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DATA-DRIVEN INSIGHTS FOR TOURISM DEVELOPMENT IN EAST JAVA USING DIRECTED GRAPHS

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Abstract

This study aims to analyze the tourism network in East Java using Google Trends data and directed graph models. Data were collected based on search queries combining the keyword "wisata" (tourism) with city or regency names in East Java for the year 2023. The analysis employed the PageRank algorithm to identify key network hubs and the Adamic-Adar index to predict new connections between regions. Spatial visualization was conducted using QGIS, while network analysis was carried out using NetworkX. The results revealed that Malang and Surabaya act as central hubs in the tourism network, with high connectivity to other regions. Meanwhile, regions such as Pacitan were identified as isolated nodes within the network. Based on these findings, the study recommends strategies to enhance inter-regional connectivity, including infrastructure development and integrated tourism promotion. This study provides data-driven insights that can assist tourism authorities in improving the attractiveness and sustainability of the tourism sector in East Java.

Keywords: Network Analysis; Tourism; Directed Graph; Google Trends; QGIS; NetworkX

INTRODUCTION

The tourism sector is one of the contributing sectors in the economy. The development of the tourism sector can boost economic growth and create employment opportunities (Mariyono, 2017). The job opportunities generated by the tourism sector can accommodate workers with fewer skills, thereby reducing poverty (Mariyono, 2017). However, Rasool et al. explain that economic growth and the tourism sector have a significant long-term relationship (Rasool et al., 20[illegible]).

East Java Province is one of the provinces in Indonesia that uses the tourism sector to boost economic growth. This is due to the immense potential of tourism in East Java, especially in Malang Regency (Murniati et al., 2024; Murniati, 2023). Research conducted by Riswandha Risang Aji et al. (2018) explains that tourism contributes to economic growth. According to data from the Central Statistics Agency (BPS) of East Java, the tourism level increased in 2023 but was not followed by the economic growth rate. The increase in the tourism sector was due to the post-COVID-19 pandemic. On the other hand, the decline in economic growth was caused by the Agriculture, Forestry, and Fisheries sectors and the Mining and Quarrying sectors, which fell by –25.64% and –3.13% in the fourth quarter of 2023.

The development of tourism in East Java Province, based on data from BPS East Java and the increase in searches for East Java tourism keywords, shows great potential. Research-based strategies have been developed to enhance the tourism potential of East Java Province. Kumala et al. (2017) used LQ and Klassen Typology analysis methods to identify the tourism sector's potential in East Java. Research conducted by Kurniawan (2018), using the 2010 East Java Input-Output Table, explains that the Trade, Hotel, and Restaurant sectors need to be developed to enhance the tourism sector. The use of contribution analysis tools, input-output analysis, and path analysis shows that the tourism sector contributes to the regional economy in East Java Province through the enhancement of the information and communication sector (Aji et al., 2018). On the other hand, research development to enhance the tourism sector has progressed using big data and network analysis (Li & Law, 2020).

Based on the phenomenon of tourism potential and the development of previous research in formulating tourism development policies in East Java Province, this research aims to provide new insights into formulating tourism strategies in East Java Province. Using big data through Google Trends and graph analysis can provide an overview (Galih Pradananta & Bintis Ti'anatud Diniati, 2023) of the potential of tourism that needs to be developed. Additionally, this research forecasts the tourism dynamics that will occur.

Tourism, in general, is the temporary travel from one place to another, which can be done individually or in groups, to seek balance and happiness through interaction with the living environment in various dimensions such as social, cultural, natural, and scientific (Murniati et al., 2021). The tourism sector's contribution covers various dimensions, not only economic but also socio-political, cultural, regional, and environmental. This is because tourism affects three main aspects: economic aspects (such as foreign exchange sources and taxes, regional income, and community income), social aspects (such as job creation), and cultural aspects (Murniati, 2023).

Tourist attractions are anything located in a tourist destination that serves as an attraction to draw visitors to the place. According to Undang-Undang Republik Indonesia Nomor 10 Tahun 2009 tentang Kepariwisataan, tourist attractions include anything that has uniqueness, beauty, and value consisting of the diversity of natural, cultural, and human-made wealth that becomes a tourist destination. A tourism destination is defined as a geographical area within one or more administrative areas which contains tourist attractions, public facilities, tourism facilities, accessibility, and a community that is interconnected and complementary to realize tourism.

The research conducted by Li & Law (2020) aims for comprehensive network analysis to understand the current state of big data research in tourism by investigating multidisciplinary contributions relevant to big data. A comprehensive network analysis method, including co-citation analysis, clustering, and trend analysis, was applied to analyze publications from 2008 to 2017 systematically. Using network analysis and visualization tools, this research uncovered major research trends, research focuses, and emerging patterns in big data research related to tourism and hospitality, providing a comprehensive view of the current state of research in this field.

Onder's (2017) research explains that using Google Trends can improve the accuracy of forecasting tourism demand compared to autoregressive models. The results show that using web or image search indices for Vienna is more accurate than for Belgium, Barcelona, and Austria. Using the same concept based on Google Trends in China explains that applying the Random Forest (RF) model accurately predicts tourist volumes (Feng et al., 2019).

Based on the phenomenon of tourism potential and the development of previous research in formulating tourism development policies in East Java Province, this research aims to provide new insights into formulating tourism strategies in East Java Province. This study aims to explore the tourism network in East Java and provide data-driven recommendations for strategic development.

The remainder of this paper is organized as follows: Section 2 describes the methods and data used in this study, including data collection and network analysis techniques. Section 3 presents the findings and discussion, highlighting key insights from the network analysis and their implications. Section 4 concludes the paper with a summary of findings, policy recommendations, and suggestions for future research.

METHOD

The methodology employed in this study is designed to analyze the tourism network in East Java through a series of structured steps, integrating data analysis and network modeling techniques.

Research Steps:

1. **Data Collection**
   Data were collected from Google Trends for the year 2023, using the keyword 'wisata' combined with the names of cities or regencies in East Java.
2. **Graph Construction**
   The collected data were processed using NetworkX to construct a directed graph, where nodes represent regions and edges represent the direction and weight of connectivity based on search volumes.
3. **Data Visualization**
   Spatial visualization of the tourism network was performed using QGIS to map inter-regional connections.
4. **Network Analysis**
   The analysis applied algorithms such as PageRank to identify central nodes, Adamic-Adar for link prediction, and Girvan-Newman for community detection.
5. **Result Interpretation**
   Findings from the analysis were interpreted to identify potential connections and provide policy recommendations for improving the tourism network.

Data Limitations

This study relies solely on Google Trends data for the year 2023, focusing on search queries related to tourism in East Java. While Google Trends provides valuable insights into online search behavior, it may not fully capture actual tourist flows or account for seasonal variations. However, given the dynamic nature of tourism trends and the rapid influence of viral content, the use of the most recent data from 2023 is highly relevant for predicting tourism patterns in 2024, as it reflects the latest shifts in public interest and behavior.

Graph Construction

This study aims to predict new linkages between cities/regions in East Java Province by examining geomap big data. This geomap data contains information about the searcher's location. The data were collected from Google Trends with configurations set for 2023. We used the keyword "wisata" (tourism) combined with the city name for each city in East Java Province. There are differences between the total number of cities in this study and the total number of cities. This arises from a rational logic: searching for "wisata Blitar" is more common than "wisata kota Blitar." Hence, we merged cities and regencies with the same name. Our geomap data includes the following regions: Bangkalan, Banyuwangi, Batu, Blitar, Bojonegoro, Bondowoso, Gresik, Jember, Jombang, Kediri, Lamongan, Lumajang, Madiun, Magetan, Malang, Mojokerto, Nganjuk, Ngawi, Pacitan, Pamekasan, Pasuruan, Ponorogo, Probolinggo, Sampang, Sidoarjo, Situbondo, Sumenep, Surabaya, Trenggalek, Tuban, and Tulungagung, with total 31 regions.

We used several software to gain the results. QGIS was utilized to visualize spatial data and map tourism connectivity across regions in East Java (QGIS Development Team, 2023). NetworkX was employed to construct and analyze the directed graph, calculate PageRank scores, and apply algorithms such as Adamic-Adar for link prediction (Hagberg et al., 2008). NetworkX is a powerful tool for network analysis, particularly effective in handling complex graph structures, computing centrality measures, and applying link prediction algorithms like Adamic-Adar. Despite its strengths, NetworkX's performance can decrease with very large datasets, potentially affecting the efficiency of calculations. Moreover, the accuracy of network metrics is highly dependent on the completeness and quality of the input data, which in this study relies solely on Google Trends.

The value of a_{ij} or the element in the i-th row and j-th column represents the percentage of Google searches with the keyword "wisata j-th" from the i-th region. The order of the regions follows alphabetical order as listed above. For example, $a_{13} = 0.04$ means that 4% of Google searches with the keyword "wisata Batu," where Batu is the third city, come from Bangkalan, the first city.

We construct a directed graph $G = (V, E)$ where V is the set of vertices representing the 31 regions, and E is the set of edges where an edge e_{ij} exists if $a_{ij} \neq 0$. The weight w_{ij} of each edge is defined as $w_{ij} = 1/a_{ij}$, indicating that a higher search percentage (closer relationship) results in a lower weight (Diestel, 2017).

We employ the Kamada-Kawai layout algorithm, which positions vertices in a way that reflects the distances between them based on edge weights. The goal is to minimize the energy function:

$$E = \sum_{i<j} \left(d_{ij} - l_{ij}\right)^2$$

where d_{ij} is the distance between vertices i and j, and l_{ij} is the graph-theoretic distance. In our case, $d_{ij} = w_{ij}$ (Kamada & Kawai, 1989).

Connected Components

We analyze both weakly and strongly connected components. Weakly Connected Component: A subset of vertices with a path between any two vertices, ignoring the direction of edges.Strongly Connected Component: A subset of vertices with a path in both directions between any two vertices (Tarjan, 1972).

Girvan-Newman Communities

We apply the Girvan-Newman algorithm to detect communities. This algorithm removes edges with the highest betweenness centrality iteratively:

$$C_B(e) = \sum_{s \neq t} \frac{\sigma(s,t|e)}{\sigma(s,t)}$$

where $C_B(e)$ is the betweenness centrality of edge e, $\sigma(s,t)$ is the total number of shortest paths from s to t, and $\sigma(s,t \mid e)$ is the number of those paths passing through e (Girvan & Newman, 2002).

Weighted Pagerank

To rank the cities based on their importance in the network, we use the weighted PageRank algorithm:

$$PR(i) = (1 - d) + d \sum_{j \in M(i)} \frac{PR(j)}{L(j)}$$

where $PR(i)$ is the PageRank of the regions i, d is the damping factor (usually set to 0.85), $M(i)$ is the set of regions linking to city i, and $L(j)$ is the number of outbound links from the regions j (Tarjan, 1972).

Adamic Adar Prediction Link

To estimate the likelihood of future links, we use the Adamic Adar index:

$$AA(i,j) = \sum_{z \in \Gamma(i) \cap \Gamma(j)} \frac{1}{\log |\Gamma(z)|}$$

where $\Gamma(i)$ is the set of neighbours of i and $|\Gamma(z)|$ is the degree of node z. This index measures the similarity between two nodes based on their common neighbours (Adamic & Adar, 2003).

FINDINGS AND DISCUSSION

This section comprises five subsections. We discuss several descriptive features of the data in the first subsection and examine connected components. In the fourth subsection, we strengthen our analysis with our findings about the Girvan Newman communities. After all, we discuss our new link prediction in the fifth subsection.

Descriptive Directed Graph (Digraph)

First, we have the original directed graph below.

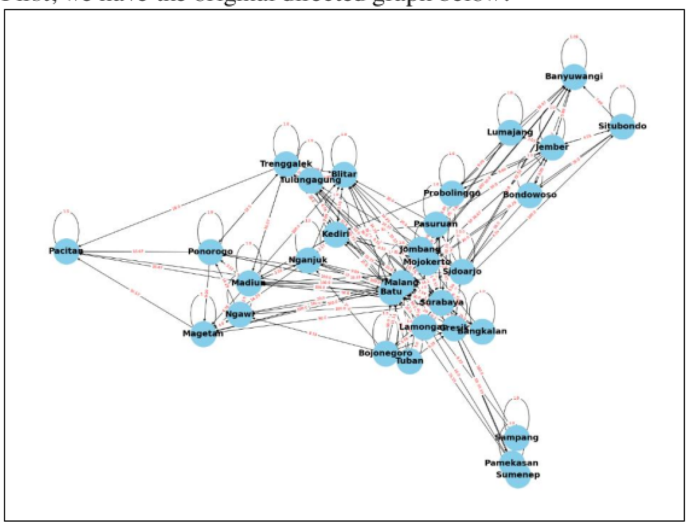

Figure 1. Original directed graph

Using the Kamada-Kawai layout, we display our digraph where closer distances in the graph signify stronger relationships between regions. For example, Sampang, Pamekasan, and Sumenep are very close to each other, whereas Bangkalan is closer to Gresik and Surabaya than to other regions on Madura Island. The graph still includes all edges with small percentages or far distances between nodes.

We remove edges with distances greater than 10 to emphasise significant relationships, translating to less than 10% of Google search results. Self-loops are also removed to focus on inter-regional directions. The resulting new digraph shows regions with strong interconnections, such as Malang and Surabaya, becoming central nodes with many close neighbours.

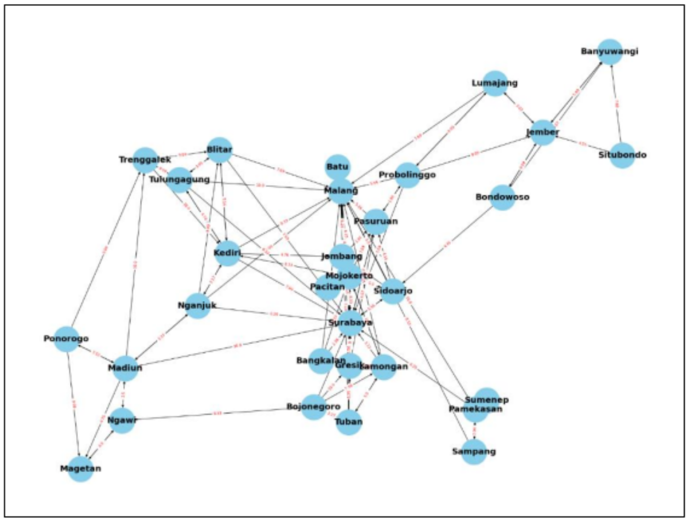

Figure 2. A graph without a loop and small percentages

As you can see, now Pacitan is isolated from other regions. It conveys that Google search to "wisata Pacitan" or from Pacitan is under 10 percent. It is tiny. This picture shows that Malang and Surabaya are important and have many close neighbours.

The Kamada-Kawai layout algorithm was chosen for its ability to produce visually intuitive network diagrams by minimizing the 'energy' of the graph, which helps in representing the strength of relationships through node positioning. This visualization aids in easily identifying central hubs and isolated regions in the tourism network. Nevertheless, the Kamada-Kawai algorithm can struggle with large, dense networks, potentially leading to overlapping nodes and less clear visual representations. It also does not account for temporal dynamics in tourism trends.

Connected Components

We analyze the digraph by examining the connected components. Strongly connected components represent bidirectional relationships between regions, indicating mutual Google searches. A large strongly connected component includes the following regions: Ngawi, Kediri, Probolinggo, Malang, Jombang, Tulungagung, Mojokerto, Lumajang, Ponorogo, Trenggalek, Surabaya, Magetan, Gresik, Nganjuk, Lamongan, Bondowoso, Banyuwangi, Batu, Jember, Sidoarjo, Pasuruan, Madiun, Blitar, and Tuban.

In contrast, Bangkalan, Bojonegoro, Pacitan, Sumenep, and Situbondo do not have bidirectional searches with other regions. However, Bojonegoro and Pacitan have unique cases, which will be discussed later. The weakly connected components analysis reveals that Pacitan is isolated, indicating no significant search connections to or from this region.

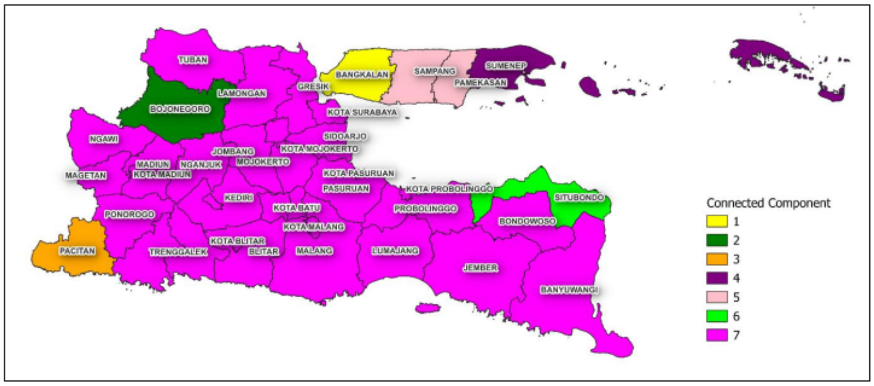

Figure 3. Strongly connected component

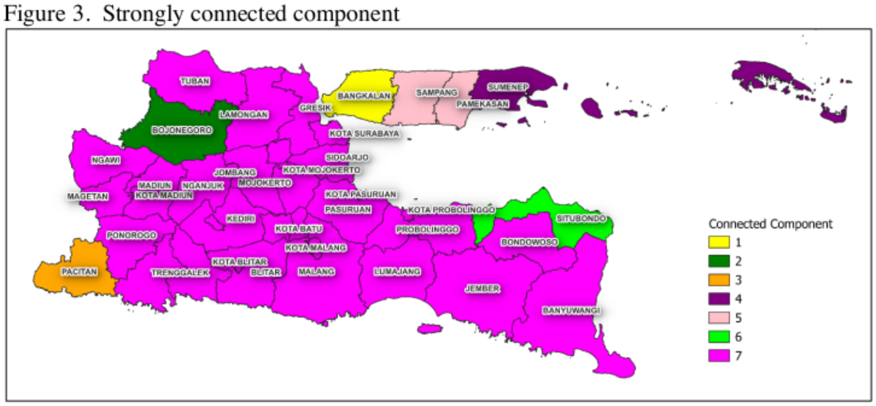

Figure 4. Weakly connected component

The weakly connected components will strengthen our findings. We have two weakly connected components here. The first component is Pacitan itself, and the other becomes one weakly connected component. From this, we know that there are no arrows out of Pacitan.

Concrete evidence is provided by data from BPS East Java, which shows that the average number of visits to Pacitan is 230,327. This is the lowest number of visits among all regions in East Java. The five regions with the lowest average visits are Pacitan, Situbondo, Sumenep, Bojonegoro, and Bangkalan. In more detail, the data shows Situbondo with 243,953 visits, Sumenep with 265,509 visits, Bojonegoro with 417,642 visits, and Bangkalan with 430,683 visits (BPS Provinsi Jawa Timur, 2025).

Situbondo and Sumenep show higher numbers compared to Pacitan, but their visit counts are still significantly lower than other regencies/cities in East Java, such as Malang or Surabaya. This indicates partial isolation, although there is still a notable flow of tourists. Bojonegoro and Bangkalan present unique cases. Despite having relatively high average tourist visits, both regions still exhibit isolation in the tourism network analysis.

Girvan-Newman Communities

To further validate our findings, we apply the Girvan-Newman algorithm to detect communities by removing crucial edges. This results in three communities:

- Pacitan is an isolated community.
- Banyuwangi, Bondowoso, Jember, Lumajang, and Situbondo forming a community.
- The remaining regions form a large, interconnected community.

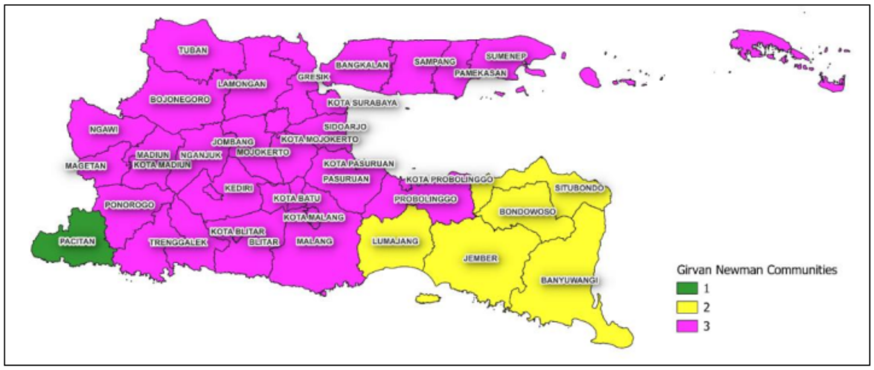

Figure 5. Girvan-Newman communities

Based on the tourism network analysis in East Java using the Girvan-Newman algorithm, it has been identified that Banyuwangi, Bondowoso, Jember, Lumajang, and Situbondo form a tightly connected community. This indicates a strong interrelation in terms of tourist destinations and the flow of visitors among these regions.

One of the key destinations that strengthens this connectivity is Kawah Ijen, located on the border between Banyuwangi and Bondowoso Regencies. Kawah Ijen is renowned for its unique blue fire phenomenon, making it a major attraction for both domestic and international tourists (Eka Rimawati, 2024). The presence of this destination enhances the interaction of tourists between Banyuwangi and Bondowoso. In addition, Baluran National Park, which spans the areas of Situbondo and Banyuwangi, also serves as a magnet for tourists. Nicknamed the "Little Africa in Java", this national park offers vast savanna landscapes and rich biodiversity, attracting visitors from various regions (Triyasni, 2022).

The existence of these prominent tourist destinations across the mentioned regions creates an interconnected tourism network, supporting the finding that Banyuwangi, Bondowoso, Jember, Lumajang, and Situbondo form a closely-knit community within the tourism network of East Java.

Weighted Pagerank

We can rank the region in the components or communities by weighted pagerank. This rank is determined by the link structure in the digraph.

Table 1. Pagerank Score

Region	Pagerank	Region	Pagerank	Region	Pagerank
Bangkalan	0.0051	Lumajang	0.0262	Ponorogo	0.0074
Banyuwangi	0.0252	Madiun	0.0162	Probolinggo	0.0337
Batu	0.0622	Magetan	0.0236	Sampang	0.0064
Blitar	0.0174	Malang	0.1396	Sidoarjo	0.0319
Bojonegoro	0.0051	Mojokerto	0.0608	Situbondo	0.0051
Bondowoso	0.0195	Nganjuk	0.0127	Sumenep	0.0054
Gresik	0.045	Ngawi	0.0273	Surabaya	0.1765
Jember	0.0435	Pacitan	0.0051	Trenggalek	0.0133
Jombang	0.0374	Pamekasan	0.0062	Tuban	0.0094
Kediri	0.0261	Pasuruan	0.0677	Tulungagung	0.0111
Lamongan	0.0279				

Source: personal processing with NetworkX

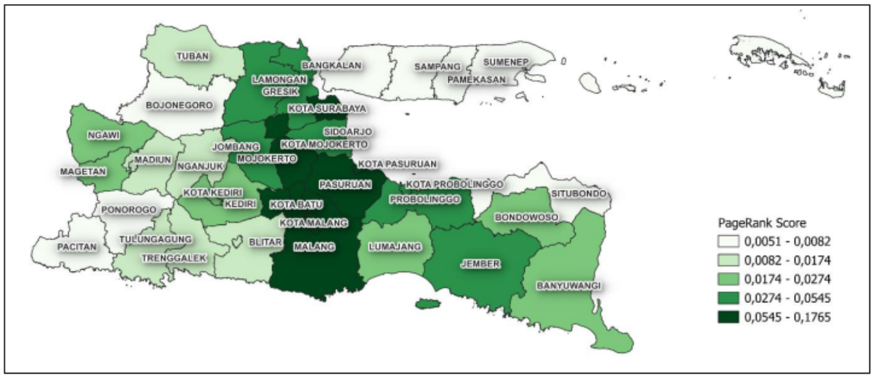

Figure 6. PageRank score clustering

The regions with the highest PageRank scores are Surabaya (0.1765), Malang (0.1396), Pasuruan (0.0677), Mojokerto (0.0608), and Batu (0.0622). These cities are central hubs in the tourism network, indicating their significant role in attracting tourist searches and serving as important links between other cities.

The high PageRank scores for Surabaya and Malang underscore their prominence as major urban centers and tourist destinations in East Java (Prastya et al., 2022). Surabaya, as the provincial capital, serves as a central hub for commerce, culture, and tourism, attracting a significant number of visitors annually. Similarly, Malang is renowned for its cool climate, colonial architecture, and proximity to attractions like Mount Bromo and Batu, making it a favored destination for both domestic and international tourists.

Batu, often associated with Malang due to its close proximity. It is celebrated for its natural attractions and theme parks, such as Jatim Park and Batu Secret Zoo, which draw substantial tourist numbers. The city's focus on family-friendly attractions and agro-tourism contributes to its high connectivity within the tourism network.

Pasuruan benefits from its strategic location along major transportation routes. Its array of attractions includes natural sites like the Tretes mountain resort and the Bromo Tengger Semeru National Park. The city's accessibility and diverse tourism offerings enhance its role as a significant node in the network.

Mojokerto holds historical significance as part of the ancient Majapahit Kingdom. It includes archaeological sites such as Trowulan attracting history enthusiasts (Tus Saidah et al., 2023). Its cultural heritage and proximity to Surabaya contribute to its importance in the tourism landscape.

These cities' high PageRank values reflect their central roles in East Java's tourism network, serving as key hubs that facilitate tourist flows and connect various destinations across the region.

Adamic Adar Prediction Link

The Adamic-Adar index is used for link prediction, providing insights into potential future connections between regions based on shared features and common neighbours. This index is handy for identifying regions likely to develop new tourism relationships.

The predicted new links based on the Adamic-Adar index are as follows:

- Bojonegoro and Malang: Score 0.9899
- Bojonegoro and Mojokerto: Score 0.9899
- Trenggalek and Malang: Score 0.7508

- Trenggalek and Surabaya: Score 0.7508
- Bangkalan and Pasuruan: Score 0.6698

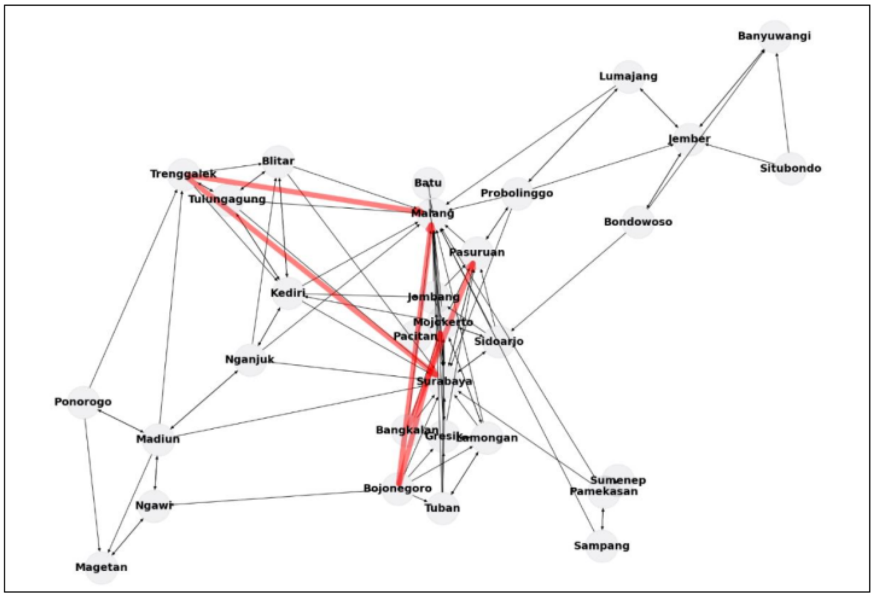

Figure 7. Adamic Adar's new link in red color

The Adamic-Adar index was selected for its effectiveness in predicting potential new connections within sparse networks, such as regional tourism linkages. This index considers the common neighbors between nodes, giving more weight to less-connected nodes, which helps in identifying emerging or hidden relationships that might not be apparent from direct search data. However, a limitation of the Adamic-Adar index is its reliance on the existing network structure, which may overlook entirely new tourism destinations that lack historical search data connections.

Implications and Policy Recommendations

Network Structure Implications

The strong centrality of Malang and Surabaya suggests that these cities play a crucial role in sustaining the flow of tourists across East Java. Their positions as network hubs enhance accessibility and provide economic benefits not only locally but also to neighboring regions through spillover effects.

Social, Cultural, and Environmental Impacts:

Tourism development centered around these hubs may lead to both positive and negative impacts:

- **Social:** Increased tourism can foster cultural exchange and create job opportunities, but it may also lead to overcrowding and strain on local infrastructure.
- **Cultural:** The promotion of local heritage sites can preserve cultural identities, yet commercialization risks diluting traditional practices.
- **Environmental:** While tourism growth can support conservation efforts through eco-tourism, it can also contribute to environmental degradation if not managed sustainably.

Isolated Regions and Potential Development

Regions like Pacitan were identified as isolated nodes within the network. This isolation presents both a challenge and an opportunity. Strategic interventions, such as improved transportation links and targeted marketing campaigns, could integrate these areas more effectively into the tourism network, boosting local economies and diversifying tourist experiences.

Policy Recommendations

Based on the network analysis, several policy recommendations emerge:

- Strengthening infrastructure in central hubs while ensuring balanced development in less connected regions.
- Promoting sustainable tourism practices to mitigate environmental impacts.
- Enhancing digital marketing strategies to increase the visibility of underrepresented destinations.

These findings provide a foundation for developing comprehensive tourism strategies that leverage data-driven insights to foster sustainable growth in East Java's tourism sector.

CONCLUSION

Providing a new precise link between can be a key to boost economic advantages. Many strategies can be applied to this case. Potential future linkages were identified, including Bojonegoro with Malang and Mojokerto and Trenggalek with Malang and Surabaya, suggesting shared interests and common tourism themes. We can give an example of new connections between Trenggalek and Surabaya. Local government can rebrand the tourist place to attract new visitors from other regions. However, many studies have to be conducted to optimize a limited budget.

The component analysis revealed a large strongly connected component consisting of 24 regions with mutual search interests. In contrast, regions like Bangkalan, Bojonegoro, Pacitan, Sumenep, and Situbondo were isolated in terms of bidirectional searches. The Girvan-Newman algorithm identified three distinct communities, reinforcing the observed connectivity patterns. Pacitan emerged as an isolated community, while Banyuwangi, Bondowoso, Jember, Lumajang, and Situbondo formed a separate community. Surabaya, Malang, Pasuruan, Mojokerto, and Batu were identified as central hubs in the tourism network, highlighting their strategic importance in attracting and distributing tourist interest.

The findings provide valuable insights for regional tourism authorities to develop targeted marketing strategies and infrastructure investments. By identifying central hubs and potential new linkages, resources can be allocated more efficiently to boost tourism in regions with high growth potential. Understanding community structures within the tourism network can help foster collaborations between cities and promote regional tourism packages.

The study is limited by the scope of the data, focusing only on Google search trends for a single year. Seasonal variations and other data sources were not considered, which could impact the generalizability of the findings. Despite its valuable insights, this study is limited by the scope of Google Trends data from 2023. However, this temporal focus enhances its relevance for short-term tourism predictions in 2024, as it captures the most recent trends and emerging patterns in tourist interests.

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