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Research Article

Resilience and Recovery: Clustering International Tourism Trends in Indonesia Amidst COVID-19

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ABSTRACT

This study presents a hierarchical clustering analysis of international tourism to Indonesia, examining the shifts in tourist volumes from various countries during the pre-pandemic, pandemic, and post-pandemic periods. Utilizing the agglomerative method with Euclidean distance and Ward linkage, the research identifies 13 distinct clusters, each reflecting unique patterns of tourism volume change. The analysis reveals the resilience of the tourism industry, with some clusters demonstrating remarkable recovery, surpassing pre-pandemic levels, while others indicate a more gradual return to normalcy. The findings offer significant implications for tourism policy and management, suggesting the need for targeted strategies to foster recovery and growth. The study also underscores the importance of crisis management and preparedness, highlighting the role of data analytics in strategic decision-making within the tourism sector. Future research directions include incorporating additional variables, conducting longitudinal studies, and exploring the relationship between tourism and public health measures.

INTRODUCTION

The COVID-19 pandemic significantly disrupted international travel and tourism, impacting economies worldwide. Indonesia, a nation heavily reliant on tourism, has witnessed a dramatic decline in international tourist arrivals since the pandemic's emergence in 2019. In 2019, Indonesia welcomed 16.1 million foreign tourists. This number plummeted to 4.05 million in 2020 and then dipped further to 1.5 million in 2021[1]. These figures represent a staggering 74.8% decrease in 2020 and a further 90.3% decline in 2021 compared to pre-pandemic levels in 2019. Despite a nearly 98% surge in tourist arrivals in 2023 compared to 2022, the numbers still fell short of pre-pandemic levels, reaching only 11.7 million arrivals[1]. This research investigates the recovery patterns of international tourism to Indonesia from 2019 to 2023, employing cluster analysis to identify distinct country responses to the pandemic and their subsequent trajectories towards recovery.

Tourism is a cornerstone of the Indonesian economy, contributing significantly to GDP and employment. The nation's diverse cultural heritage, ecosystems, and landscapes have historically positioned it as a premier tourist destination. However, the COVID-19 pandemic halted this thriving industry. Global travel restrictions and border closures significantly reduced international tourist arrivals. This not only impacted hotels and restaurants but also rippled through related sectors, posing challenges to Indonesia's economic stability. The hotel industry bore the brunt of these restrictions, with occupancy rates plummeting and cancellations soaring. Consequently, hotel profits plunged by up to 40%[2], leading to operational difficulties and layoffs of a staggering

78.5% of registered workers[3]. The restaurant industry also suffered immensely, with around 1 million of the 1.5 million registered workers either furloughed or laid off since the beginning of the outbreak in Indonesia[3]. Airlines, taxis, and other transportation services witnessed a sharp decline in passengers, with many companies forced to shut down due to the dramatic decrease in travel demand[4].

Governments implemented various measures to curb the pandemic's spread, including lockdowns and travel restrictions. These measures, while crucial for public health, negatively impacted international mobility and tourism. Indonesia was no exception, with government policies restricting inbound travel and impacting tourist volume. As of 2023, with vaccination campaigns and travel restrictions easing, the global tourism industry shows signs of revival. This presents a unique opportunity to analyze the resurgence patterns in international tourist arrivals to Indonesia and explore the factors influencing recovery pace and extent across different countries.

This study utilizes a clustering approach to categorize countries based on their monthly tourist arrival volumes in Indonesia. Clustering, an unsupervised machine learning technique, excels at identifying inherent data groupings, making it ideal for our analysis. By segmenting countries into clusters, we can identify patterns and compare nations with similar recovery profiles. This methodology enables a detailed examination of data while allowing for aggregated insights across clusters.

Understanding these recovery dynamics holds significant value for policy-making and strategic planning within the Indonesian tourism industry. Stakeholders can leverage these insights to tailor their approaches to the evolving international travel landscape. Moreover, the study's findings may provide valuable insights for other pandemic-affected sectors, offering a framework for navigating post-crisis recovery complexities.

To provide a comprehensive understanding of tourism recovery patterns, this research utilizes meticulously collected and processed data encompassing the pre-pandemic (2019), pandemic (2020-2021), and post-pandemic (2022-2023) periods. Subsequent sections present the literature review, methodology details, clustering analysis results, and a discussion on the implications of our findings. Through this exploration, this paper aims to contribute meaningfully to the body of knowledge surrounding the COVID-19 pandemic's impact on international tourism, with a specific focus on the Indonesian context.

LITERATURE REVIEW

The COVID-19 pandemic has undeniably reshaped the landscape of global tourism, presenting unprecedented challenges and catalyzing shifts in tourist behaviors, governmental policies, and industry strategies. The impact of the pandemic on global tourism has been profound, with international tourism recovering only 63% of pre-pandemic levels[5]. The crisis has necessitated a reevaluation of tourism resilience and recovery strategies, emphasizing the need for sustainable practices and innovative marketing approaches to adapt to the new normal[6].

Governmental and business responses have been pivotal in addressing the immediate effects of the pandemic and setting the stage for recovery. Countries like Indonesia have implemented policies to support the tourism sector, focusing on health protocols and economic incentives to mitigate the impact on livelihoods and the economy[5,7]. The psychological and behavioral responses of tourists have also shifted, with a growing preference for destinations that prioritize health and safety measures[8,9].

Indonesia’s tourism, rich in cultural and natural assets, has faced a significant downturn due to the pandemic but is poised for recovery by leveraging its biodiversity and cultural heritage[4,10]. Sustainable tourism has emerged as a cornerstone for the future of the industry in Indonesia, with initiatives aimed at reducing carbon emissions and promoting eco-friendly tourism practices[11,12]. The country’s tourism policy during COVID-19 has been reformed to support sustainable development and ensure the safety of both tourists and residents[13,14].

Marketing strategies in Indonesia have adapted to the changing landscape, with a focus on digital platforms and sustainable tourism offerings to attract domestic and international tourists[8,15]. As the world moves towards recovery post-COVID-19, Indonesia is actively seeking to revive its tourism industry by offering investment opportunities and focusing on sustainable and inclusive growth[16,17].

In conclusion, the pandemic has served as a catalyst for change within the tourism sector, prompting a shift towards sustainability, resilience, and digitalization. Indonesia, with its rich cultural and natural resources, is well-positioned to emerge stronger from the crisis by embracing these new paradigms and redefining its tourism industry for the future[18].

One key element to this redefinition is understanding the evolving preferences of tourists. This is where clustering in tourism research becomes crucial. Clustering in tourism research has gained relevance as it aids in understanding the evolving preferences of tourists and the segmentation of markets based on new travel patterns[19,20]. It has become an indispensable tool in tourism research,

Table 1. *Descriptive Statistics of Features Used in This Study*

Feature	Mean	Median	Standard Deviation
Average Volume Pre-Covid (2019)	11,623.10	835.75	35,338.27
Covid Ratio (2020-2021)	0.14	0.11	0.09
Post-Covid Ratio (2022)	0.38	0.35	0.20
Post-Covid Ratio (2023)	0.92	0.85	0.74

particularly for understanding the multifaceted nature of tourist behaviors and preferences. It allows researchers to identify homogenous groups of tourists based on a variety of characteristics, such as demographics, trip-related factors, motivations, and expectations[21]. This segmentation enables the tourism industry to tailor its offerings to specific groups, ensuring a more targeted and efficient allocation of marketing resources.

For instance, a study in Bali, Indonesia, utilized cluster analysis to examine tourism objects using K-Means and X-Means clustering algorithms[22]. This study aimed to categorize tourism sites to better understand visitor patterns and preferences, which could then inform strategic planning and promotional activities. By leveraging cluster analysis, Indonesian tourism stakeholders can gain valuable insights into the desires of today's travelers, allowing them to craft experiences that resonate with these new market segments. This targeted approach will be instrumental in reviving Indonesia's tourism industry and ensuring its long-term success in the post-pandemic era.

Building upon the valuable insights gained from cluster analysis, researchers can delve deeper into the specific techniques employed. The methods used in cluster analysis can be broadly categorized into nonhierarchical and hierarchical. Nonhierarchical clustering assigns observations into a pre-specified number of clusters, while hierarchical clustering creates a tree-like structure of clusters, which can be particularly useful for visualizing the data and understanding the nested relationships between clusters[21]. Emerging applications of cluster analysis in tourism research are increasingly relevant due to the availability of big data sets, such as those derived from social media or online reviews. These data sources provide rich insights into tourist behavior and preferences.

By applying cluster analysis to Indonesian tourism data, researchers can gain a nuanced understanding of how international tourist preferences have shifted during COVID-19. This knowledge can then be used to inform the development of targeted marketing strategies, the creation of new sustainable tourism experiences, and the overall revitalization of Indonesia's tourism industry in the post-pandemic era.

Table 2. *Cluster Characteristics*

Cluster	Avg. Vol. Pre-Covid (2019)	Covid Ratio (2020-2021)	Post-Covid Ratio (2022)	Post-Covid Ratio (2023)
1	33.42	0.23	1.76	7.89
2	98,198.40	0.77	0.60	0.62
3	77.00	0.46	1.16	1.51
4	12,355.81	0.12	0.30	0.73
5	67,326.95	0.13	0.45	0.90
6	443.29	0.10	0.68	2.14
7	3,618.37	0.11	0.52	1.05
8	31,054.42	0.09	0.13	0.37
9	1,643.45	0.25	0.26	0.76
10	515.92	0.18	0.39	0.91
11	224.87	0.11	0.22	0.53
12	148.80	0.10	0.42	1.10
13	833.11	0.10	0.32	0.81

METHODOLOGY

This study employs a comprehensive methodology to analyze the shifts in international tourism to Indonesia, focusing on the period from 2019 to 2023. The approach is designed to capture the nuances of tourism volume changes due to the COVID-19 pandemic and subsequent recovery phases.

Data Collection and Selection

The primary dataset for this analysis comprises monthly tourist volumes from various countries visiting Indonesia. This data[1], sourced from Badan Pusat Statistik (BPS) Indonesia, covers the period from 2019 to 2023, encapsulating the pre-pandemic, pandemic, and post-pandemic tourism landscapes. To ensure a focused and meaningful analysis, the study includes countries that have recorded at least 1000 yearly tourists visiting Indonesia in one or more years within the specified timeframe. This criterion was established to maintain a dataset with significant tourism interactions, thereby enhancing the reliability of the clustering outcomes.

Feature Engineering

From the raw monthly tourist volumes, four critical features were derived to serve as the basis for the clustering analysis:

1. **Pre-Covid Average Volume (2019)**: This feature represents the baseline tourism volume before the pandemic's impact, providing a reference point for subsequent comparisons.
2. **Covid Ratio (2020-2021)**: This ratio measures the relative change in tourism volume during the pandemic years compared to the pre-pandemic period.

3. **Post-Covid Ratio (2022)**: This feature assesses the recovery progress in 2022 relative to the pre-pandemic tourism volume.
4. **Post-Covid Ratio (2023)**: Similar to the previous feature, this ratio evaluates the continued recovery in 2023.

These features were meticulously calculated to reflect the temporal dynamics and provide a multi-dimensional view of the tourism volume changes.

Data Transformation

Given the skewed distribution of tourist volumes, a log transformation was applied to normalize the data. The transformation formula used is:

$$x_{\log} = \ln(x + 1)$$

where x and $x_{\log}$ denote the original and log scaled feature value respectively. Here 1 is added to ensure no errors occur for zero values in the data. This approach effectively mitigates the influence of extreme values, facilitating a more balanced clustering process.

Following the log scaling, standard scaling was employed to ensure all features were on a comparable scale. The standard scaling formula is:

$$x_{\text{std}} = \frac{x_{\log} - \overline{x_{\log}}}{s}$$

where x_{std} denotes the standard scaled feature value, $x_{\log}$ denotes the log scaled feature value, $\overline{x_{\log}}$ denotes the mean of the log scaled feature, and s denotes the standard deviation of the log scaled feature.

Clustering Algorithm

The hierarchical clustering algorithm using the Agglomerative method was chosen for its ability to construct a hierarchy of clusters based on the data. This method is particularly suitable for exploratory data analysis where the number of clusters is not predetermined. The Euclidean distance was used to measure the dissimilarity between data points, and Ward linkage[23] was selected to minimize the variance within clusters.

Determining the Number of Clusters

The dendrogram, a visual representation of the hierarchical clustering process, was utilized to determine the number of clusters. By setting a threshold at 25% of the dendrogram's height, a natural division within the data was identified, allowing for the delineation of distinct clusters. This threshold was chosen based on empirical observations and the desire to achieve a balance between within-cluster homogeneity and between-cluster heterogeneity.

RESULTS AND DISCUSSION

This section presents the findings derived from the application of hierarchical clustering analysis on the international tourist volume data for Indonesia from 2019 to 2023. The analysis aimed to identify distinct clusters of countries based on their tourist volume patterns throughout the pre-pandemic, pandemic, and post-pandemic periods.

Descriptive Statistics

Descriptive statistics shown in Table 1 provided an overview of the data, indicating a significant drop in tourist volumes during the Covid period, followed by a gradual recovery in 2022 and 2023.

Number of Clusters

The hierarchical clustering process, utilizing the dendrogram and a threshold of 25% of its height as shown in Figure 1, yielded 13 distinct clusters. This selection aimed to achieve a balance between within-cluster homogeneity (similarity of countries within a cluster) and between-cluster heterogeneity (dissimilarity between clusters). To further illustrate the cluster distribution, Figure 2 shows the relationships between the selected features across different countries. Notably, aside from a positive correlation between Post-Covid Ratio (2022) and Post-Covid Ratio (2023), no clear linear relationships are evident among the remaining features. However, the clustering, represented by color-coded dots, reveals distinct country groups based on these features. Tightly clustered groups suggest similar pandemic responses, while well-separated clusters indicate contrasting characteristics.

Cluster Characteristics and Interpretations

Table 2 shows the cluster characteristics across four clustering features. As can be seen, each cluster shows a unique pattern of tourism volume change over the specified periods.

Cluster 1: Macau

This cluster shows an extraordinary recovery post-pandemic, with a Post-Covid Ratio (2023) of 7.89, indicating a significant increase in tourism volume compared to the pre-pandemic period. This could suggest that Macau has emerged as a strong source of tourists post-pandemic.

Cluster 2: East Timor

With a pre-Covid average volume of 98,198.40, this cluster had a substantial tourist base before the pandemic. The Covid Ratio of 0.77 reflects a relatively lower impact during the pandemic and shows a slight decrease in tourism volume post-

pandemic. This cluster might represent countries with strong ties to Indonesia, resulting in consistent tourist flow despite global challenges. The Post-Covid Ratios of 0.60 in 2022 and 0.62 in 2023 demonstrate a slow recovery, with tourism volumes remaining below pre-pandemic figures.

Cluster 3: Israel

This cluster had a moderate pre-Covid average volume of 77 tourists. The Covid Ratio of 0.46 indicates a moderate impact during the pandemic but shows a steady recovery in the following years. This could reflect a resilient tourist relationship that is rebounding as travel restrictions ease.

Cluster 4: Diverse Group Including South Korea, Philippines, Canada, etc.

Cluster 4 represents a diverse group of countries with a high pre-Covid average volume of 12,355.81. The Covid Ratio of 0.12 shows a drastic reduction in tourism during the pandemic. The recovery is ongoing, with Post-Covid Ratios of 0.30 in 2022 and 0.73 in 2023, suggesting a gradual return to pre-pandemic tourism volumes.

Cluster 5: Major Tourism Contributors Including Malaysia, Singapore, Australia, etc.

This cluster includes some of the largest contributors to tourism in Indonesia, with a pre-Covid average volume of 67,326.95. The Covid Ratio of 0.13 indicates a significant drop in tourism volume during the pandemic. The Post-Covid Ratios of 0.45 in 2022 and 0.90 in 2023 show an ongoing recovery, yet the tourism volume remains below pre-pandemic levels.

Cluster 6: Colombia and Tunisia

Cluster 6 had a moderate pre-Covid average volume of 443.29 and one of the lowest Covid Ratio of 0.10 among all clusters, suggesting a relatively high impact of the pandemic on tourism volumes. The Post-Covid Ratios of 0.68 in 2022 and 2.14 in 2023 reflect a robust recovery, with the number of tourists in 2023 more than doubling the pre-pandemic level.

Cluster 7: A Diverse Group Including Vietnam, Italy, Spain, etc.

This cluster comprises a wide range of countries with a moderate pre-Covid average volume of 3,618.37. The Covid Ratio of 0.11 indicates a drastic decrease in tourism volume during the pandemic. The Post-Covid Ratios of 0.52 in 2022 and 1.05 in 2023 show a steady recovery, with tourism volumes slightly surpassing pre-pandemic levels by 2023.

Cluster 8: East Asian Countries Including China, Japan, Taiwan, etc.

Cluster 8 includes East Asian countries with a high pre-Covid average volume of 31,054.42. The Covid Ratio of 0.09, the lowest among all clusters, suggests a significant impact of the pandemic on tourism volumes. The Post-Covid Ratios of 0.13 in 2022 and 0.37 in 2023 indicate a slow recovery, with tourism volumes significantly below pre-pandemic levels. This could be due to prolonged travel restrictions or shifts in travel preferences post-pandemic.

Cluster 9: Countries Including Papua New Guinea, Ukraine, Kazakhstan, etc.

This cluster had a low pre-Covid average volume of 1,643.45. The Covid Ratio of 0.25 reflects a moderate decrease in tourism volume during the pandemic. The Post-Covid Ratios of 0.26 in 2022 and 0.76 in 2023 suggest an ongoing recovery, with tourism volumes not yet reaching pre-pandemic levels.

Cluster 10: Countries Including Pakistan, Hungary, Argentina, etc.

Cluster 10 had a low pre-Covid average volume of 515.92. The Covid Ratio of 0.18 indicates a high decrease in tourism volume during the pandemic. The Post-Covid Ratios of 0.39 in 2022 and 0.91 in 2023 show an ongoing recovery, with tourism volumes approaching pre-pandemic levels.

Cluster 11: Countries Including Serbia, Algeria, Mauritius, etc.

This cluster had a low pre-Covid average volume of 224.87. The Covid Ratio of 0.11 suggests a slight decrease in tourism volume during the pandemic. The Post-Covid Ratios of 0.22 in 2022 and 0.53 in 2023 indicate a slow recovery, with tourism volumes reaching only about half of the pre-pandemic levels by 2023.

Cluster 12: Countries Including Peru, Maldives, Qatar, etc.

Cluster 12 had a very low pre-Covid average volume of 148.80. The Covid Ratio of 0.10 reflects a significant drop in tourism volume during the pandemic. The Post-Covid Ratios of 0.42 in 2022 and 1.10 in 2023 demonstrate a good recovery, with tourism volumes exceeding pre-pandemic levels.

Cluster 13: Countries Including Czech Republic, Egypt, Brunei, etc.

This cluster includes countries with a moderate pre-Covid average volume of 833.11. The Covid Ratio of 0.10, one of the lowest among all clusters, suggests a substantial impact of the pandemic on tourism volumes. The Post-Covid Ratios of 0.32 in 2022 and 0.81 in 2023 show a steady recovery, with tourism volumes nearing pre-pandemic levels.

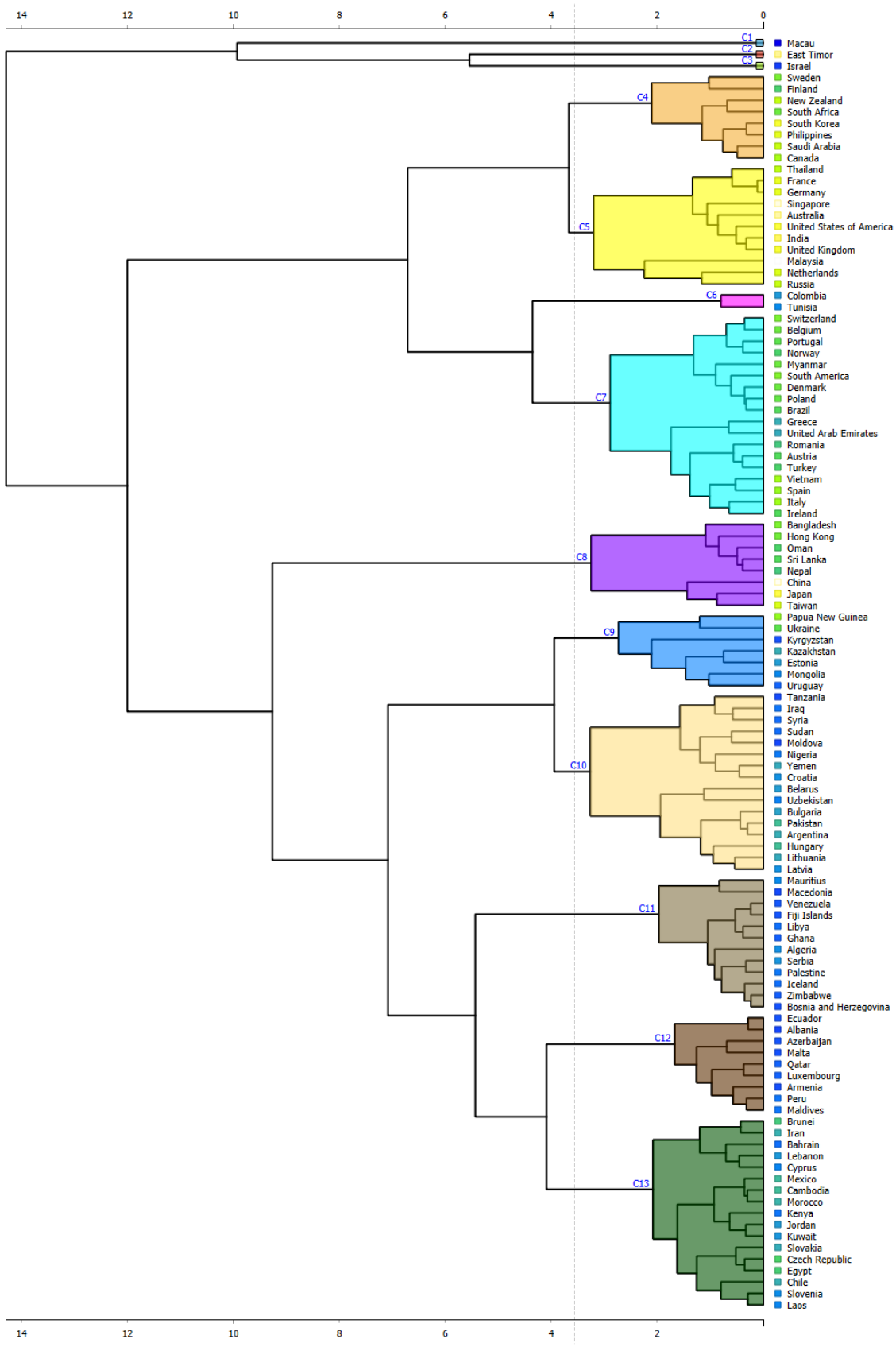

Figure 1. *Dendogram illustrating the hierarchical clustering results. The dotted line marks the clustering distance threshold while the colored boxes on the left of the country names indicate the average monthly tourist volume pre-Covid. Darker shades represent lower volumes, while brighter colors indicate higher volumes.*

Key Findings and Interpretation

The hierarchical clustering analysis of international tourism to Indonesia has yielded several key findings that provide a nuanced understanding of the pandemic's impact and the subsequent recovery patterns. The analysis delineated 13 clusters, each representing a distinct group of countries with similar tourism volume trends across the pre-pandemic, pandemic, and post-pandemic periods.

A remarkable observation is the resilience of certain tourist markets. For instance, Cluster 1, represented solely by Macau, demonstrated an extraordinary recovery, with the post-pandemic tourist volume in 2023 being almost eight times the pre-pandemic level. This suggests that some markets may have pent-up demand, leading to a surge in tourism once travel restrictions are lifted.

Clusters such as 6, 7, and 12, which include countries like Colombia, Tunisia, Vietnam, and the Maldives, showed a significant impact from the pandemic and a steady recovery. The recovery ratios in these clusters indicate that tourism volumes have either approached or surpassed pre-pandemic levels by 2023. This could be attributed to effective pandemic management, swift vaccination rollouts, or the appeal of these countries as post-pandemic travel destinations.

Major tourism contributors, as seen in Cluster 5, which includes Malaysia, Singapore, and Australia, experienced a significant drop in tourism volume during the pandemic. However, the recovery has been gradual, with volumes still below pre-pandemic levels by 2023. This pattern may reflect more cautious reopening strategies and the lingering effects of travel hesitancy.

East Asian countries in Cluster 8, such as China and Japan, had a significant drop in tourism volume during the pandemic. Their recovery has also been slow, with volumes significantly below pre-pandemic levels by 2023. This could be due to prolonged travel restrictions or changes in travel preferences post-pandemic.

The clustering results have strategic implications for Indonesia's tourism industry. Countries in clusters with strong recoveries could be targeted with marketing campaigns to capitalize on the high demand. Conversely, countries in clusters with slow recoveries might require more focused efforts to rebuild confidence in travel and promote Indonesia as a safe destination.

The findings also have economic and policy considerations. For countries with a significant drop in tourism volume, there may be a need for continued support to the tourism sector to aid in recovery. Policy measures could include promoting domestic tourism, providing financial incentives for international tourists, and investing in health and safety protocols to reassure potential visitors.

The analysis highlights the importance of understanding long-term trends in tourism and the need for sustainable practices. The pandemic has underscored the vulnerability of the tourism industry to global shocks. Therefore, diversifying tourism offerings and investing in sustainable tourism infrastructure could make the industry more resilient to future challenges.

Comparison to Existing Literature

The findings of this study resonate with the broader themes identified in existing literature on the impact of pandemics on international tourism and the subsequent recovery patterns. The resilience and recovery trajectories observed in the clusters align with the predictions and observations made by tourism researchers and economists.

The extraordinary recovery observed in Cluster 1, particularly for Macau, is consistent with the "pent-up demand" theory discussed in the literature, where a surge in tourism is expected once travel restrictions are lifted[24,25]. This aligns with previous observations suggesting that tourism is an adaptable economic sector that can experience rapid growth post-crisis[26].

The high impact and steady recovery seen in Clusters 6, 7, and 12 reflect the resilience of certain tourist markets in the context of tourism-dependent economies[27]. These economies are highlighted as being among the most harmed by the pandemic but also stand to benefit significantly from a well-managed recovery process.

The significant drop and gradual recovery pattern in major tourism contributors, as seen in Cluster 5, echo the concerns raised about sustainable tourism and the need for long-term planning. Literature on sustainable tourism development[28], emphasizes the importance of managing tourism growth to avoid issues like overtourism[26].

The substantial impact and slow recovery in East Asian countries, particularly in Cluster 8, can be compared to the selective types of tourism and their adaptability to COVID-19 measures discussed in recent studies[29]. These studies highlight how

different tourism sectors have adapted to the new normal, with varying degrees of success.

Furthermore, the overall resilience observed across the clusters can be linked to the concept of tourism destination resilience. A comprehensive review by experts in the field suggests that destination management plays a crucial role in how quickly and effectively a tourist destination can recover from crises like pandemics[16].

The clustering analysis conducted in this study provides empirical evidence that supports the theoretical frameworks and observations presented in the existing literature. It underscores the complex interplay of economic, social, and policy factors that influence the resilience and recovery of international tourism in the face of global challenges such as pandemics.

Limitations of the Study

This study is limited by its reliance on tourist arrival data, which does not capture other aspects of tourism recovery, such as tourist expenditure or length of stay. Additionally, the chosen features only represent a snapshot of potential influencing factors. Future research could incorporate additional variables like travel restrictions, economic indicators, and marketing campaigns to gain a more comprehensive understanding of the recovery process.

Implications and Future Research

The results of the hierarchical clustering analysis on international tourism to Indonesia offer insightful implications for both policy and management, and they pave the way for future research directions. From a policy perspective, the distinct patterns of tourism volume trends identified across clusters can serve as a basis for crafting targeted strategies aimed at fostering recovery and growth within the tourism sector. For instance, tourism authorities might consider developing bespoke strategies for each cluster, diversifying target markets to reduce reliance on a few source countries, and focusing on sustainable tourism development to ensure the industry's long-term resilience.

In terms of management, the study highlights the value of data-driven decision-making. Tourism managers can utilize analytics to monitor trends and adapt strategies in real-time. Moreover, the importance of crisis management and preparedness is underscored, suggesting that a robust framework for responding to future crises is essential to minimize their impact on tourism.

Looking ahead, this study opens several avenues for future research. Incorporating additional variables such as tourist spending and satisfaction levels could yield a more comprehensive understanding of tourism patterns. Longitudinal studies could provide insights into the long-term effects of the pandemic and the sustainability of the recovery. Comparative analyses might reveal effective strategies for managing tourism during and after pandemics, and research into the impact of tourism trends on local communities could inform policies designed to maximize benefits while minimizing negative impacts. Finally, exploring the relationship between tourism and public health measures could offer valuable guidelines for managing tourism amidst health crises.

In conclusion, this clustering analysis has shed light on the diverse impact and recovery patterns of international tourism to Indonesia, influenced by various economic, social, and policy factors. These findings not only contribute to strategic decision-making in the tourism industry but also highlight the need for adaptive and resilient approaches to managing tourism in the face of global uncertainties. The study's implications for policy and management, along with the proposed future research directions, underscore the ongoing need to understand and respond to the dynamic nature of the tourism sector.

CONCLUSION

The hierarchical clustering analysis conducted on international tourism to Indonesia has provided a comprehensive overview of the shifts in tourist volumes from various countries during the pre-pandemic, pandemic, and post-pandemic periods. The study's findings have significant implications for tourism policy and management, offering a data-driven foundation for strategic decision-making aimed at fostering the sector's recovery and growth.

The resilience and adaptability of the tourism industry are evident from the varied recovery patterns across the clusters. While some clusters have shown remarkable recovery, surpassing pre-pandemic levels, others have indicated a more gradual return to the norm. These insights are crucial for tailoring marketing strategies, diversifying tourism offerings, and ensuring sustainable development within the industry.

Moreover, the study underscores the importance of preparedness and effective crisis management, highlighting the need for robust frameworks capable of mitigating the impacts of future global disruptions. The use of data analytics in tourism management emerges as a key tool for real-time monitoring and strategy adjustment, emphasizing the role of technology in the industry's future.

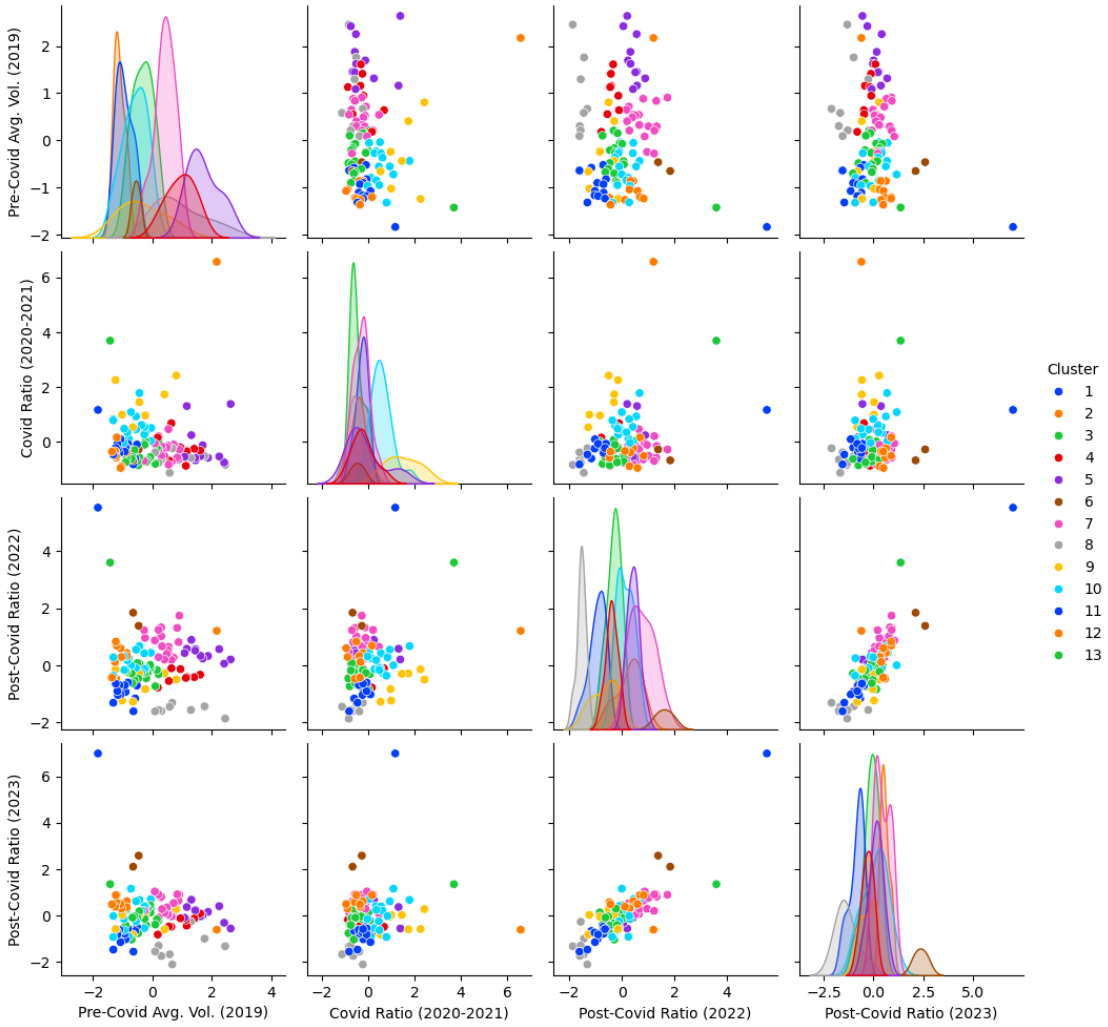

Figure 2. *Pairplot of four features used in this study. Each dot represents a country, color-coded by cluster. The diagonal shows kernel density estimation for each feature, while the off-diagonal scatter plots reveal correlations.*

Future research directions proposed by this study include the incorporation of additional variables, longitudinal tracking, comparative analyses, and the exploration of the relationship between tourism and public health measures. These avenues promise to enrich the understanding of tourism dynamics further and aid in the development of resilient tourism practices.

In conclusion, this research contributes valuable insights into the impact of global crises on international tourism and the subsequent recovery patterns. It serves as a testament to the sector's resilience and provides a roadmap for navigating the challenges and opportunities that lie ahead in the ever-evolving landscape of global tourism.

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AUTHOR CONTRIBUTIONS

M.A.R.: conceived the study, conducted the research, analyzed the data, and wrote the manuscript.

COMPETING INTERESTS

Authors have no competing interest to declare.

DATA AVAILABILITY

The raw data used in this study are available at https://www.bps.go.id/id/statistics-table/2/MTQ3MCMy/jumlah-kunjungan-wisatawan-mancanegara-per-bulan-menurut-kebangsaan--kunjungan-.html. The preprocessed data are available upon request to the corresponding author.