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Distance-Based Spatial Analysis of Urban Tourist Attractions Relative to the Administrative Center of Sorong City, Southwest Papua

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Abstract. Sorong City is the main gateway to the Raja Ampat Islands, yet its own tourist attractions have rarely been examined as a spatial system. This study measured how far the city's attractions lie from the Mayor's Office, used as the administrative reference point, and whether they are clustered, random, or dispersed. Eight attractions with verified coordinates were analyzed. Straight-line distances and bearings were computed with the haversine formula, road distances were obtained from the OpenStreetMap network, and the spatial pattern was tested with nearest neighbor analysis. Robustness was examined with alternative reference points and boundaries, leave-one-out and omitted-attraction tests, coordinate perturbation, and three clustering methods. All attractions lie within ten kilometers of the reference point (mean 6.86 km) and of the airport and the Raja Ampat ferry terminal; road distances are 1.2–2.1 times longer. The nearest neighbor index of 0.26 ($Z = -4.03$) indicates a significantly clustered pattern relative to the 1,105 km² municipal territory, and held when any attraction was removed or four omitted attractions were added. Within tighter boundaries (58–102 km²), however, the global pattern did not differ significantly from random, and clustering was confined to short distances on the northern coast. Hierarchical clustering, DBSCAN, and kernel density analysis identified the same three groups: four beaches on the northern coast, a western waterfront pair, and a looser eastern nature pair. The results support planning Sorong as a compact, cluster-based urban destination; route and transport priorities should next be tested with visitor and travel data.

Keywords: Nearest Neighbor Analysis, Sorong City, Spatial Distribution, Tourism Accessibility, Tourism Planning.

1 Introduction

Sorong City, the capital of Southwest Papua Province, is the principal air and sea gateway to the Raja Ampat Islands. Atmodjo [1] showed that the growth of Raja Ampat tourism increases tourist arrivals in Sorong as a transit city, but has not been reflected in growth of the city's own tourism sector. At the regional scale, research has

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concentrated on the carrying capacity and infrastructure of Raja Ampat [2], leaving the attractions inside the city comparatively unexamined.

Sorong nevertheless has a set of attractions that could retain transit visitors for longer. Marau et al. [3] assessed five natural attractions in the city and rated Tanjung Kasuari Beach and Doom Island as having the highest potential. Naa et al. [4] described the ecotourism potential of the Klawalu mangrove forest, and Murni and Handyni [5] showed that destination planning and community participation significantly affect tourism sustainability at Tanjung Kasuari. Serkadifat et al. [6] documented the palm diversity of the Sorong Nature Park, which supports its role as a nature-based attraction. These studies evaluate attractions one at a time; none examines how the attractions are arranged in space relative to one another or to the city's administrative center.

The spatial arrangement of attractions shapes visitor movement, route design and the allocation of infrastructure. Studies in China have repeatedly used the nearest neighbor index and kernel density estimation to show that attractions tend to cluster around urban cores, transport corridors and water bodies [7]–[13]. Similar techniques have been applied in Egypt [14] and Thailand [15], where the resulting patterns were used to delimit development zones and design integrated routes.

Distance and accessibility are equally central to tourism planning. Network-based studies show that accessibility to attractions generally decreases from the city center outward [16], [17], and that peripheral attractions require deliberate transport planning if visitors are to be dispersed beyond the core [18]–[20]. Time–distance analysis has also been used to design day-trip routes from a central district [21], to evaluate the physical accessibility of attractions [22], and to identify anchor attractions within destination networks [23].

In Indonesia, city-scale and regency-scale applications of these methods remain limited. Yuniarti et al. [24] found a random-to-dispersed pattern of attractions in Pontianak, whereas Sunarno et al. [25] found a clustered pattern along the northern coast of Rembang Regency. No comparable study has been carried out for Sorong. This study therefore aims to (i) measure the distance and direction of the city's tourist attractions from the Mayor's Office as the administrative reference point and test whether the distance pattern changes when the airport, the seaports or the commercial center is used instead, (ii) determine the spatial distribution pattern of the attractions and its sensitivity to the study-area boundary, the attraction inventory and coordinate error, and (iii) identify attraction clusters with formal clustering methods that can inform tourism planning in Sorong City.

2 Materials and Methods

2.1 Study Area and Data

The study area is the administrative territory of Sorong City, Southwest Papua Province, Indonesia, covering approximately 1,105 km² across ten districts, including the Sorong Islands district [26]. Thirteen tourist attractions were initially listed from an online compilation of attractions in the city. A site was treated as a tourist attraction if

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it (i) is a named, publicly accessible place promoted for leisure visits, (ii) is visited mainly for its natural, recreational, heritage or religious-cultural interest rather than solely for accommodation, dining or shopping, and (iii) lies within the municipal boundary. Attractions outside the municipal boundary (Um Island, the Arfak Mountains, Lake Ayamaru and Sasnek Waterfall) were excluded. To assess completeness, the list was compared with the places shown for the city on Google Maps, OpenStreetMap and Wikivoyage. The inventory covers the principal promoted attractions but is not a complete census: smaller or recently opened sites, such as community-managed beaches and Raam Island, are promoted online but were not in the compilation. The effect of an incomplete inventory on the results was therefore tested (Sect. 2.5).

Coordinates were obtained by decoding the Google Maps Plus Codes listed for each attraction, using the Open Location Code reference library with the city as the reference location. A ten-character Plus Code identifies a cell of about 14 × 14 m, so encoding precision is not a material source of error; the larger uncertainty lies in where each place marker is put on the ground, which is assessed in Sect. 2.5. The coordinates of Doom Island, for which no Plus Code was available, were taken from OpenStreetMap. Five attractions without verifiable coordinates (Buddha Jayanti Temple, MOOI Park, Soop Island Beach, Panjang Beach and Tampa Garam) were excluded from the main analysis, leaving eight attractions (N = 8): Tanjung Kasuari, Alinda, Saoka and Tanjung Batu beaches (*Pantai*), Doom Island (*Pulau Doom*), Tembok Berlin, Klawalu Mangrove Park (*Taman Wisata Mangrove Klawalu*) and Sorong Nature Park (*Taman Wisata Alam Sorong*, KM 16). The reference point was the Sorong Mayor's Office complex in Malaingkedi (0.8812° S, 131.2876° E), taken from OpenStreetMap.

2.2 Distance and Direction

The straight-line distance d between the reference point and each attraction was calculated with the haversine formula:

$$d = 2R\arcsin\sqrt{\sin^2\left(\frac{\Delta\varphi}{2}\right) + \cos\varphi_1\cos\varphi_2\sin^2\left(\frac{\Delta\lambda}{2}\right)} \quad (1)$$

where R is the mean Earth radius (6,371 km), φ1 and φ2 are the latitudes of the two points, and Δφ and Δλ are the differences in latitude and longitude in radians. The initial bearing from the reference point to each attraction was calculated and grouped into eight compass directions. Distances were classified as 0–5 km, 5–10 km, 10–15 km and more than 15 km. Road distance and free-flow travel time were computed for every pair of locations on the OpenStreetMap road network with the Open Source Routing Machine (OSRM) car profile [27], queried on 16 November 2026. OSRM assumes uncongested speeds, so its travel times are lower bounds rather than expected journey times, and they are reported separately from the straight-line measures. For Doom Island, the road distance ends at the nearest mainland point on the old-town waterfront, and the boat crossing is reported separately. The ratio of road to straight-line distance, known as the detour index [28], was calculated for all mainland pairs of locations more than 1 km apart, instead of assuming a fixed detour factor.

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2.3 Alternative Reference Points

The Mayor's Office was used as the primary reference point because the municipal government is the body that plans and budgets city tourism infrastructure, and because the office is a fixed, unambiguous location close to the airport and the central commercial district. An administrative office is not, however, necessarily the functional center of tourism. All distance measures were therefore repeated for five alternative nodes: Domine Eduard Osok (DEO) Airport, the city's air gateway; *Pelabuhan Rakyat*, the ferry terminal for passenger services to Waisai in Raja Ampat; the passenger terminal of the Port of Sorong on the old-town waterfront; Ramayana Mall, used as a proxy for the central commercial district; and the mean center of the eight attractions, which represents the geometric center of the attraction system. Coordinates of these nodes were taken from OpenStreetMap or Google Maps (Supplementary File S2). For each node, the mean and range of straight-line and road distances to the attractions and the number of attractions within 10 km were calculated, and Spearman's rank correlation (ρ) was used to compare the node's distance ranking of the attractions with that from the Mayor's Office.

2.4 Nearest Neighbor Analysis

The spatial pattern was tested with the nearest neighbor index (T) of Clark and Evans [29]:

$$T = \frac{J_u}{J_h}, \quad J_h = \frac{1}{2\sqrt{\rho}}, \quad \rho = \frac{N}{A} \tag{2}$$

where Ju is the observed mean distance from each attraction to its nearest neighbor, taken from a pairwise haversine distance matrix, Jh is the expected mean distance under a random pattern, ρ is point density and A is the study area. Values of $T \leq 0.7$ were interpreted as clustered, 0.7–1.4 as random and above 1.4 as dispersed. Significance was evaluated with the standardized score:

$$Z = \frac{J_u - J_h}{\mathrm{SE}}, \quad \mathrm{SE} = \frac{0.26136}{\sqrt{N\rho}} \tag{3}$$

where $|Z| > 1.96$ indicates significance at $\alpha = 0.05$. All calculations were implemented with formulas in a spreadsheet so that they can be recalculated when attractions are added; the figures were produced in Python. The robustness analyzes described below were also run in Python with NumPy and SciPy; the script and its input data are provided as Supplementary File S2.

2.5 Robustness of the Spatial Pattern

Four sets of tests were applied to the nearest neighbor result. First, because Jh depends on A, the index was recalculated for four attraction-relevant boundaries: the minimum enclosing rectangle of the eight attractions, their convex hull, and the convex hull buffered by 1 km and by 2 km, the buffered hulls approximating the urbanised zone in

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which the attractions lie. For these smaller windows, the expected distance was also corrected for edge effects following Donnelly [30], and significance was assessed with a Monte Carlo test that compared the observed mean nearest neighbor distance with 4,999 simulations of complete spatial randomness inside each window [31]. The study areas at which T would reach 0.7 and Z would reach −1.96 were calculated, and short-range clustering was tested by comparing the number of attraction pairs less than 0.5, 1 and 2 km apart with the same simulations.

Second, a leave-one-out analysis recalculated T and Z eight times, each time without one attraction, and once more without the four northern beaches. Third, the effect of the five excluded attractions was tested. Approximate coordinates were assigned to four of them: Buddha Jayanti Temple from OpenStreetMap, and MOOI Park, Soop Island Beach and Tampa Garam Beach from their Google Maps place markers. Panjang Beach could not be located; it was therefore represented by a hypothetical point placed, by a 100 m grid search, at the location inside the 2 km buffered hull that would most weaken clustering. Fourth, positional uncertainty was assessed by comparing coordinates from different sources for the same features and by perturbing every coordinate 10,000 times with isotropic Gaussian errors of 15, 50, 100, 250 and 500 m. Because the name Tanjung Kasuari refers both to the beach and to the cape about 1.9 km to the west, the analysis was also repeated with the cape coordinate.

2.6 Cluster Identification

The three clusters were first identified from the directional groups in which each attraction's nearest neighbor lies. To test whether this grouping reflects a formal clustering structure, three procedures were applied. Agglomerative hierarchical clustering was run with single, average, complete and Ward [32] linkage, and the number of clusters was chosen from the largest gap in merge distances and from the mean silhouette width [33]. Density-based spatial clustering of applications with noise (DBSCAN) [34] was run with a minimum of two points per cluster and neighborhood radii (ε) from 0.25 to 7 km in steps of 0.05 km. Kernel density estimation with a Gaussian kernel [35] was applied with bandwidths (h) of 0.5–3 km, and each attraction was assigned to a density peak by mean-shift hill climbing. A grouping was regarded as robust if all methods reproduced it over a contiguous range of parameter values. The procedures were repeated with the four approximately located attractions added.

3 Results

3.1 Distance and Direction from the Mayor’s Office

Table 1 lists the eight attractions with their distances, directions and nearest neighbors. All attractions lie within 10 km of the Mayor's Office. Distances range from 4.18 km (Klawalu Mangrove Park) to 8.76 km (Alinda Beach), with a mean of 6.86 km (SD = 1.77 km). Two attractions (25%) fall in the 0–5 km class and six (75%) in the 5–10 km class; none lies beyond 10 km. Road distances are considerably longer: 5.96–16.71 km

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for the mainland attractions, with free-flow driving times of 5–17 min. The detour index ranges from 1.19 (Sorong Nature Park) to 2.07 (Saoka Beach) and averages 1.66, because the road network does not follow the straight line between the administrative center and the northern coast. Across all 101 mainland pairs of locations more than 1 km apart, the median detour index was 1.64 (interquartile range 1.39–1.84), so a fixed factor of 1.3 would underestimate road distances in Sorong. Doom Island is 5.67 km by road from the Mayor's Office to the nearest mainland point, followed by a boat crossing of about 1.3 km to the center of the island.

Table 1. Distance, direction, and nearest neighbor of tourist attractions from the Sorong Mayor's Office.

No	Attraction	District	Distance (km)	Direction	Road distance, km (free-flow time, min)a	NN distance (km)c
1	Klawalu Mangrove Park	Sorong Timur	4.18	South-east	7.13 (9)	3.18
2	Tembok Berlin	Sorong	4.76	West	5.96 (5)	1.97
3	Doom Islandb	Sorong Kepulauan	5.77	West	5.67 (6)	1.97
4	Sorong Nature Park (KM 16)	Klaurung	6.77	South-east	8.05 (7)	3.18
5	Saoka Beach	Sorong Barat	8.08	North-west	16.71 (17)	0.42
6	Tanjung Batu Beach	Sorong Manoi	8.15	North-west	16.18 (17)	0.42
7	Tanjung Kasuari Beach	Sorong Utara	8.39	North-west	14.75 (15)	0.43
8	Alinda Beach	Sorong Barat	8.76	North-west	14.40 (14)	0.43

a Shortest road distance and free-flow driving time on the OpenStreetMap road network (OSRM car profile); times exclude congestion and are therefore lower bounds. b Road distance to the nearest mainland point on the old-town waterfront; excludes the boat crossing (about 1.3 km). Reference point: 0.8812° S, 131.2876° E. c Distance to the nearest neighboring attraction. Coordinates are given in Supplementary File S1.

Direction from the reference point divides the attractions into three sectors (Fig. 1). The four beaches lie to the north-west at 8.08–8.76 km, Doom Island and Tembok Berlin lie to the west at 4.76–5.77 km, and the two nature-based attractions lie to the south-east at 4.18–6.77 km. Fig. 2 ranks the attractions by distance.

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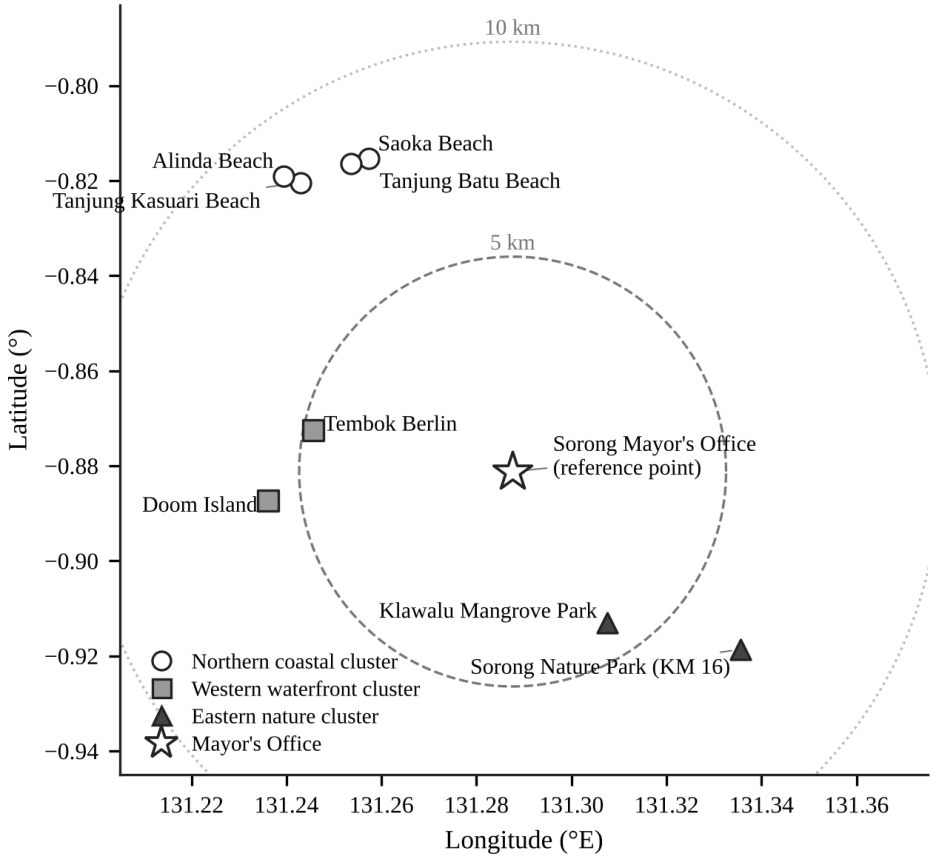

Fig. 1. Distribution of tourist attractions in Sorong City relative to the Mayor's Office, with 5 km and 10 km straight-line distance rings.

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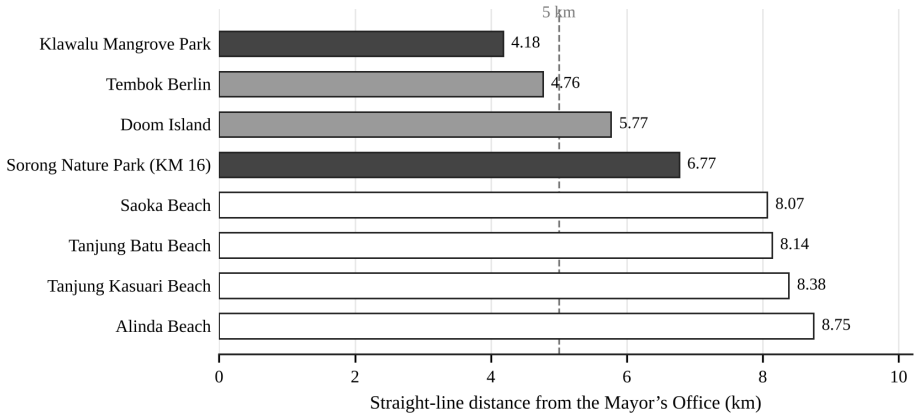

Fig. 2. Straight-line distance of tourist attractions from the Sorong Mayor's Office; the dashed line marks 5 km.

3.2 Spatial Distribution Pattern

The nearest neighbor distances ranged from 0.42 km (Saoka Beach–Tanjung Batu Beach) to 3.18 km (Klawalu Mangrove Park–Sorong Nature Park), with an observed mean of 1.50 km. Under a random pattern with eight points in 1,105 km², the expected mean distance would be 5.88 km. The resulting index of T = 0.26 is well below the 0.7 threshold, and Z = −4.03 is significant at α = 0.05 (Table 2). The attractions are therefore significantly clustered relative to the municipal territory. Because this result depends on the study area, it is examined further in Sect. 3.4.

Table 2. Nearest neighbor analysis of tourist attractions in Sorong City.

Parameter	Value
Number of attractions (N)	8
Study area (A, km²)	1,105
Density (ρ, attractions/km²)	0.0072
Observed mean nearest neighbor distance (Ju, km)	1.502
Expected mean distance (Jh, km)	5.876
Nearest neighbor index (T)	0.256
Standard error (SE)	1.086
Z-score	−4.03
Pattern	Clustered relative to the municipal area (significant, α = 0.05)

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3.3 Attraction Clusters

Each attraction's nearest neighbor lies within the same directional group, which yields three mutually exclusive clusters (Table 3). The northern coastal cluster has the most members and the greatest distance from the administrative center but the shortest internal spacing. The western waterfront and eastern nature clusters are closer to the center but more loosely spaced. Whether formal clustering methods reproduce these groups is examined in Sect. 3.4.

Table 3. Tourist attraction clusters in Sorong City.

Cluster	Members	n	Direction	Mean distance (km)	Mean NN distance (km)
Northern coastal	Tanjung Kasuari, Alinda, Saoka and Tanjung Batu beaches	4	North-west	8.34	0.43
Western waterfront	Doom Island and Tembok Berlin	2	West	5.27	1.97
Eastern nature	Klawalu Mangrove Park and Sorong Nature Park	2	South-east	5.47	3.18

3.4 Robustness of the Spatial Pattern and Clusters

The clustered result depends on the scale at which randomness is defined (Table 4, Fig. 3a). For the eight attractions, T remains below 0.7 only if the reference area exceeds 147 km², and Z falls below −1.96 only if it exceeds 177 km². The attractions occupy a convex hull of 58 km², or 96 km² with a 1 km buffer, less than 9% of the municipal territory. Within the minimum enclosing rectangle (102 km²) and the 1 km buffered hull, T was 0.84 and 0.86 (0.70 and 0.72 after edge correction), and the Monte Carlo tests were not significant ($p = 0.085$ and 0.094); within the convex hull itself the pattern was close to random ($T = 1.12$, $p = 0.34$). Only the 2 km buffered hull (141 km²) gave a significant result, at the threshold of clustering ($T = 0.71$, $p = 0.024$). By contrast, two pairs of beaches lie less than 0.5 km apart, whereas fewer than 0.25 such pairs would be expected under randomness in any of the windows ($p = 0.009$–0.022). The pattern is therefore best described as strong concentration at the city scale combined with short-range clustering on the northern coast, rather than as clustering at every scale.

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Table 4. Sensitivity of the nearest neighbor result to the study-area boundary and the attraction inventory.

Scenario	N	A (km²)	T	Z	TDa	Monte Carlo pb
Eight attractions: administrative area	8	1,105	0.26	−4.03	–	–
Eight: minimum enclosing rectangle	8	102	0.84	−0.87	0.70	0.085
Eight: convex hull	8	58	1.12	0.64	0.92	0.344
Eight: convex hull + 1 km	8	96	0.86	−0.73	0.72	0.094
Eight: convex hull + 2 km	8	141	0.71	−1.55	0.60	0.024
Twelvec: administrative area	12	1,105	0.37	−4.19	–	–
Twelvec: convex hull + 1 km	12	124	1.10	0.65	0.95	0.379
Twelvec: convex hull + 2 km	12	174	0.93	−0.47	0.81	0.125
Thirteend: administrative area	13	1,105	0.45	−3.78	–	–
Thirteend: convex hull + 1 km	13	138	1.28	1.92	1.12	0.768

a Index with the expected distance corrected for edge effects [30]. b One-sided p-value for clustering from 4,999 (N = 8) or 2,999 (N = 12, 13) simulations of complete spatial randomness inside the window [31]. c Adds Buddha Jayanti Temple, MOOI Park, Soop Island Beach and Tampa Garam Beach at approximate locations. d Adds a hypothetical point for Panjang Beach at the location that most weakens clustering.

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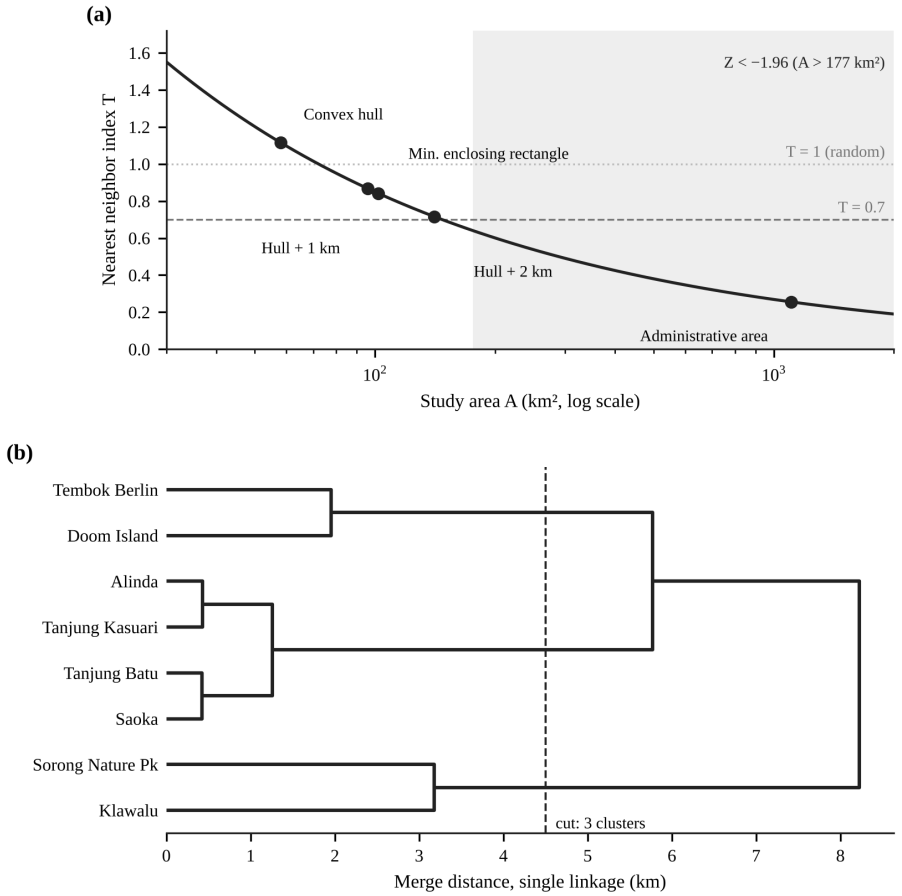

Fig. 3. (a) Nearest neighbor index of the eight attractions as a function of the study area, with the five boundaries tested; the shaded zone marks study areas for which Z < −1.96. (b) Single-linkage dendrogram of the eight attractions; the dashed line marks the cut that yields the three clusters.

Removing any single attraction left T between 0.28 and 0.38 and Z between −3.64 and −3.12 at the city scale (Table 5). T rose most when Klawalu Mangrove Park or Tembok Berlin was removed, because their partners then had to find a more distant nearest neighbor, and fell slightly when a northern beach was removed. Removing all four northern beaches still gave T = 0.31 (Z = −2.64), so the city-scale result is not driven only by the closely spaced northern group. Within the 1 km buffered hull, none of the leave-one-out sets was significantly clustered (p = 0.18–0.61), which is consistent with the window analysis above.

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Table 5. Leave-one-out sensitivity of the nearest neighbor index.

Attraction removed	N	Ju (km)	T	Z	T, hull + 1 km	p, hull + 1 kma
None (all eight)	8	1.50	0.26	−4.03	0.86	0.094
Klawalu Mangrove Park	7	2.41	0.38	−3.12	1.31	0.609
Tembok Berlin	7	2.22	0.35	−3.27	1.20	0.457
Doom Island	7	1.98	0.31	−3.47	1.15	0.373
Sorong Nature Park	7	1.98	0.32	−3.46	1.20	0.476
Saoka Beach	7	1.77	0.28	−3.63	0.97	0.198
Tanjung Batu Beach	7	1.83	0.29	−3.58	0.99	0.200
Tanjung Kasuari Beach	7	1.82	0.29	−3.60	0.98	0.205
Alinda Beach	7	1.77	0.28	−3.64	0.97	0.178
All four northern beaches	4	2.57	0.31	−2.64	–	–

T and Z use the administrative area (A = 1,105 km²). a One-sided Monte Carlo p-value from 1,999 simulations inside the 1 km buffered convex hull of the remaining attractions.

Adding the four approximately located attractions (Fig. 4) gave T = 0.37 (Z = −4.19) at the city scale. MOOI Park and Tampa Garam Beach lie 1.1 km and 2.0 km from the nearest northern beach, Buddha Jayanti Temple lies in the city center 2.7 km from Tembok Berlin, and Soop Island Beach lies 3.4 km west of Doom Island, so none falls outside the existing groups. A hypothetical thirteenth attraction placed where it would most weaken clustering still left T = 0.45 (Z = −3.78) at the city scale. Within the buffered hulls, the twelve- and thirteen-attraction sets did not differ significantly from random (Table 4).

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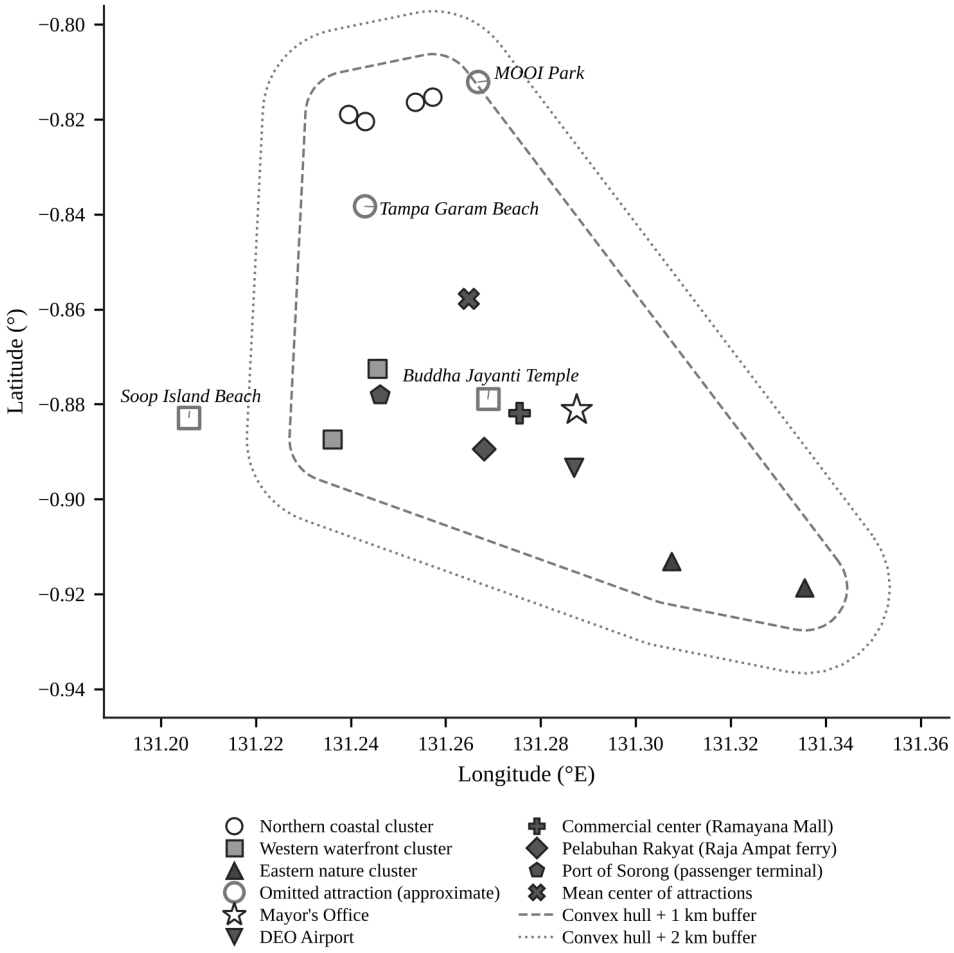

Fig. 4. Tourist attractions, approximately located omitted attractions, and alternative reference points in Sorong City, with the 1 km and 2 km buffered convex hulls used as alternative study areas.

Coordinates of the same feature from independent sources agreed closely: within 2–9 m for Tembok Berlin, Tanjung Batu Beach and Klawalu Mangrove Park (Plus Code, Google Maps and Wikivoyage), within 34–57 m for Doom Island (OpenStreetMap and Wikipedia) and within 24 m for the Mayor's Office. The largest difference, 83 m, separated the Klawalu Plus Code from the centroid of the mangrove polygon in OpenStreetMap, which reflects the size of the site rather than an error. With random errors of up to 250 m, the 95% interval of T was 0.22–0.32, Z remained below −1.96 in every run and cluster membership never changed; at 500 m, membership was unchanged in 99% of runs. At 100 m, the mean nearest neighbor distance among the four northern beaches ranged from 0.26 to 0.64 km, so their sub-kilometer spacing is not an artifact of coordinate error. Place-name ambiguity is a larger risk: replacing the

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Tanjung Kasuari Beach coordinate with that of the cape, 1.93 km to the west, raised T to 0.30 (Z = −3.77) but left the clusters unchanged.

The three-cluster grouping was reproduced by the formal procedures (Table 6, Fig. 3b). All four hierarchical linkages produced the same three clusters at k = 3, which also had the highest mean silhouette width (0.76, compared with 0.65 for k = 2 and 0.59 for k = 4). In the single-linkage hierarchy the three groups are complete at a merge distance of 3.18 km, and the next merge occurs only at 5.77 km, the largest gap in the hierarchy. DBSCAN produced the same partition for every ε from 3.20 to 5.75 km, and kernel density mode-seeking did so for bandwidths of 2.0–2.5 km. The groups differ in cohesion. The northern beaches form one group from ε = 1.30 km and the western pair from ε = 2.00 km, whereas the eastern pair forms a cluster only from ε = 3.20 km and splits into two density peaks at bandwidths below 2 km; at bandwidths of 2.75 km or more, including the rule-of-thumb value of 3.2 km, the northern and western groups merge. The eastern group is therefore better described as a loose pair along the eastern corridor than as a compact cluster. With the four approximately located attractions added, single, average and Ward linkage again gave three clusters: MOOI Park and Tampa Garam Beach joined the northern group, and Buddha Jayanti Temple and Soop Island Beach joined the western group.

Table 6. Cluster solutions obtained with formal clustering methods.

Method	Settings reproducing the three clusters	Other solutions
Hierarchical, single linkage	k = 3 (merge gap 3.18–5.77 km)	k = 2: northern and western groups merge; k = 4: eastern pair splits
Hierarchical, average, complete and Ward linkage	k = 3	Same as single linkage
Mean silhouette width	Highest at k = 3 (0.76)	k = 2: 0.65; k = 4: 0.59
DBSCAN (minimum 2 points)	ε = 3.20–5.75 km	ε = 2.00–3.15 km: northern and western groups, eastern attractions as noise; ε = 0.45–1.95 km: northern beaches only; ε ≥ 5.80 km: two groups
Kernel density, mean shift	h = 2.0–2.5 km	h = 1.0–1.5 km: four groups (eastern pair split); h ≤ 0.75 km: six groups; h ≥ 2.75 km, including the rule-of-thumb 3.2 km: northern and western groups merge
Twelve attractionsa (single, average and Ward linkage)	k = 3	MOOI Park and Tampa Garam join the northern group; Buddha Jayanti Temple and Soop Island join the western group

a Including the four approximately located attractions.

Apollo: Journal of Tourism and Business
Vol 5, Issue 1, January 2027, Page 1229-1249
ISSN: 2985-5810 (Media Online)
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3.5 Alternative Reference Points and Network Accessibility

The Mayor's Office lies 1.33 km from DEO Airport and 1.34 km from the commercial center, and the distance rankings from these nodes closely match those from the Mayor's Office ($\rho = 1.00$ and 0.79; Table 7, Fig. 4). From the airport all eight attractions remain within 10 km (mean 7.25 km), and from the Raja Ampat ferry terminal within 8.5 km (mean 6.67 km; $\rho = 0.83$). The passenger terminal of the Port of Sorong, on the old-town waterfront 4.6 km west of the Mayor's Office, gives a different pattern: the western pair lies about 1 km away, the northern beaches 6.8 km and the eastern attractions 9.4 km on average, so its ranking is unrelated to that from the Mayor's Office ($\rho = -0.05$). This node also has the shortest mean road distance to the attractions (8.72 km). The mean center of the attractions lies 3.6 km north-west of the Mayor's Office, but it is not a place through which visitors pass. On the road network, the northern cluster is the farthest group from every node, at 10.7–16.9 km on average. The compactness of the attraction system is therefore not an artifact of the administrative reference point, but which cluster is near and which is far depends on the gateway through which visitors arrive.

Table 7. Distances from alternative reference points to the eight attractions.

Reference point	Distance from Mayor's Office (km)	Mean straight-line distance, km (range)	≤ 10 km (n)	Mean road distance (km)	Mean free-flow time (min)	ρa
Mayor's Office	–	6.86 (4.18–8.76)	8	11.11	11.2	1.00
DEO Airport	1.33	7.25 (3.18–9.81)	8	12.16	14.3	1.00
Commercial center (Ramayana Mall)	1.34	6.49 (3.49–8.08)	8	10.31	10.4	0.79
Pelabuhan Rakyat (Raja Ampat ferry)	2.35	6.67 (3.14–8.48)	8	11.10	13.7	0.83
Port of Sorong (passenger terminal)	4.62	6.01 (0.65–10.91)	7	8.72	9.8	−0.05
Mean center of attractions	3.64	5.62 (2.68–10.38)	7	–	–	0.14

Road distances and free-flow times from OSRM; for Doom Island, to the nearest mainland point. a Spearman rank correlation with the distances from the Mayor's Office.

Between attractions, road distances are 0.68–2.66 km within the northern cluster, 0.93 km between Tembok Berlin and the mainland point nearest Doom Island, and 4.21 km between the two eastern attractions. Between clusters they are 8.7–11.6 km (northern–western), 12.5–13.5 km (western–eastern) and 20.9–24.1 km (northern–eastern). The shortest closed road circuit that starts at the Mayor's Office and visits all seven mainland attractions and the Doom Island crossing point is 53.5 km long and requires about 60 min of free-flow driving; starting from the airport or the ferry terminal lengthens it to

Apollo: Journal of Tourism and Business
Vol 5, Issue 1, January 2027, Page 1229-1249
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54.9 km and about 65 min. These figures exclude congestion, the boat crossing and the time spent at each attraction.

4 Discussion

4.1 Scale-Dependent Clustering in a Compact Destination

The clustered pattern found here (T = 0.26) agrees with most studies of attraction distribution, which report that attractions concentrate around particular resource settings rather than spreading evenly [7], [8], [10]. The robustness tests show, however, that this agreement holds at the city scale. As in regional and national studies, which compare attraction locations with large reference areas, the index here expresses the concentration of attractions in less than a tenth of the municipal territory; within the urban zone that contains them, the global pattern is indistinguishable from random, and clustering is limited to short distances along the northern coast. Dependence on the study area is an inherent property of the nearest neighbor index [29], [30], so reporting it for several boundaries makes the scale of the claim explicit. The city-scale pattern contrasts with Pontianak, where attractions were spread in a random-to-dispersed pattern across a riverine city [24], and with Udon Thani, where dispersion reflected rural settlement patterns [15]. In Sorong the clusters follow physical settings: the northern beaches share the Tanjung Kasuari coastline, Doom Island and Tembok Berlin share the western waterfront facing the city's harbour, and the eastern attractions are tied to the mangrove and protected forest areas described in [4] and [6]. The formal clustering confirms the northern and western groups, whereas the eastern pair is held together more by its shared forest and mangrove setting than by proximity. This resembles the coastal clustering reported for Rembang [25] and the role of rivers and coastlines identified in Chinese case studies [8], [13].

The distances also show that Sorong is a compact destination. All verified attractions lie within 10 km of the administrative center, and the same holds for the airport and the Raja Ampat ferry terminal. Road distances are longer, up to 16.7 km, and actual driving times will exceed the free-flow estimates of up to 17 min, so the city is compact in straight-line terms and moderately compact on the road network. Studies elsewhere show accessibility declining from city center to periphery [16], [17]. In straight-line terms the Mayor's Office sits roughly between the three clusters, so no cluster is remote from the administrative core; on the road network, however, the northern cluster is the most remote group from every gateway, and from the old-town port the western pair is the nearest. For transit visitors heading to Raja Ampat [1], the 54 km road circuit that links all clusters suggests that a half-day or one-day city circuit is physically feasible, which could help convert transit arrivals into local tourism spending, although whether visitors would use it depends on their interests, attraction opening hours and crossing schedules, which were not observed.

Apollo: Journal of Tourism and Business
Vol 5, Issue 1, January 2027, Page 1229-1249
ISSN: 2985-5810 (Media Online)
DOI: https://doi.org/10.58905/apollo.v5i1.843

4.2 Planning Implications as Testable Hypotheses

Because the study did not measure visitor volumes, road capacity, travel demand, attraction quality, opening hours, carrying capacity or tourist preferences, the three planning implications that follow are spatial hypotheses rather than demonstrated investment priorities. First, the northern coastal cluster combines the highest density of attractions with the longest road distance from every gateway, which makes it a candidate priority for road quality, public transport and shared facilities such as parking, sanitation and information points. Siting facilities at the cluster level rather than at each beach is consistent with hub-oriented approaches to attraction systems [23] and with community-based management at Tanjung Kasuari [5]; whether such investment is warranted depends on visitor numbers and on the condition and capacity of the coastal road, which should be measured first. Second, the western waterfront pair, although close to the center and to the old-town port, depends on a boat crossing to Doom Island, so pier and crossing services rather than road distance are likely to determine its accessibility. Third, the eastern pair is environmentally sensitive and only loosely clustered; access improvements should be combined with visitor limits, in line with carrying-capacity concerns raised for the wider region [2].

The three clusters could also form a city tourism circuit anchored at the administrative center, the airport or the ferry terminal, following route-design approaches based on time–distance savings [21]. The road circuit estimated here is only a starting point; network-based measures of accessibility [17], [19], [20], combined with observed travel times, visitor flows and tourist preferences, could then be used to test such a circuit for different travel modes before it is adopted in planning.

4.3 Limitations

The study has several limitations. The sample is small (N = 8), which reduces the reliability of the significance test; the leave-one-out and Monte Carlo tests reduce, but do not remove, this concern. The nearest neighbor index is sensitive to the size of the study area, and the significant clustering found with the full administrative area does not hold within boundaries drawn around the attractions; the result therefore applies to the city scale. Road distances depend on the completeness of OpenStreetMap in Sorong, which was not verified in the field, and the free-flow times ignore congestion, road quality and terrain. Coordinates were not field-verified; cross-source comparison and perturbation indicate that positional error is small relative to the distances analyzed, but place names such as Tanjung Kasuari can refer to more than one location. The clusters describe the spatial arrangement of the attractions; whether they operate as a functional tourism system, with visitors moving within and between them, would require visitor-flow data. Finally, the inventory is incomplete: one listed attraction could not be located and four others only approximately, and no visitor data were analyzed. Future work should complete the inventory with field-verified coordinates, apply network analysis with field-verified road data [16], [22], record actual travel times and relate the clusters to visitor numbers, travel demand, carrying capacity and facilities.

Apollo: Journal of Tourism and Business
Vol 5, Issue 1, January 2027, Page 1229-1249
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5 Conclusion

The tourist attractions of Sorong City form a compact system that is strongly concentrated at the city scale. All eight georeferenced attractions lie within 10 km of the Mayor's Office (mean 6.86 km), and also within 10 km of the airport and the Raja Ampat ferry terminal, although road distances are up to twice as long. The nearest neighbor index of 0.26 confirms clustering relative to the municipal territory, and this result is robust to the removal of any attraction, the addition of omitted attractions and plausible coordinate error; within the urban zone that contains the attractions, however, clustering is limited to short distances along the northern coast. Three clusters were identified and confirmed by hierarchical clustering, DBSCAN and kernel density analysis: a northern coastal cluster, a western waterfront cluster and an eastern nature pair. These clusters provide a spatial basis for planning Sorong as a cluster-based urban destination. Shared facilities within clusters, access priority for the northern coast and the Doom Island crossing, and a city circuit linking the clusters for visitors in transit to Raja Ampat are hypotheses to be tested with visitor, travel-time and capacity data rather than established priorities.

DECLARATIONS

Author Contributions

Conceptualization, M.M.; methodology, M.M. and E.A.; formal analysis, M.M.; data curation, L.I. and N.K.M.; visualization, M.M.; writing—original draft preparation, M.M.; writing—review and editing, E.A., L.I., and N.K.M.; supervision, E.A. All authors have read and approved the final version of the manuscript.

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Disclosure of Interests

The authors declare that they have no competing interests relevant to the content of this article.

Data Availability Statement

All data supporting the findings of this study are included in the article and in Supplementary File S1, a spreadsheet containing the attraction coordinates, the formula-based distance calculations, the pairwise distance matrix, and the nearest neighbor analysis. Attraction coordinates were derived from publicly available Google Maps Plus Codes and OpenStreetMap. Supplementary File S2 contains the Python script used for the robustness analyses, the coordinates of the alternative reference points and of the approximately located attractions, and the road distance and travel time matrix obtained from OSRM on 16 November 2026.

Apollo: Journal of Tourism and Business
Vol 5, Issue 1, January 2027, Page 1229-1249
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Research Ethics
Ethical review and approval were not required for this study because it used only publicly available locational data on tourist attractions and did not involve human participants, animals, or personal data.

Use of Artificial Intelligence
During the preparation and revision of this manuscript, the authors used a generative artificial intelligence assistant (Claude, Anthropic) to support literature retrieval, the distance and nearest neighbor calculations, the robustness and clustering analyses, the road-network queries, figure preparation, and drafting of the text. All calculations were reproduced from the supplementary script and data, and the authors reviewed and revised all generated content and take full responsibility for the final manuscript.

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