial level.

Variables/Source	Attributes	Unit	Municipality				District	Province
			1	**2**	**3**	**4**	**5**	**6**
Gender (registered population) /Municipality office	Male	Person	39,158	15,385	30,546	15,444	100,533	568,877
	Female	Person	45,386	18,329	33,879	17,334	114,928	632,655
	Others	Person	-	-	-	-	-	-
Gender/ Survey	Male	Person	91	25	56	41	213	380
	Female	Person	64	30	61	23	178	299
	Other	Person	4	-	2	3	9	21
Religion/ Survey	Buddhist	Person	149	55	118	59	381	655
	Christian	Person	5	-	1	3	9	18
	Islam	Person	3	-	-	5	8	24
	Others	Person	2	-	-	-	2	3
Marital status/ Survey	Married	Person	68	31	90	25	214	326
	Single	Person	28	7	15	17	67	138
	Divorce	Person	57	16	13	23	109	209
	Others	Person	6	1	1	2	10	27
Age structure/Municipality office	Population	Person	84,544	33,714	64,425	32,778	215,461	1,201,532
	Number of households	Unit	57,307	16,224	34,458	17,903	125,892	677,046
	Family size	Person/Unit	1.475	2.078	1.870	1.831	1.870	1.775
	Male elderly	Person	6037	2233	4373	2556	15,199	83,888
	Female elderly	Person	8725	3211	6004	3187	21,127	111,694
	Elderly	Person	14,762	5444	10,377	5743	36,326	195,582
	%Elderly	Percent	17.5	16.1	16.1	17.5	33.5	16.278
Age/ Survey	Less than 25	Person	41	4	1	16	62	118
	25–35	Person	37	13	26	28	104	216
	36–45	Person	49	12	41	14	116	199
	46–55	Person	23	14	35	6	78	114
	56–65	Person	5	8	10	2	25	31
	More than 65	Person	4	4	6	1	15	22
	All	Average	36	44	46	34	40	38

Note: 1 = Rangsit city municipality; 2 = Bueng Yitho town municipality; 3 = Thanyaburi subdistrict municipality; 4 = Sanan Rak town municipality; 5 = Thanyaburi district; 6 = Pathum Thani province.

Table 2. Economic aspect at the municipality level, district level and provincial level.

Variables/Source	Attributes	Unit	Municipality				District	Province
			1	2	3	4	5	6
Workforce	Male workforce	Person	26,146	10,490	20,113	10,100	40,703	381,998
	Female workforce	Person	30,385	12,592	22,577	11,554	46,723	425,490
	Total workforce	Person	56,531	23,082	42,690	21,654	87,426	807,488
Income and expenditure/Municipality office	Income	THB/Month	38,972.02	56,206.88	48,945.19	47,784.41	50,978.83	39,506.99
	Expenditure	THB/Month	25,995.00	36,725.00	28,718.00	20,831.00	28,758.00	31,639.92
Higher education	Education (Higher education: university)	Person	3126	1432	2466	2190	9214	52,922
Education level/Survey	Primary school	Person	6	8	8	0	16	22
	Junior high school	Person	14	5	6	3	14	28
	High school	Person	35	8	22	11	41	76
	Vocational college	Person	27	8	22	13	43	70
	Bachelor's degree	Person	58	25	59	30	114	172
	Postgraduate	Person	19	2	13	8	23	42
Occupation/Survey	Government	Person	19	2	13	8	23	42
	Private agency	Person	41	20	30	19	69	110
	Students	Person	28	3	1	10	14	42
	Personal business	Person	49	19	48	20	87	136
	General employee	Person	17	4	19	7	30	47
	Farming/garden	Person	0	0	5	1	6	6
	Other	Person	5	7	3	2	12	17
Average income, baht/Survey	Less than 5000	Person	10	6	4	2	12	22
	5001–10,000	Person	17	4	7	4	15	32
	10,001–15,000	Person	31	9	19	21	49	80
	15,001–20,000	Person	39	9	26	12	47	86
	20,001–25,000	Person	14	8	32	8	48	62
	25,001–30,000	Person	21	5	15	4	24	45
	30,001–35,000	Person	13	11	13	4	28	41
	35,001–40,000	Person	6	3	0	5	8	14
	More than 40,000	Person	8	0	3	7	10	18

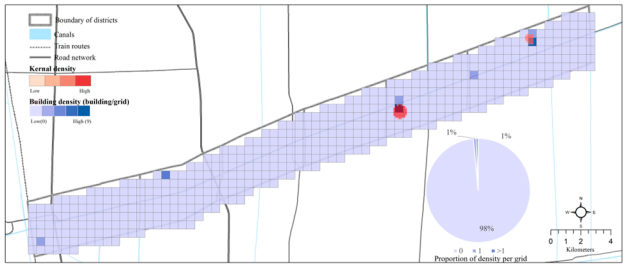
Note: 1 = Rangsit city municipality; 2 = Bueng Yitho town municipality; 3 = Thanyaburi subdistrict municipality; 4 = Sanan Rak town municipality; 5 = Thanyaburi district; 6 = Pathum Thani province.

Table 3. Built environmental aspect at the municipality level, district level and provincial level.

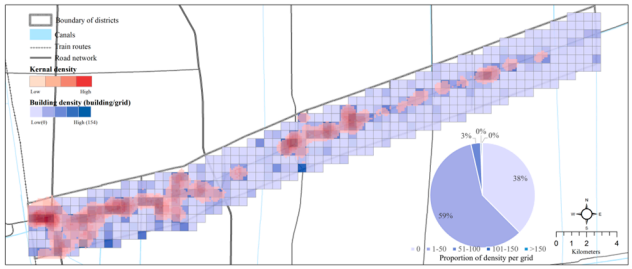
Variables/Source	Attributes	Unit	Municipality				District	Province
			1	2	3	4	5	6
Land classification/GIS data	Area boundary	sq.km	21.77	16.42	33.93	42.81	115.17	1518.23
	Urbanized area	sq.km.	16.82	8.89	16.59	8.03	49.86	462.77
	Agricultural area	sq.km	1.05	2.41	6.67	2.38	33.95	825.78
	Water body	sq.km	1.08	0.50	2.00	1.34	0.52	63.46
	Miscellaneous	sq.km	2.86	4.58	8.63	9.41	26.14	168.43
Number of buildings/GIS data	Resident	No. of unit	31,704	13,490	29,485	16,708	91,387	622,474
	Commercial	No. of unit	1816	860	1207	584	4467	33,093
	Industry	No. of unit	738	396	325	218	1677	23,300
	Mixed use	No. of unit	1864	725	1546	834	4969	32,949
	Utility	No. of unit	52	44	72	23	191	2079
	Education	No. of unit	337	109	228	147	821	6375
	Religion	No. of unit	115	115	147	118	495	9059
	Government	No. of unit	210	45	914	99	1268	4827
	Recreation	No. of unit	34	31	50	17	132	677
	Agriculture	No. of unit	1	2	-	17	20	1168
Residential period, years/Survey	1–10	Person	98	24	31	39	94	192
	11–20	Person	31	19	40	16	75	106
	21–30	Person	16	7	16	5	28	44
	31–40	Person	7	1	15	5	21	28
	41–50	Person	5	3	12	2	17	22
	More than 51	Person	2	1	5	0	6	8

As shown in Figure 7, the Sananrak municipality had the highest learning activity participation rates ($\overline{x}$ = 1.41) followed by Thanyaburi municipality ($\overline{x}$ = 1.37), Bueng Yitho municipality ($\overline{x}$ = 1.26) and Rangsit city municipality ($\overline{x}$ = 1.18). Although the Sanarak municipality had the poorest access to learning activities compared to larger cities such as Rangsit (highest urban centrality score), it had the highest participation among learning activities.

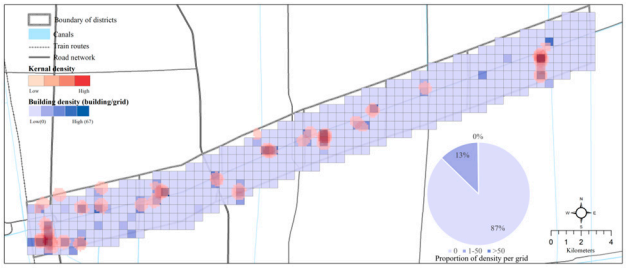
Figure 8 presents the associations between centrality scores and activity participation rates by municipality. Commercial and mixed land use were the most common activities across all municipalities. The findings show that the urban centrality scores were highest in Rangsit city, which was also associated with greater commercial and mixed land use developments, although there were few recreational activities, similar to all other municipalities.



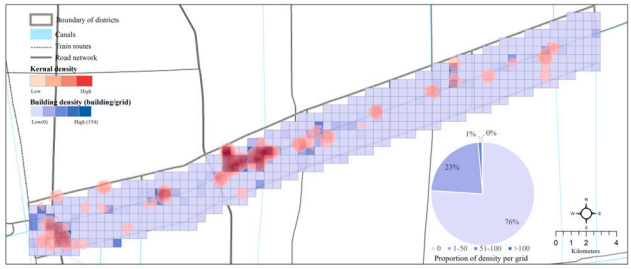
(**a**) Agriculture



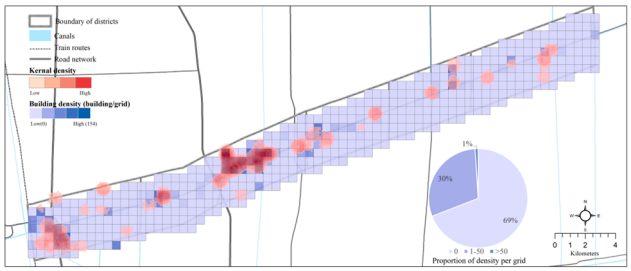
(**b**) Commercial



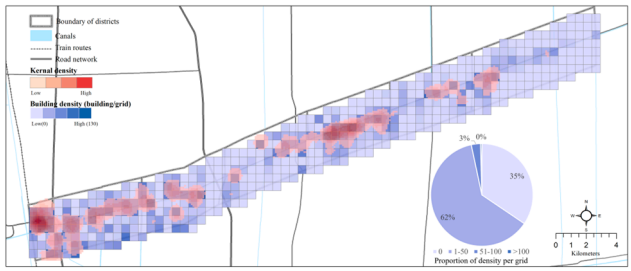
(**c**) Education



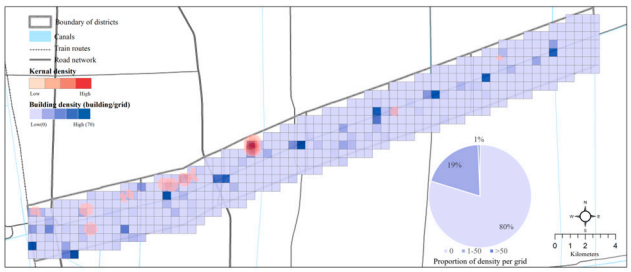
(**d**) Government office



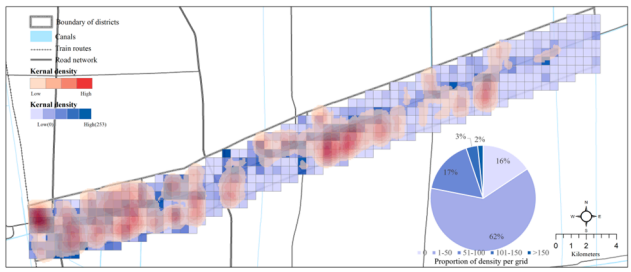
(**e**) Industry



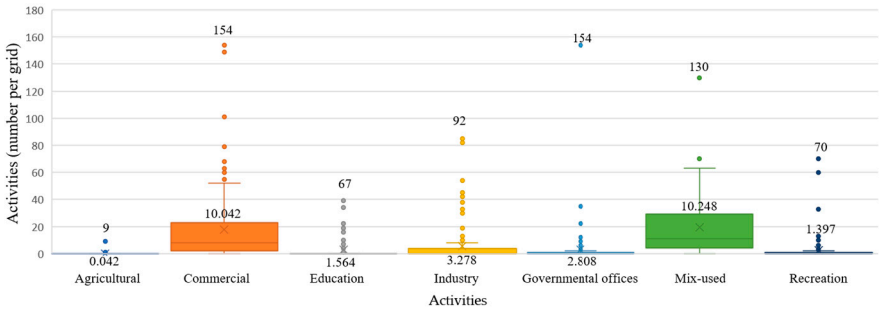
(**f**) Mixed use



(**g**) Recreation

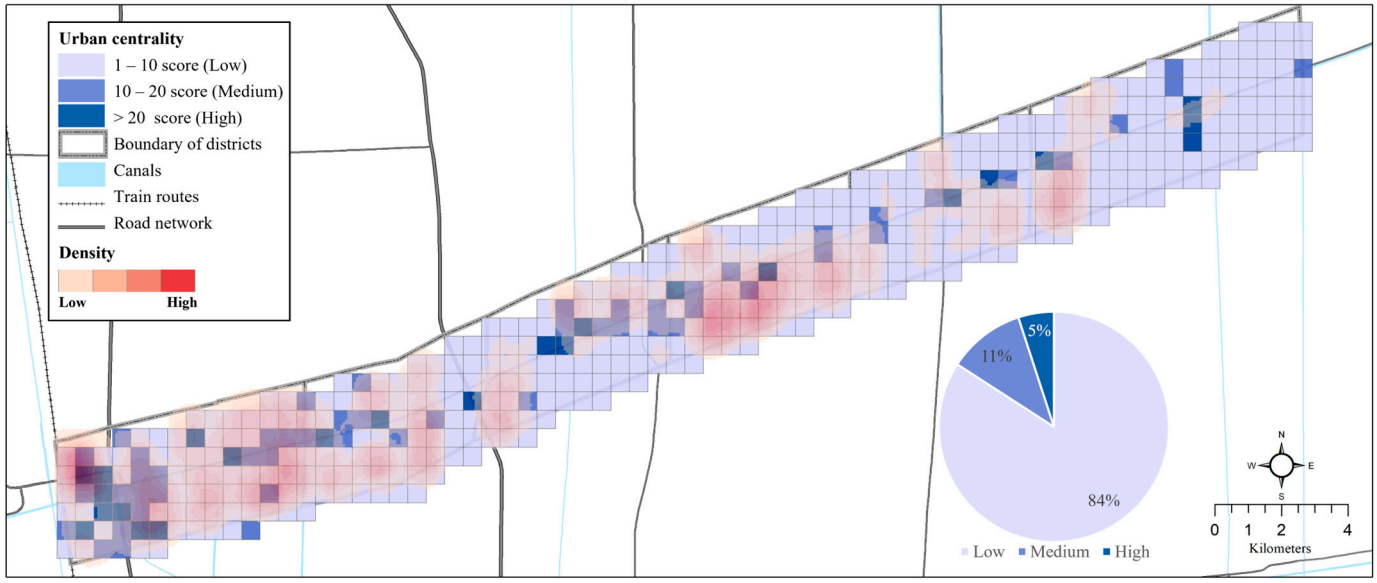


(**h**) All activities

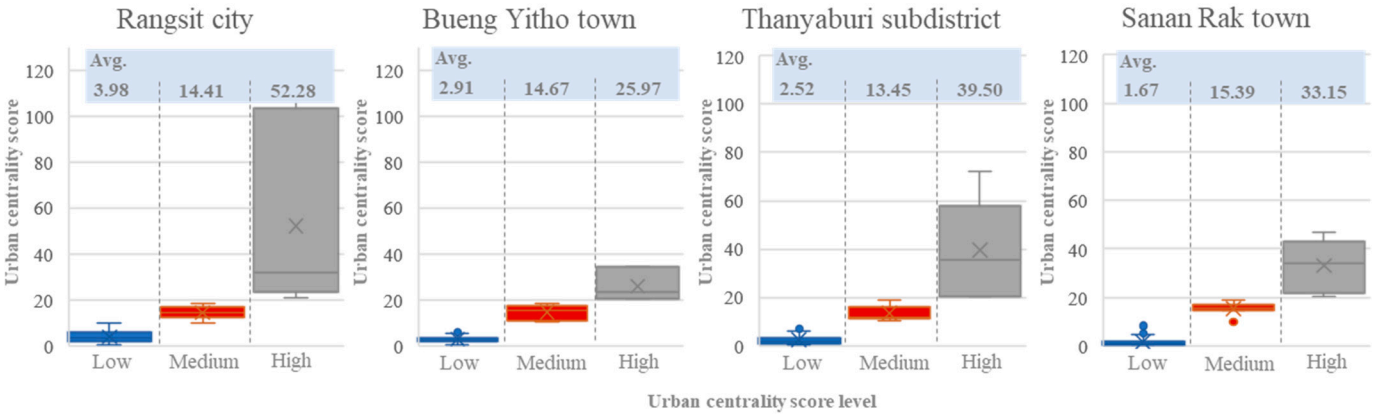


(**i**) Activities in the Thanyaburi District

Figure 4. Density and diversity of different activities in Thanyaburi district.



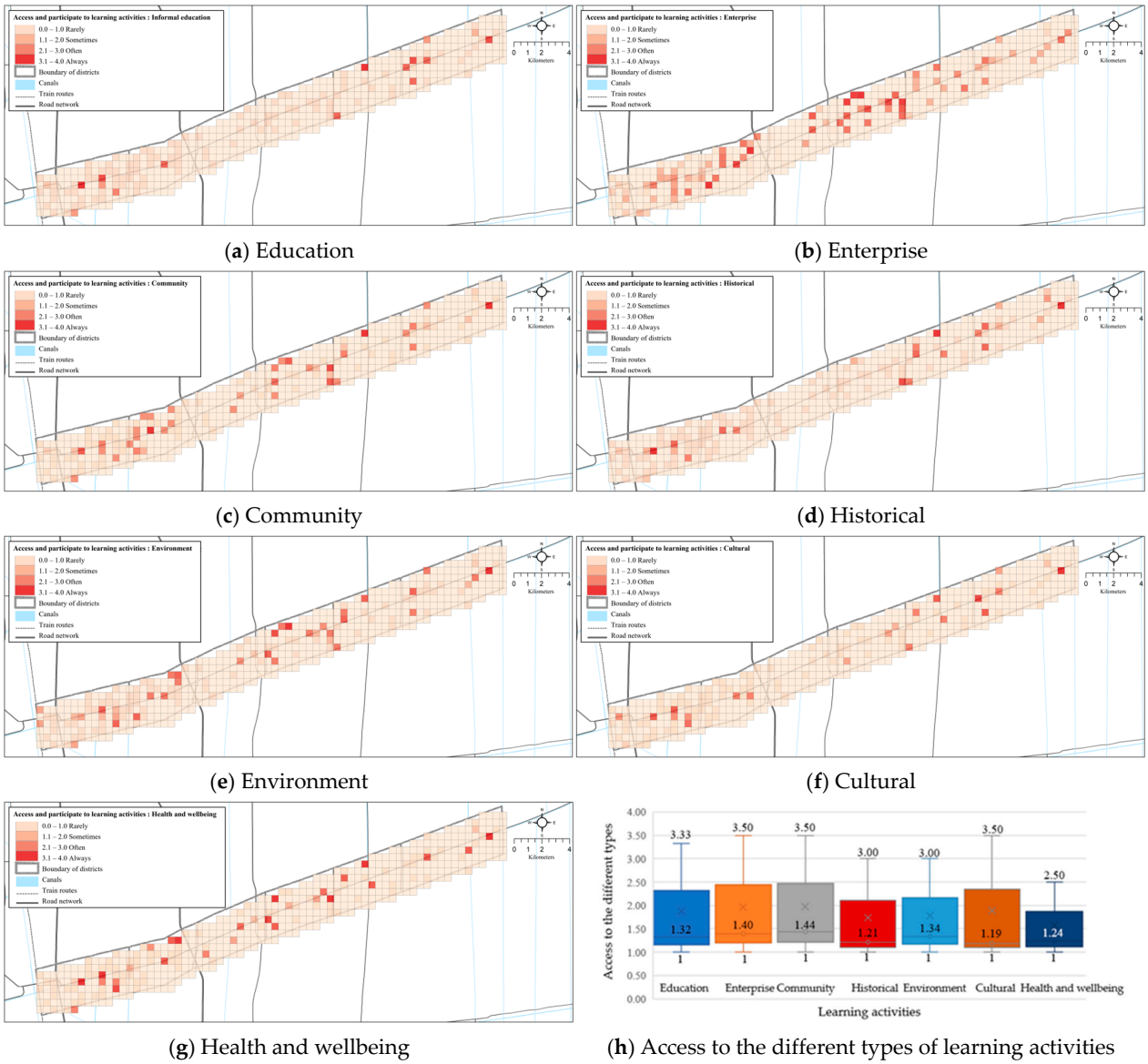
(**a**)



(**b**)

Figure 5. Urban centrality scores of each the Thanyaburi municipalities. (**a**) Spatial analysis of centrality of Thanyaburi district. (**b**) Distribution of centrality level in different municipalities.

Figure 9 incorporates the centrality index with geospatial modeling to examine the association between location and activity accessibility. The data show a significant association between the degree of centrality and access to learning activities. However, when examining each municipality individually at the district level, there was a significant association between activity participation and accessibility (significance level of $p < 0.001$ for all within municipality analyses).



(**a**) Education (**b**) Enterprise

(**c**) Community (**d**) Historical

(**e**) Environment (**f**) Cultural

(**g**) Health and wellbeing (**h**) Access to the different types of learning activities

Figure 6. Access to the different types of learning activities.

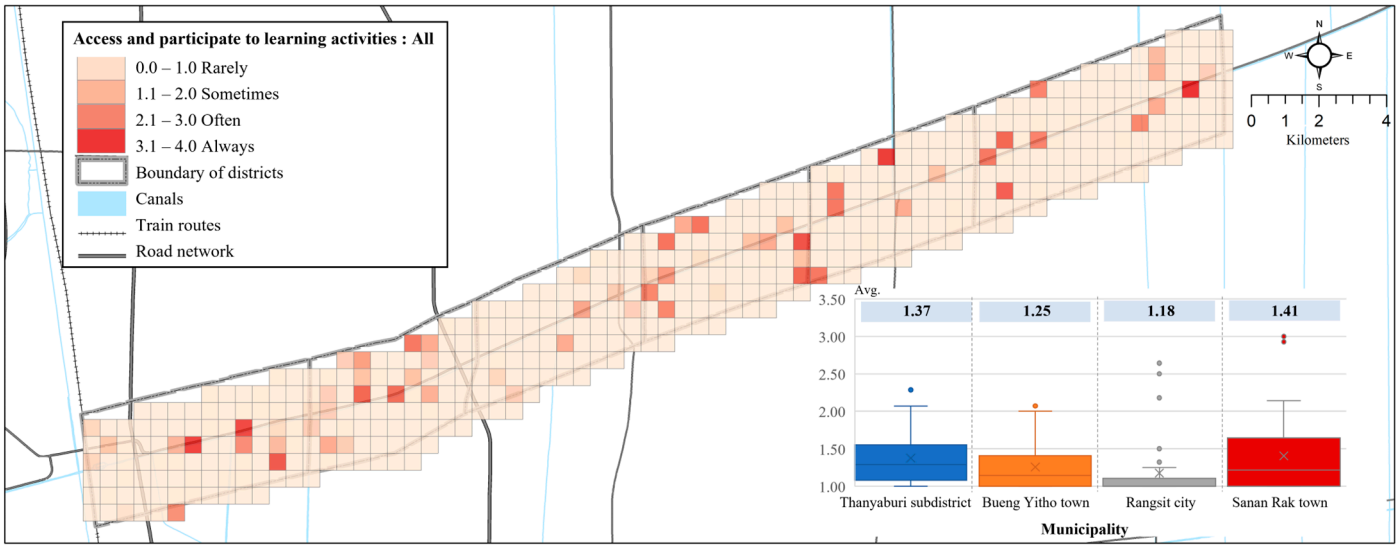


Figure 7. Learning activity participation rates by Thanyaburi municipalities.

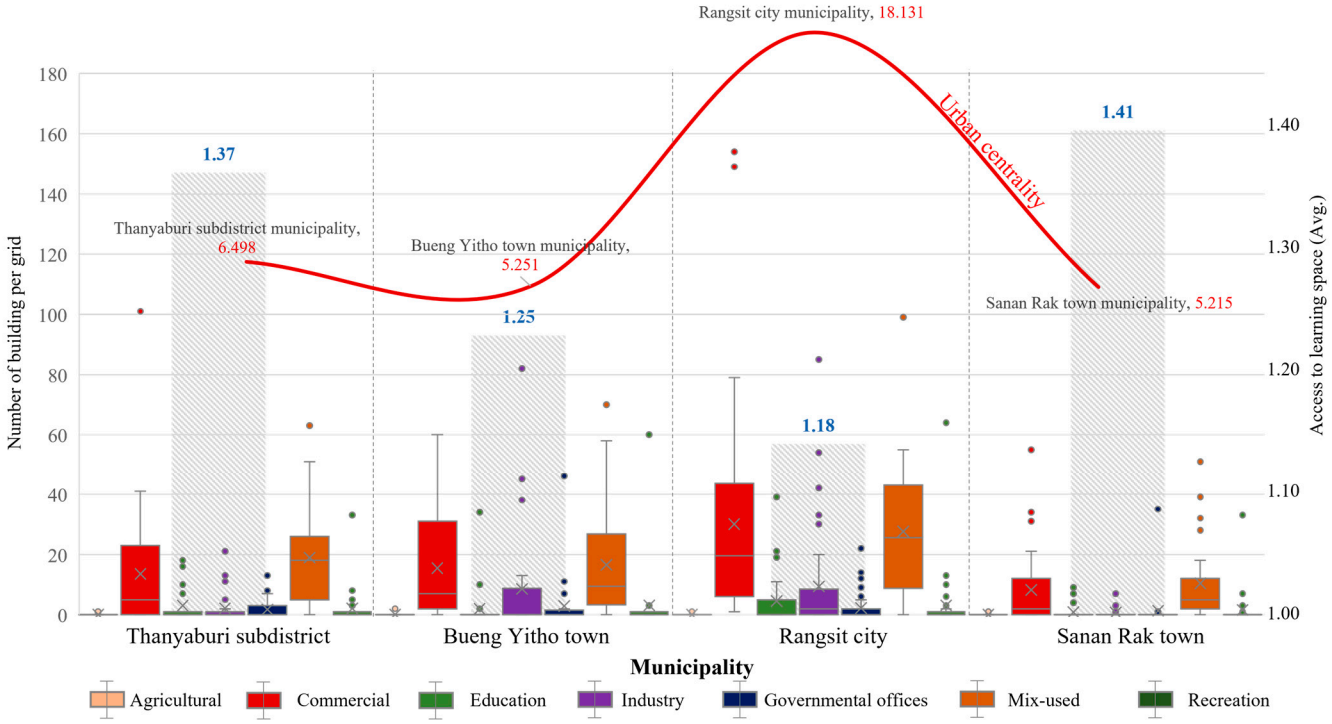


Figure 8. Centrality score and activities by municipality.

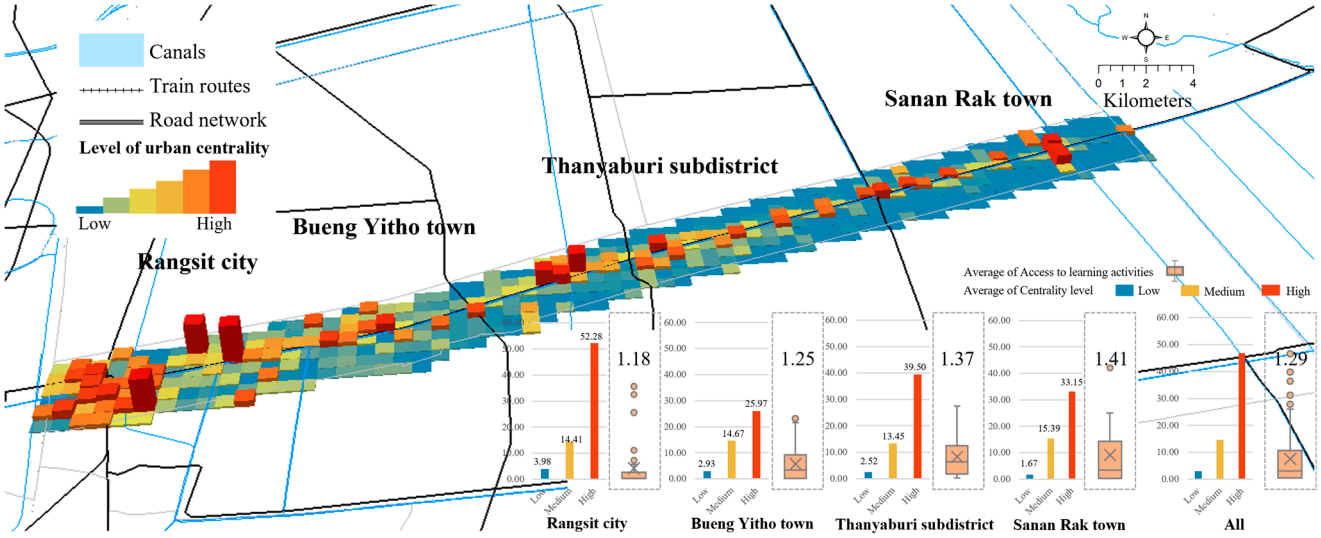


Figure 9. Centrality index scores and accessibility of learning activities of each area.

4. Discussion

The findings show that urbanization in the province of Pathum Thani, Thailand, does not contain adequate learning activities for its residents. It is possible that life circumstances such as work may influence opportunities to access learning activities or that urban centers do not have the appropriate learning activities desired by its residents. Thus, prior to creating urban planning and design for new infrastructures, facilities and services, it is imperative to understand the needs of people who live in the community. There is a clear need to better link urban development with learning activities desired by residents to make cities more vibrant. Additionally, from an urban planning perspective, better understanding the capacity of cities (space and cost) to create activity hubs can improve the design and attractiveness of learning activities for residents and visitors.

The creation of "learning cities" requires not only ample activities but a range of different activities. It is well known that migration moves towards cities from suburban and rural areas in search of better opportunities including education, employment or more attractions [30,36]. Cities must be constructed in a way that provides opportunities for a wide range of activities. Our findings show that the most popular activities were community-based, environmental and educational activities, respectively. However, it was also clear that different municipalities provide different opportunities that are unique to each area. The centrality score provides a metric for understanding activity allocation based on infrastructures, facilities and services; however, there is limited information on activity usage. It is likely that centrality and accessibility also highly influence participation in activities, especially if they are not within their home municipality. Additionally, all municipalities were focused on commercial and mixed land-use developments compared to providing opportunities for recreational activities. To enhance attractiveness for all municipalities, all should provide greater opportunities for activities and have activities that are related to the interests of its residents. Simply having space or having activities in general does not guarantee activity participation, as people generally have a wide range of interests. The findings indicate that urban planners should place more emphasis on creating opportunities for learning when considering their urban planning and design. However, it is also important that urban planning approaches solicit input from community members to maximize the benefit of urban development.

Planning the creation and development of accessible and desired activities is an important indicator for a city's sustainability [42]. Additionally, such activities are a driver to develop and improve skills at the individual, family and community levels, all of which can improve social dynamics and drive the economy. In addition to improving planning and infrastructures to support learning cities, online learning has become a popular medium.

Online learning, otherwise known as field-based learning, is more effective especially when creating interaction between learners [43] and includes education and training (learning new skills or upgrading qualifications) for community members to ensure they have the skills required for employment opportunities [14,30]. Future studies are needed to examine whether there is a strong preference for online learning vs. more traditional learning activities that require travel. This can help inform how future activities are promoted and developed.

While this study shows the association between available activities and centrality scores of each municipality, it is also possible that learning opportunities are influenced by socio-economic factors. It is possible that despite municipalities having the desired activities, some of them may not be affordable to low-income residents. Unfortunately, this study could not examine the residential location and where they were going to access activities. We hypothesize that many residents participate in activities within their home municipality; however, it is also possible that residents travel to other municipalities to access certain activities. The complexities of spatio-functional interactions can efficiently capture and translate to spatial descriptions in explaining functional structures and residents' learning activity utilization patterns. Better understanding the learning opportunities desired by residents and travel patterns to access learning opportunities, in tandem with socio-demographic factors, would provide a more comprehensive picture of lifelong learning opportunities among a range of diverse users, which is important from a planning perspective. The geospatial modeling used in this study should be incorporated into urban planning developments to better visualize where opportunities for learning activities can exist or where they can be allocated. Understanding the capacity of municipalities to host a range of activities can help reduce economic divide and allow for a more prosperous local economy, supporting the movement towards a "learning city".

Our findings provide urban planners with additional considerations when designing and developing urban structures given their association with learning activities. While centrality scores are useful for examining urban density, merging centrality scores with both physical data (building structures) and activity participation can further validate and expand its use. This novel approach helps address limitations of prior research that have used either GIS or focus groups to capture data on learning activities. Our current approach using geospatial analyses with various metrics allows further examination considering geographical boundaries and various socio-economic factors (e.g., income, vulnerable groups), which are important considerations for urban planners. More importantly, incorporating community needs (e.g., surveys or focus groups) with the modeling techniques used in the present study can enhance urban planning and ensure the voices of the community are heard. Additionally, community members can often provide input, not otherwise captured, to improve urban planning and design. Moreover, community members are more likely to participate in activities and have a stronger sense of community if they are provided the opportunity to provide input on urban planning and design. This bottom-up approach can ensure many facets of planning are incorporated including the interaction between land use and transportation to ensure activities are needed and accessible. This would also ensure the long-term development goals of urban planning and ensure its sustainability through the provision of appropriate learning activities [30]. The findings must take into account the study's limitations. While we identified centrality scores and their association with learning activities, we could not describe the community's actual utilization of those learning activities. Future studies need to examine who is accessing what learning activities and from where. This will provide important information about whether local residents are using the existing learning activities and would provide further validation of using centrality scores as a design metric. Additionally, despite employing a 500×500 grid to ensure adequate geographic representation, it is unclear whether our sample is the representative of the demographics within each district. This may directly influence the responses for what learning activities are the most desirable as well as the association between centrality scores and learning activities. Moreover, we could not identify participants who accessed

learning activities. Although the GIS maps show roadways, we do not know if the transit routes are in near proximity to learning activities. This is another factor that could influence activity uptake.

5. Conclusions

This study considered the association between urban development and learning activities in Thanyaburi district, Pathum Thani province. The findings show that the most popular activities were community-based, environmental and educational activities, respectively. However, various municipalities had few learning opportunities for local residents. The results also indicate a significant conflict between the pattern of urbanization and accessibility across a variety of learning activities within Thanyaburi district. This may be due to several factors that influence activity uptake including land-use patterns, transportation and spatial configuration of urban structures [44]. Future studies need to capture additional information on demographics, transportation availability and usage, travelling distance and urban design to determine how best to develop "learning cities". Promoting lifelong learning opportunities is an essential response to establishing a vibrant environment for individuals, communities and cities and is a key driver to improving economic development (e.g., employment and education) and sustainability.

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