EXPLORING THE SPATIAL LINKAGES BETWEEN TOURIST ATTRACTION LOCATION WITH SURROUNDING FACILITIES IN BANDUNG CITY, INDONESIA

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ABSTRACT: Bandung is one of the holiday destination cities in Indonesia. The city of Bandung is located in the Bandung Basin area, surrounded by mountains. However, the location of the arrival gate for domestic and foreign tourists is still centered in the city of Bandung, both for airports, train stations, and travel agencies. This provides many opportunities to develop various tourist areas. Previous studies showed that there is a relationship between the location of tourism sites and supporting facilities. This study aims to explore the spatial linkages between tourist attraction locations with surrounding facilities in Bandung City, Indonesia. The spatial data were edited and visualized using the Geographic Information System (GIS). PostgreSQL managed the spatial database management systems as well as utilizing various query functions for spatial data in the PostGIS extension. This study also used Python programming language to automate the SQL query execution in connection to PostgreSQL using the Psycopg2 library. Co-location pattern mining is used to analyze spatial behavior between the tourism site and its supporting facility in Bandung City, namely leisure facilities, accommodation, food services facilities, shopping facilities, and transportation facilities. There are sets of facilities in a spatial neighborhood that have a co-location pattern, also known as co-location rules. The computational results show a strong co-location pattern between spatial data sets, which consist of accommodation, food services facilities, leisure facilities, and shopping facilities. Related to the object of this research, tourist attractions also have a co-location rule, as a set with accommodation, food services facilities, and leisure facilities. This co-existence of tourism features in the spatial neighborhood can be used as a consideration for government and business developers to develop and improve both tourism destinations and facilities to attract more tourists, as known that the tourism sector is a new economic source in Indonesia.

1. INTRODUCTION

The tourism sector contributes 4.8% to Indonesia's GDP in 2019 according to the Ministry of Tourism and Creative Economy. The national tourism sector experienced consistent and significant growth in 2015-2019 although there's a decline in 2016. The tourism sector's contribution to GDP is increasing continuously and achieve the target, hence this sector is ranked as a foreign exchange earner just after the palm oil industry (Ministry of Tourism and Creative Economy, 2019). One main agenda of the National Mid-Term Development Plan (RPJMN) is strengthening economic resilience for quality growth, and it can be achieved by accelerating the value-added increase in agro-fishery industry, maritime, energy, industry, tourism, and digital & creative economy. The predicted tourism sector's contribution to national GDP in 2024 is 5.5% (Ministry of National Development Planning of the Republic of Indonesia, 2019). Tourist attraction consists of all non-home elements that drive travelers to leave their homes (Lew, 1987). Tourist attraction also includes a full range of services, product, and experiences in supporting the activities. It includes the attractions themselves, accommodation, transportation, food and drink services, retail outlets, gallery/museum, and even the place where the local community resides (UNESCO, 2016). The number of foreign tourists visiting Indonesia in 2017-2019 is growing 5.37% annually (Statistics Indonesia, 2021). In Bandung, the annual growth of number for both domestics and foreign tourists during 2014-2019 is 7.29% and 6.39% respectively (Kementerian Keuangan, 2020).

However, the tourism sector which continues to grow, both in Indonesia in general and in tourist cities in particular, has been disrupted by the Covid-19 pandemic. Figure 1 shows the time series data for 2015-2020, for foreign tourists numbers who visit West Java via Husein Sastranegara Airport Entrance Bandung City (BPS-Statistics of Bandung Municipality, 2021a). This data indicates a decrease in tourism activity that occurred in Bandung city. Another indicator is indicated by data on the occupancy rate of star hotels. Figure 2 shows the star hotel occupation rate (%), in the 2011 - 2021 time series (21st-year data includes January to July data), for the province of West Java and all provinces in Indonesia (STB, 2016). The decline in the number of tourism activities shown by the star hotel occupation rate data occurred starting in 2020 and continue in 2021. This is under the discussion on the 2020-2024 Strategic Plan from The Ministry of Tourism and Creative Economy published in July 2020, that "The United Nation World Tourism Organization (UNWTO) estimates that there will be a decline in international tourist arrivals by 58% to 78%. in 2020 compared to 2019". To revive from this adversity, all stakeholders need to prepare for a new normal situation, by providing various tourism activities in destinations, as well as supporting facilities for tourism activities.

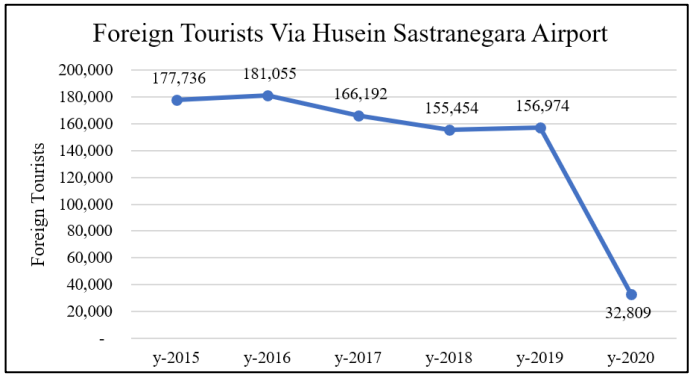

Figure 1 Foreign Tourists Numbers Who Visit West Java Via Husein Sastranegara Airport Entrance Bandung City, 2015-2020

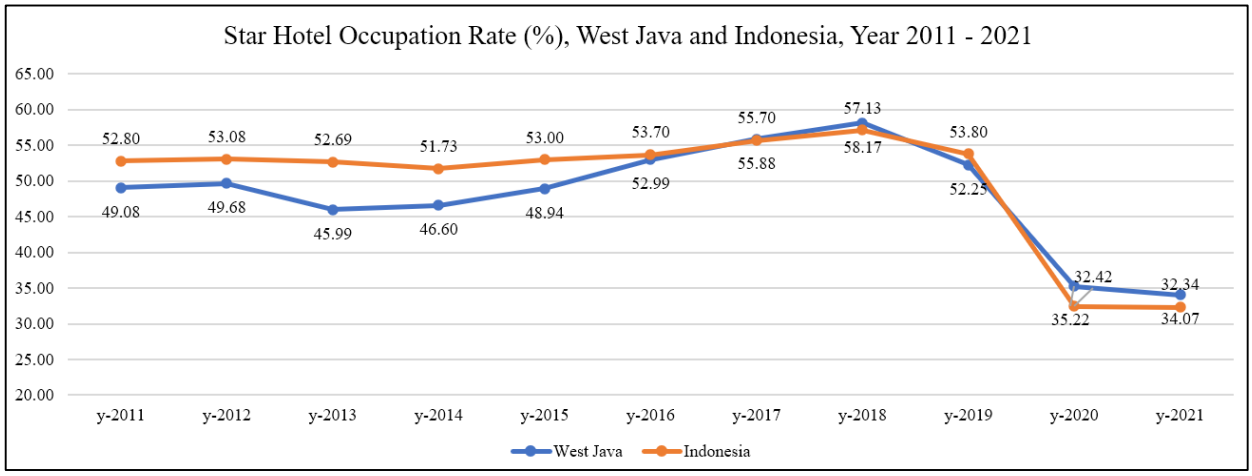

Figure 2 Star Hotel Occupation Rate (%), West Java and Indonesia, the Year 2011 - 2021

The objects of this study are the tourist attraction sites and the tourism support facilities, including accommodation facilities, food services facilities, leisure facilities, shopping facilities, and transportation services facilities. The spatial linkages between tourist attraction locations with surrounding facilities need to explore, as the foundation for the stakeholders for determining the strategy for developing the service chain of tourism support facilities. The accommodation and food & beverages services sector contributed 4.94% to Bandung City's regional GDP in 2019, which is ranked as the 7th largest contributing sector to Bandung's regional GDP. Other tourism supporting sectors such as the transportation & warehousing sector contributed 10.83% (BPS-Statistics of Bandung Municipality, 2021b). It can be said that location is one factor that highly influencing visitors (Berné & García-Uceda, 2007). This finding is applicable for accommodation facilities, in which location, price, and business functions are the factors influencing guests' choices (Yang *et al*., 2017). The differences among tourist attractions are classified by grouping into such classes that reflect the behavior of tourists (Navarro, 2015). According to Song and Ko (2017), sightseeing activities, transportation - business accessibilities, and market share are the factors that influencing area demand. Cong, Wu, Morrison, and Xi (2014) use minimum distance points index, kernel density estimation, and radius of gyration methods to visualize the distributions and relationships of convention facilities, tourist attractions, and supporting facilities.

This study used co-location pattern mining to determine which objects are co-located with each other. The algorithm used to discover co-location patterns is based on a mining algorithm proposed by Huang *et al*. (2004), using the concept of proximity neighborhood. Spatial co-location pattern mining is one kind of data mining to discover spatial patterns (Sheshikala *et al*., 2016). The pattern mining is derived from association rules theory, but no transactions are used in co-location pattern mining, instead, it utilizes iteration between all possible combinations of spatial data points with R-proximity neighborhood to discover the spatial pattern. An enhanced algorithm for co-location pattern mining algorithm from Huang *et al*. (2004) is taking the pruned version of the first combination of co-location patterns to calculate the prevalence of assured co-location patterns (Sheshikala *et al*., 2016). There's another improved algorithm to find co-location patterns from Sheshikala *et al*. (2016), by using a parallel join-less algorithm based on grid-based partition and map-reduce approach, that can be used for clustered datasets. However, the objective of this study is to give an overview of Bandung City's spatial characteristics for tourism and supporting facilities development by looking for any patterns of each spatial data without any further clustering. This study aims to explore the spatial

linkages between tourist attraction locations with surrounding facilities in Bandung City, Indonesia. Choosing the location for development can be determined by applying the result of co-location pattern result in this study, benefiting business developers and the government. This paper also introduces an integrated method of co-location pattern mining using PostgreSQL for the data mining and Python for the automation of SQL querying to minimize the manual work in the mining process.

The present study is organized as follows. The introduction part explains the current tourism situation and the motivation and purpose of this research. The methods used to achieve the research objectives are stated in the introduction section, and explained in subsections 1.1 and 1.2, to position this research compared to previous studies. The literature review in Section 1.1 is discussing previous research about tourism development by using other methods than co-location pattern mining, and Section 1.2 is discussing the co-location pattern mining method. Section 2 clarifies the research methodology, the calculations, and the data used in this paper. Section 3 shows the results of the study and discusses the finding issues. Section 4 concludes the study and recommends further action for development.

1.1 Previous Research about Tourism Development

The preliminary study by Hermawan *et al*. (2018) is about urban tourism development in Bandung City. The method used in the study is factor analysis to discover patterns in Bandung City Tourism, and cluster analysis to strengthen each city segmentation based on tourists' characteristics. Data is collected through questionnaires filled by 100 respondents. The 2 factors why tourists visiting Bandung City are social expression and interactive learning. While in cluster analysis, the K-Means method was used to process all variables, resulting in 5 clusters that produced significant value in ANOVA results. The clusters were based on how often the tourists visit Bandung City for vacation, resulting in that 32% of visiting tourists have less experience according to visitation frequency, number of destinations, and number of media information they know.

Wulung (2021) has researched continuous development for tourism destinations using a spatial approach. The object of the research is tourist attraction sites and amenities in the District of Lembang, West Bandung Regency, which is close to Bandung City. The qualitative approach was used as the method of the research. There is no calculation performed in determining spatial characteristics, but a simple clustering and categorizing each object by sub-district and type of tourist attraction sites such as nature, human-built, and cultural tourism sites. The results are visualized using ArcGIS and Adobe Illustrator, showing that there are special characteristics of tourism sites. The northern and eastern parts of Lembang have dominated with nature tourism sites and the theme of tourism is ecotourism for that part. Meanwhile, the southern and western parts of Lembang are dominated by human-built tourism sites, and it's suitable for recreation and education-themed tourism.

Dewanti *et al*. (2019) also researched spatial patterns in West Bandung Regency, especially for agro-tourism development, using physio geographic and sociodemographic elements based analysis, giving insights that there is a statistically significant relationship between accessibility indicators (socio-geographic) and physio geographic elements, hence it is recommended to develop agro-tourism areas in the location that satisfied those criteria.

1.2 Co-Location Pattern Mining

The closest field of data mining to the co-location rule is the association rule. Agrawal and Srikant (1994) presented 2 fast algorithms for mining association rules especially for large datasets, Apriori and AprioriTid. It is faster than the previously known algorithm which is AIS and SETM algorithm. Co-location can be defined as a group of dissimilar objects which are located in determining proximity (Maiti & Subramanyam, 2018). There is no natural notion of transactions in spatial datasets in the co-location rule, which the association rule has, resulting in a transaction-free approach for co-location patterns mining by using the proximity neighborhood concept (Huang *et al*., 2004). The approach from Huang *et al*. (2004) includes a multi-resolution pruning technique by filtering out combinations according to the participation index threshold value, which is 50%.

Another method for co-location pattern mining is by using the Q-statistics approach (Yan *et al*., 2018). Yan *et al*. (2018) used this approach to determine the co-location pattern between hotels' level: budget, mid-level, and luxury hotels. The results are hotels' location can be affected by the types of their neighboring hotels. Flores *et al*. (2017) used the CLQ-statistic approach for mining the co-location pattern of aerospace industry firms in Mexico. The CLQ-statistic is used by geographers and economists to assess the specialization of a region based on specific industries due to its root in the classical location quotient, and one of the features of CLQ statistic is that the possibility to obtain unidirectional or bidirectional spatial co-location patterns (Flores *et al*., 2017). It is concluded that the aerospace industry cluster in Mexico is composed of itself, metal and product manufacturing, machinery and equipment industry, electronics industry, and services.

Widaningrum *et al*. (2020) researched spatial characteristics of tourism sites in cultural world heritage sites. The research applied co-location pattern mining to examine the behavior between tourism sites and supporting facilities by using the participation index as the metric (Widaningrum *et al*., 2020). The results show that tourism sites need more development in supporting facilities surrounding the sites, giving us an insight that tourism sites were not well supported by the surrounding facilities, and suggested a further development based on research results to promote the tourism sectors. Jabbar *et al*. (2018) proposed AGT-Fisher (Aggregate Grid Transactionization) approach for co-location pattern mining. The process of this algorithm consists of transactionizing the spatial dataset with AGT, and mining for association rules with Fisher's statistical significance test. In this paper, the algorithm from Huang *et al*.(2004) is used.

2. METHOD

The spatial data required in this study are Bandung City area boundaries, locations of tourism sites, and locations of supporting facilities. Figure 3 shows the stages of the research, which include the process of collecting, pre-processing, visualizing, and processing data. This stage used the Google Maps Python library to geocode location data, QGIS as the open-source Geographic Information System, PostgreSQL as the open source object-relational database system, and Python as the programming language to integrate the system.

The administrative area boundaries were retrieved from Indonesia Geospatial Portal. In this study, boundaries by the district are used as the data, and a number of the total district in Bandung City is 30 districts. Tourism sites and tourism services businesses data were retrieved from the website of Bandung City's Department of Culture and Tourism. Each data was categorized and can be seen in Table 1. The retrieved data contained the business or site's name, short address, coordinates, and some sub-categories. Further retrieval is conducted by utilizing the Google Maps Python library to verify each object's address and the full address components and to geocode the missing coordinates information. Both administrative area boundaries and locations data are imported to QGIS for visualization, and then clipped the coordinates that lay outside the boundaries. The visualization result can be seen in Figure 4. The data were split based on category and exported as shapefile format (.shp) for further processing in PostgreSQL.

Data in shapefile format is imported to PostgreSQL by using an extension called PostGIS, which allows PostgreSQL to read the shapefile format, preserving the spatial attributes, which in this case is an additional column named "geom" that locate the spatial elements for each item. PostGIS extension is the key that makes PostgreSQL able to calculate the distance of 2 points by using the ST_DISTANCE function. The method of distance calculation is Euclidean distance, which is shown in Equation (1).

$$d_{(p,q)} = \sqrt{(q_1 - p_1)^2 + (q_2 - p_2)^2} \quad (1)$$

Previously, location data had been re-projected in QGIS from WGS84 - World Geodetic System 1984 (EPSG:4326) to WGS 84 / UTM zone 48S (EPSG:32748). The scope of the research area is not wide, therefore distance measurement using the Euclidean distance technique with this projected coordinate system is considered adequate. Otherwise, Haversine distance could be an alternative for calculating the distance from coordinates without any projection, since it accounts for the curvature of the Earth in the calculations.

Co-location pattern mining will be determined by the participation ratio (PR) of each combination of categories and the participation indices (PI) of the combinations of 2 categories co-located. The value of PR and PI can be obtained by using Equations (2) and (3).

$$PI = \min(PR_1, PR_2, \dots, PR_n) \quad (2)$$

$$PR = \frac{number\ of\ unique\ occurrences\ in\ combinations}{number\ of\ total\ count\ of\ corresponding\ category} \quad (3)$$

According to Huang *et al*. (2004), the approach to obtain PR is by calculating the number of unique occurrences in combinations and divided by the total count of the category. The R-proximity in this study is based on geographic distance. For example, the proximity of R is 1 kilometer, which means the dataset is containing every item inside the radius of 1 kilometer. The datasets in the proximity R (1 kilometer) for example will be like $\{A1, A2, B1, B7, B4, A4, A5\}$. Given that the total count of datasets A is 5 (A: $\{A1, A2, A3, A4, A5\}$), and datasets B is 8 (B: $\{B1, B2, B3, B4, B5, B6, B7, B8\}$) The participation ratio for category A is $^4/_5 = 80\%$, and for category B is

$^3/_8 = 37.5\%$. From these two numbers, the participation index could be calculated by taking the minimum value between PR A and PR B, which is 37.5%.

The co-location threshold is 50% (Huang *et al*., 2004), therefore in this example, A and B do not meet the co-location rule since 37.5% < 50%. The number of combined combinations will follow the combination formula $C(n,r)$, where r is $2 \leq r \leq n-1$. Hence in this study, the combination will be $C(6,2) = 15$, $C(6,3) = 20$, $C(6,4) = 15$, and $C(6,5) = 6$, so the total number of unique combination will be 56 combinations. In order to minimize manual works, Python is used for automating the SQL query execution, using psycopg2 library allowing Python connection to PostgreSQL databases in local machine.

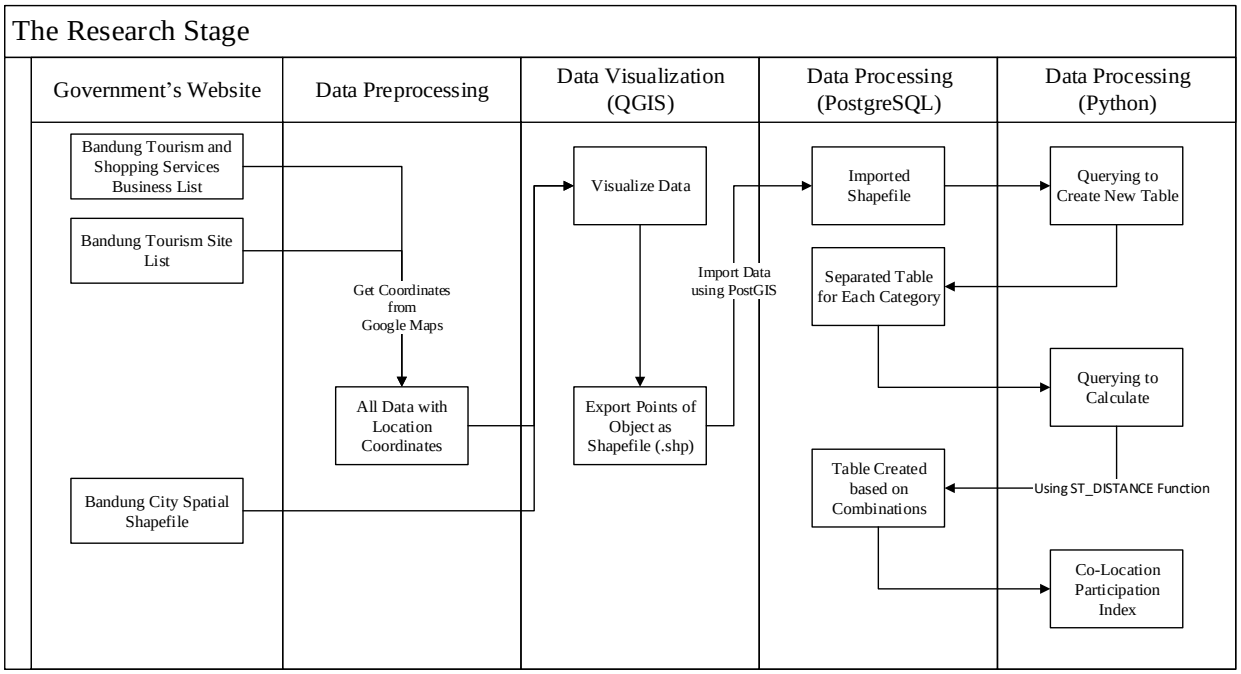

Figure 3 The Research Stage

3. RESULT AND DISCUSSION

3.1 Distribution of Tourist Attractions and Location Support Facilities Location Data

The object of research is referred to as the 'Category' retrieved from the Bandung City Department of Culture and Tourism's website. The number for each category and sub-category can be seen in Table 1. There are 5 sub-categories of tourist attractions based on information obtained from the Bandung City Department of Culture and Tourism's website, namely cultural tourism sites, education tourism sites, natural tourism sites, recreational tourism sites, and religious tourism sites. There are only two natural tourism sites (4% of all tourist attractions) in Bandung city because areas with ecosystem services that support tourism activities are located in regencies around the city of Bandung.

Figure 4 shows the distribution of tourist attractions and location support facilities location data. There are quite a large number of location points for food service facilities, recreational facilities, accommodation, and shopping facilities. However, the locations are not evenly distributed. The west side of Bandung city has more facility points compared to the east side. Visually, it can be assumed that accommodation facilities, food services facilities, and leisure facilities have a co-location pattern. Location data from these six categories are then managed into a spatial database in PostgreSQL. The data is processed using the PostGIS function (an extension of PostgreSQL) which is executed using the Psycopg2 library of the Python programming language.

3.2 Co-location Pattern Analysis

The database contains all objects including the coordinates and geometry from QGIS and converted to PostgreSQL using PostGIS. PostGIS imports the spatial references of each data (in .shp format). Calculations of distance will use the ST_DISTANCE function from PostGIS and the data querying will be automated using Python integration to PostgreSQL. The query will return all data filtered by maximum distance, which in this study is 1 kilometer. Each

combination will be counted for a total number of unique occurrences and divided by the total count of the corresponding category to get the participation ratios. The participation index will be obtained by the minimum value for all participant ratios for each combination. The tables presented in this paper are the pruned version, which is only selecting a participation index more than or equal to 50%, as the prevalence threshold.

Table 1 The Number of Tourist Attraction and the Supporting Facility Category and Sub Category.

Category	Sub Category	Count	Total Count
Leisure Facilities	Agro Tourism	2	637
	Billiard Facilities	16	
	Bowling Alley	1	
	Cinema	15	
	Fishing Pond	51	
	Fitness Center	115	
	Games Arena Business	31	
	Golf Course	2	
	Karaoke	91	
	Nightclub or Disco	32	
	Privately Managed Museum	7	
	Soccer Field	28	
	Sport Center	22	
	Swimming Pool	53	
	Tennis Field	32	
	Theme or Amusement Park	45	
	Travel Agency	94	

Category	Sub Category	Count	Total Count
Accommodation		508	508
Food Services Facilities	Bakery	17	1447
	Cafe	318	
	Restaurant	1112	
Shopping Facilities	Distro	155	326
	Mall/ Supermall/ Plaza	36	
	Outlet	135	
Tourist Attraction	Cultural Tourism Site	9	45
	Education Tourism Site	16	
	Natural Tourism Site	2	
	Recreational Tourism Site	10	
	Religious Tourism Site	8	
Transportation Facilities	Airport	1	26
	Terminal	18	
	Train Station	7	

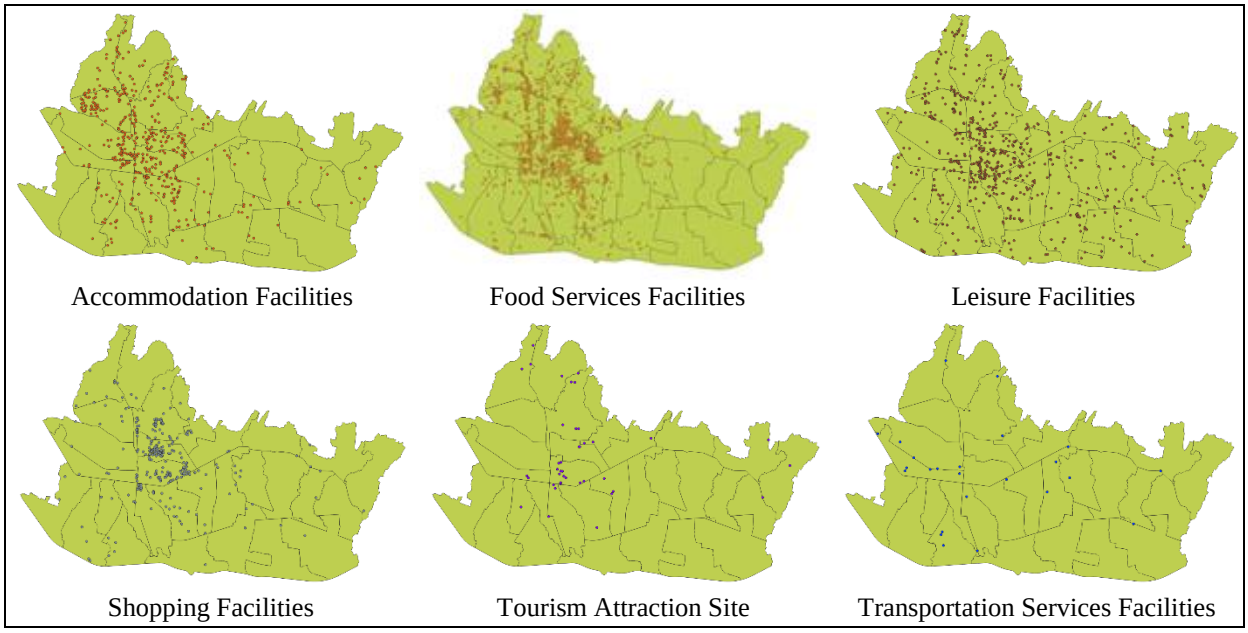

Figure 4 Distribution of Location-Based on Category

Table 2 shows the participation ratios and participation indices between pairs of categories. There are ten from fifteen co-location candidates that are co-location rules, identified with a Participation index value greater than or equal to 50%. The highest participation index between the 2 categories is accommodation and food services facilities, resulting

in 96%. It means that there is a 96% chance of both accommodation facilities and food services facilities are within a 1-kilometer range apart. Thus, it can be interpreted that accommodation and food services facilities (and so on for the other 9 combinations) are co-location rules. There are 5 pairs of combinations which have value of participation index more than or equal to 90%, accommodation – food services facilities, food services facilities – leisure facilities, accommodation – leisure facilities, food services facilities – shopping facilities, and accommodation – shopping facilities. It means that these objects categories are closely located to each other in the proximity of 1 kilometer. However, any pairs of combinations that have tourist attraction objects are the 4 lowest participation index values after all possible combinations being pruned by the threshold (>50%). The range of participation indices that have tourist attraction objects in the pairs is 53% to 78%. There are no pairs that have transportation services facilities objects in combinations resulting in a higher participation index than the threshold. This finding can be information for the government to develop more transportation services facilities in Bandung City since it can be seen in Figure 4 that the transportation services facilities category has the least number of items.

The same interpretation can be applied to other co-location sizes. Table 3 shows the participation ratios and participation indices between the 3-size combination of categories. There are eight from twenty co-location candidates (only 40%) that are co-location rules. For every set of three combinations of categories, 4 sets have a value of participation index of more than 80%, accommodation – food services facilities – leisure facilities, accommodation – food services facilities – shopping facilities, food services facilities – leisure facilities – shopping facilities, and accommodation – leisure facilities – shopping facilities. There is no tourist attraction object in the mentioned set, although all tourist attraction participation ratios are in the range of 89% to 98% as shown in Table 3. It means that tourist attractions are all surrounded by food services facilities, shopping facilities, leisure facilities, and accommodation, as Table 2 shows the participant ratios of pairs and the range for any combinations containing tourist attraction objects is 89% to 100%. The combination of size-2 and size-3 has in common that 4 of them have candidate tourist attraction members, notwithstanding the Participation Index have the lowest value from the prevalence threshold. Tourist attractions in pairs are co-location rules with shopping facilities, food services facilities, leisure facilities, and accommodation facilities.

Table 4 shows the participation ratios and participation indices between the 4-size combination of categories. However, only 2 out of 15 co-location candidates (13%) are co-location rules. The results are pruned by the threshold, and just resulting 2 sets that are beyond the threshold. In the 4-size combination of categories, tourist attractions have co-location rules with accommodation facilities, food services facilities, and leisure facilities. The co-location rule of accommodation facilities, food services facilities, leisure facilities, and shopping facilities, has the highest participation index. Further research can be conducted to clarify this phenomenon, that although not in the context of tourism activities, these four categories of facilities are clusters of service providers to support urban people activities.

Table 2 Participation Ratios and Participation Indices between Pairs of Category

No	Co-Location		Participation Ratio (Pr)		Participation Index (PI)
	A	B	A	B	
1	Accommodation	Food Services Facilities	97%	96%	96%
2	Food Services Facilities	Leisure Facilities	97%	95%	95%
3	Accommodation	Leisure Facilities	98%	93%	93%
4	Food Services Facilities	Shopping Facilities	90%	96%	90%
5	Accommodation	Shopping Facilities	90%	95%	90%
6	Leisure Facilities	Shopping Facilities	85%	97%	85%
7	Shopping Facilities	Tourist Attraction	78%	89%	78%
8	Food Services Facilities	Tourist Attraction	64%	98%	64%
9	Leisure Facilities	Tourist Attraction	56%	100%	56%
10	Accommodation	Tourist Attraction	53%	96%	53%

Table 3 Participation Ratios and Participation Indices between 3 Combination of Category.

No	Co-Location			Participation Ratio (Pr)			Participation Index (PI)
	A	B	C	A	B	C	
1	Accommodation	Food Services Facilities	Leisure Facilities	96%	95%	89%	89%
2	Accommodation	Food Services Facilities	Shopping Facilities	90%	89%	94%	89%
3	Food Services Facilities	Leisure Facilities	Shopping Facilities	89%	83%	95%	83%

4	Accommodation	Leisure Facilities	Shopping Facilities	90%	82%	95%	82%
5	Food Services Facilities	Shopping Facilities	Tourist Attraction	61%	78%	89%	61%
6	Food Services Facilities	Leisure Facilities	Tourist Attraction	63%	55%	98%	55%
7	Accommodation	Leisure Facilities	Tourist Attraction	53%	55%	96%	53%
8	Accommodation	Food Services Facilities	Tourist Attraction	53%	63%	93%	53%

For every set of four combinations of categories, there are only 2 sets left after being pruned by the threshold. The set of four with the highest participation index value is accommodation – food services facilities – leisure facilities – shopping facilities with participation index value equal to 82%. The other set is accommodation – food services facilities – leisure facilities – tourist attraction with participation index value equal to 52%. These results inform us that these categories are located within a 1-kilometer radius, as the set R-proximity at first. The last set can be classified as co-located although the participation index value is just slightly above the threshold. Based on these findings, it can be said that tourism activities in Bandung City are not 100% relying on tourist attractions, instead, the supporting facilities play a major part in the urban tourism activities. There is no combination beyond the co-location threshold for a set of five, hence the co-location pattern mining stops at $k = 4$.

Table 4 Participation Ratios and Participation Indices between 4 Combination of Category.

No	Co-Location				Participation Ratio (Pr)				Participation Index (PI)
	A	B	C	D	A	B	C	D	
1	Accommodation	Food Services Facilities	Leisure Facilities	Shopping Facilities	90%	88%	82%	94%	82%
2	Accommodation	Food Services Facilities	Leisure Facilities	Tourist Attraction	52%	63%	54%	93%	52%

There are six size-5 co-location candidates, and none meet the prevalence threshold criteria. The highest participation index is 48%, for tourist attractions and 4 supporting facilities, namely accommodation facilities, food services facilities, leisure facilities, and shopping facilities. For more detailed information, the calculation result is shown in Table 5. The results of this computation can be interpreted that the co-existence between tourist attraction location with surrounding facilities is not found simultaneously, but partially. However, for all sizes of co-location candidates, tourist attractions have never had co-location rules with transportation facilities. This may be because the transportation facilities mapped in this study are main entrances from outside the city, not the city mass transportation.

Table 5 Participation Ratios and Participation Indices between 5 Combination of Category

No	Co-Location					Participation Ratio (Pr)					Participation Index (PI)
	A	B	C	D	E	A	B	C	D	E	
1	Accommodation	Food Services Facilities	Leisure Facilities	Shopping Facilities	Tourist Attraction	48%	60%	49%	77%	87%	48%
2	Accommodation	Food Services Facilities	Leisure Facilities	Shopping Facilities	Transportation Facilities	33%	36%	32%	39%	65%	32%
3	Accommodation	Food Services Facilities	Leisure Facilities	Tourist Attraction	Transportation Facilities	27%	31%	27%	69%	35%	27%
4	Food Services Facilities	Leisure Facilities	Shopping Facilities	Tourist Attraction	Transportation Facilities	30%	25%	33%	64%	38%	25%
5	Accommodation	Food Services Facilities	Shopping Facilities	Tourist Attraction	Transportation Facilities	24%	30%	33%	62%	31%	24%
6	Accommodation	Leisure Facilities	Shopping Facilities	Tourist Attraction	Transportation Facilities	24%	24%	33%	62%	31%	24%

Bandung city has 45 tourist attraction sites listed by the government. It can be seen in Table 4 that for a set of 4, the tourist attraction participation ratio value is 93%, which is 42 sites show up in the R-proximity (1 kilometer). The attractions which do not show up can be seen in Table 6. Visualization for better insights in seeing the surrounding facilities of tourist attractions in Table 6 can be seen in Figure 5. It shows that these 3 tourist attractions are just surrounded by few facilities, hence these sites are the priority for further development.

Table 6 Tourist Attractions that Lack of Supporting Facilities

Sub Category	Place Name	Sub District	District	City	Province	Latitude	Longitude
Cultural Tourism Site	Saung Angklung Udjo	Pasirlayung	Cibeunying Kidul	Bandung City	West Java	-6.89803	107.65496
Cultural Tourism Site	Kawasan Wisata Pasir Kunci	Pasirjati	Ujung Berung	Bandung City	West Java	-6.89846	107.71397
Cultural Tourism Site	Kawasan Wisata Pasanggrahan	Palasari	Cibiru	Bandung City	West Java	-6.91131	107.72482

The method of co-location pattern mining is based on Huang *et al*. (2004) proximity neighborhood approach. This study proved that the integration between the spatial database in PostgreSQL and the execution using the python library has a good performance, in terms of computational accuracy and speed. The total data in this study is 2989 points of location categorized into 6 categories as can be seen in Table 1. The calculation involving PostGIS extension, ST_DISTANCE, and Python to automate the SQL query execution. There is a slight modification to the algorithm where no pruning is being executed after each k combination. The calculation was running with computer specification AMD Ryzen 7 2700X CPU and NVIDIA RTX 2060 6GB GPU. The iteration process, with $2 \leq k < 6$, has taking 4013 seconds to finish.

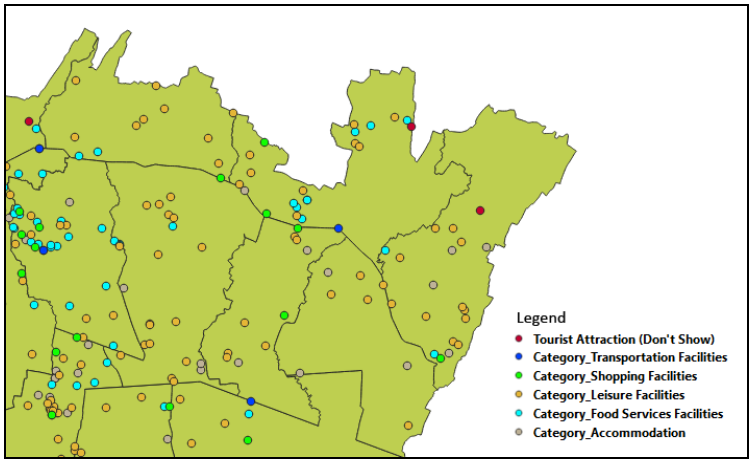

Figure 5. Plotting of Tourist Attraction that Lack of Supporting Facilities

4. CONCLUSION AND RECOMMENDATION

This study of spatial linkages between tourist attraction locations with supporting facilities in Bandung City is using co-location pattern mining as the method of exploration. It is assumed that the co-location rule is more accurate in describing points in proximity, compared to the purely qualitative approach, which doesn't account for any calculations in spatial pattern mining, so that the future location development for tourism area can be more specific according to the results. The result in this study is presented in 2 forms, the mapping of objects, and the co-location participation index for every combination of objects. The eastern side of Bandung is less developed in terms of tourism and supporting facilities based on the visualized data, therefore there is an opportunity to develop a new site for the tourism sector.

The co-location pattern results in this study can be an insight for business developers to create tourism supporting facilities with the proximity of four co-located categories mentioned, or at least by choosing the pairs from Table 2 with participation index value more than or equal to 90%. Business developers also have the chance to develop a new site with fewer competitors in the eastern side of Bandung, since as shown in Figure 4 the eastern side of Bandung city is underdeveloped in terms of the number of tourism sites and supporting facilities. The recommended prioritized districts for further development are Cibeunying Kidul, Ujung Berung, and Cibiru because the 3 tourist attractions that don't show up during the pattern mining are located in these districts each. The tourist attractions in these districts are the most underdeveloped in terms of surrounding facilities since it can be seen in Figure 5 that fewer facilities are surrounding them.

Future research could be conducted to integrate co-location pattern mining and other aspects such as socio-demographic and physio geographic elements in discovering a spatial pattern, as well as the algorithm improvement to have the automatic pruning capability. Another important further research is to analyze the co-location pattern based on the area (polygon data), for example shopping areas, culinary areas, and others, for bias reduction because of the number of facility locations with the same category in proximity.

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