

Opportunities and Strategies for Accelerating Digital Transformation: Spatial Distribution Analysis and Clustering Using K-Medoids Method in South Sulawesi, Indonesia

Aditya Idris ^{1*}, Sumarni Susilawati ²

¹ Hasanuddin University, South Sulawesi, Indonesia

² Universitas Muhammadiyah Makassar, Indonesia

*Correspondent Email: latervilla@gmail.com

ABSTRACT

The increase in internet usage among the population in South Sulawesi presents a golden opportunity for accelerating digital transformation efforts. This can be leveraged to boost economic growth, particularly by maximizing the key sectors in South Sulawesi. The aim of this study is to analyze the spatial distribution and perform clustering of the regencies/cities in South Sulawesi based on digital transformation indicators, as well as to determine the multiplier effect on other regions in Sulampua. The research method employed is quantitative, utilizing descriptive analysis and clustering analysis of regencies/cities in South Sulawesi with the K-Medoids method. The results show that spatially, the distribution of internet users, e-commerce users and SMEs using the internet have quite varied patterns and reveal a high disparity in service users among regencies/cities in South Sulawesi. Meanwhile, the clustering results indicate that the regencies/cities in South Sulawesi are balanced between cluster 1 and cluster 2, each consisting of 12 regencies/cities. It was found that cluster 2, which includes regencies and cities in South Sulawesi, has better variable values in almost all variables compared to the regencies/cities in cluster 1. Generally, cluster 2 dominates all the variables used, while cluster 1 is only superior in the variable of the number of SMEs. The suggestions and policy recommendations for the government based on this study on the acceleration of digital transformation with spatial distribution and clustering analysis can help create an environment that supports sustainable digital economic growth. With coordinated and collaborative policy strategies, South Sulawesi can achieve significant acceleration in digital transformation and enhance the overall well-being of its population in Sulampua.

Keyword: Clustering; Digital Transformation; K-Medoids; Spatial Distribution.

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1. Introduction

The era of Industry 4.0 is marked by the increasingly widespread use of digital technology, becoming a vital asset for all industry players in developing their businesses. By leveraging digital technology, industries can collaborate with each other to achieve common goals and targets (Kapur, 2018). The enhancement of economic growth is also supported by digital transformation, as it can positively impact the economic advancement of a region (Puslitbang Aptika and IKP, Ministry of Communication and Information, 2019). Digital transformation is closely related to the digital economy, where the digital economy involves economic activities that utilize information systems and digital data, information technology, the internet, and communication (Fund, 2018). In Indonesia, the digital economy is considered a new "potential" in the economic system with significant opportunities for development in the field of digital transformation acceleration in community life (Adminsiberkreasi, 2021). The growing digital transformation has influenced human life in terms of transactions, both in selling and purchasing goods, as well as its utilization in various digital-based services (Nugraha & Hayu, 2021).

According to APJII data, Indonesia's internet penetration in 2023 reached 78.19%, with an increase of 1.17% from the previous year. South Sulawesi Province is also experiencing an increase in internet utilization, with internet penetration reaching 76.13% in 2023 (APJII, 2024). This increase in internet usage in South Sulawesi Province presents a golden opportunity for accelerating digital transformation. It can be leveraged to boost economic growth, especially by maximizing the key sectors in South Sulawesi Province.

The growing internet usage in South Sulawesi Province is a promising opportunity to enhance the sales of commodities from various leading sectors, such as the industrial and agricultural sectors. This can be achieved by marketing leading products to a broader market, ranging from national to international scales. Therefore, a specific and more in-depth study is needed to analyse the behaviour and characteristics of digital transformation in South Sulawesi Province.

Mapping or clustering can be a method used to assist in formulating policy foundations by observing the characteristics of the studied regions. Clustering is a statistical method that can divide data into several groups, revealing patterns of relationships between regions or groups (Anggoro et al., 2022). The criteria for spatial distribution and mapping using digital transformation indicators are based on the variables used. This is to identify regions in South Sulawesi Province.

The main objective of this research is to analyse the spatial distribution using digital transformation indicators in South Sulawesi Province and to determine the clustering results of districts/cities in South Sulawesi Province using the K-Medoids method. By combining these two main objectives, the researcher aims to identify strategies and policy recommendations to accelerate digital transformation in South Sulawesi Province.

The criteria for spatial distribution and clustering using digital transformation indicators are based on several related variables. The outcomes of this research can be utilized by the Provincial Government, Local Governments, and other relevant stakeholders to evaluate and monitor the implementation of digital transformation in South Sulawesi Province.

2. Method

This research is a quantitative study that includes data description and data explanation. Data description is conducted to illustrate the characteristics of indicators related to digital transformation in South Sulawesi Province, both through table presentations and spatially through map visualizations. For data explanation, the approach involves grouping the districts/cities in South Sulawesi Province using cluster analysis with the K-Medoids method.

This research utilizes secondary data from 2023 obtained from several sources, including the Central Statistics Agency (BPS) of South Sulawesi Province, the BPS of each district/city, and other related institutions. The data used in this study consists of three variables related to digital transformation and five other variables that are presumed to be closely related to the development of digital transformation in South Sulawesi Province. The research units are the 24 districts/cities in South Sulawesi Province.

The variables used in this study include the following: Percentage of internet users; Percentage of E-Commerce users; Percentage of Small and Medium Industries using the internet; Economic growth; Number of villages receiving 4G/LTE signals; Number of

productive-age population; Amount of investment; and Number of Small and Medium Industries.

This study will be analysed using the K-Medoids method with the following steps: (1) Conduct descriptive analysis of the variables used, (2) Perform clustering with the K-Medoids algorithm, (3) Determine the best cluster using the Davies-Bouldin Index, (4) Interpret the results of each formed cluster. After the clustering results are obtained, interpretation of the formed groups will be conducted.

3. Result and Discussion

Descriptive Statistics and Spatial Distribution

Based on the main indicators used to represent digital transformation, it is observed that internet users in South Sulawesi have an average of 64.664%, e-commerce users at 4.1792%, and Small and Medium Industries (IKM) using the internet at 25.9862%. For the other variables, economic growth has an average of 4.24%, 4G/LTE villages at 98.825, productive-age population at 182,961.79, investment value at 671,237,819, and the number of Small and Medium Industries (IKM) at 5,403.291.

Table 1. Descriptive Statistics

Variable	Mean	Variance	Std Dev	Minimum	Maximum
X₁	64,664	75,22138	8,67302	49,79	83,41
X₂	4,1792	107,714	10,3785	0,1	50,9
X₃	25,9862	136,7678	11,6847	3,36	44,19
X₄	4,2404	2,8391	1,68498	1,43	9,66
X₅	98,625	3280,6793	57,277214	21	296
X₆	182961,79	13969004425	118190,54	72522	582708
X₇	671237819	2,9393e ¹⁷	542154193,7	111225906	1802567400
X₈	5403,291	12707812,74	3564,8019	1831	17279

Based on Figure 1, regions with the highest percentage of internet users are concentrated in administrative cities, namely Makassar, Palopo, and Parepare Regency. Additionally, internet usage in the areas surrounding these administrative cities tends to be high, indicated by darker shades. This suggests that urban areas in South Sulawesi likely have a strong correlation with significant economic activity in these regions. However, further research is needed to substantiate this hypothesis. Meanwhile, there are also regions with a low percentage of internet users, including Tana Toraja Regency and Sinjai Regency. This is a particular concern, especially for the local government, as these figures represent internet users within the productive age group, where more than half of the productive-age population in these areas have not yet used and benefited from the internet in their daily lives.

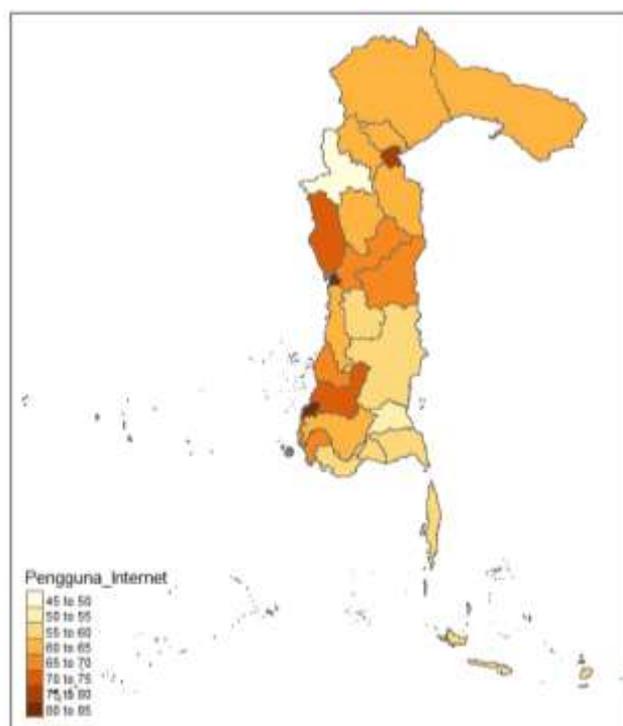


Figure 1. Spatial Distribution of Internet Users Percentage by District/City in South Sulawesi Province in 2023

For Small and Medium Industries (IKM), in Figure 2, that utilize the internet in their daily activities such as buying and selling, product promotion, and other purposes, the usage has started to become more evenly distributed and is not only concentrated in administrative cities. Besides Makassar, Bulukumba Regency also shows a high percentage of internet utilization by IKM in the area. The regions with the lowest percentage of IKM internet users are Tana Toraja Regency, Jeneponto Regency, Selayar Islands Regency, and Wajo Regency. This is a particular concern for the local government to expedite internet utilization for IKM in these regions, supporting the acceleration of digital transformation in South Sulawesi.

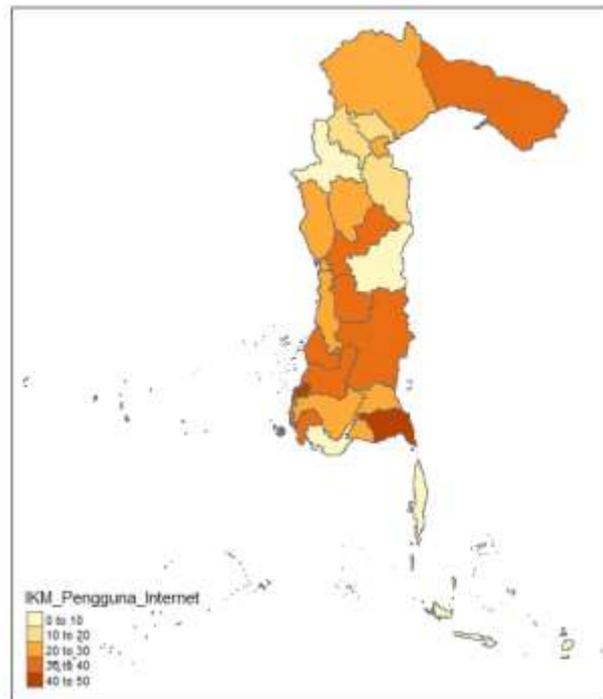


Figure 2. Spatial Distribution of the Percentage of Small and Medium Industries (IKM) Using the Internet by District/City in South Sulawesi Province in 2023

Clustering Analysis Using the K-Medoids Method

Clustering using the K-Medoids method is employed to group the districts/cities in South Sulawesi based on variables that represent digital transformation. The first step is to determine the optimal number of clusters. In this study, the method used to estimate the optimal number of clusters is the Silhouette Method. The results of the silhouette method can be seen in Figure 3. Based on these results, it appears that the clustering of regions using the K-Medoids method in South Sulawesi is estimated to form two clusters.

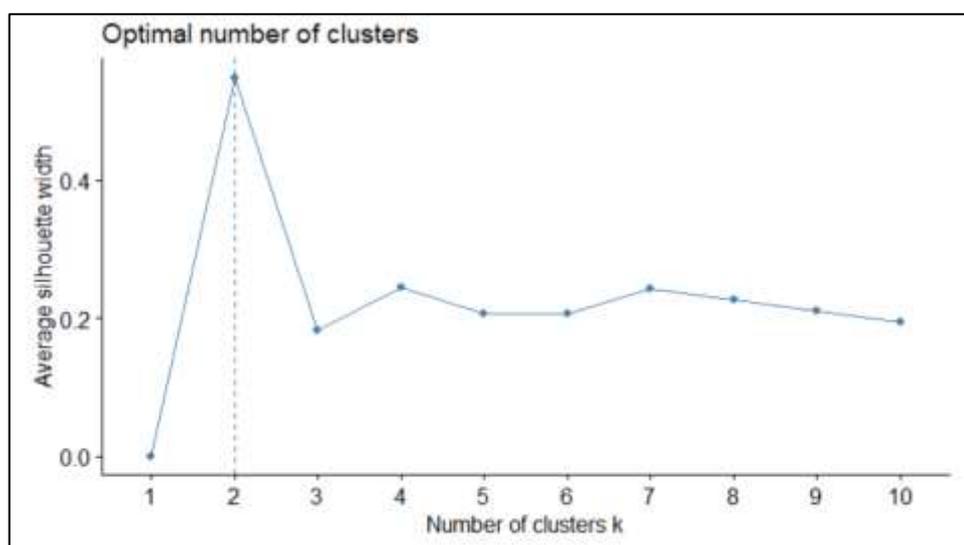


Figure 2. Estimation of Optimal Number of Clusters Using the Silhouette Method

The next step is to determine the initial cluster centers or initial centroids. Assuming we are forming 2 clusters, we need to determine 2 initial centroids. The centroids are selected randomly. In this study, clusters are determined based on the proximity of the centroids using analysis supported by R software. This ensures accurate and consistent calculations. Table 2 shows that Takalar Regency and East Luwu Regency are the initial centroids.

Table 2. Initial Centroids Formed

District/Regency	X1	X2	X3	X4	X5	X6	X7	X8
Kepulauan Selayar	59.02	0.3	6.06	3.68	40	77490	111225906	3762
Bulukumba	56.91	0.6	44.19	4.11	99	144955	323185712	5227
Bantaeng	59.14	1.1	24.87	5.56	61	114542	450912773	4246
Jeneponto	58.65	0.7	9.43	1.9	98	205998	285524127	4410
Takalar	65.81	1.2	36.53	3.86	87	149219	857166465	6703
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	
Luwu Timur	62.15	0.2	31.55	9.66	116	148779	441174870	2418
Toraja Utara	60.23	0.3	19.71	3.94	83	151165	256391075	6558
Makassar City	83.31	50.9	42.46	5.31	148	582708	1636867787	8855
Pare-pare City	83.41	13.3	25.88	3.88	21	72522	152333503	1831
Palopo City	79.73	2.1	28.91	4.34	36	87471	464246870	2355

Next, the plot shows the results of clustering the districts/cities in South Sulawesi using the K-Medoids method based on the variables used for each district/city in South Sulawesi. The determination of the best cluster is done using the Davies-Bouldin Index (DBI). Table 3 shows the DBI values for each of the formed clusters.

Table 3. Davies Bouldin Index

Cluster	Davies Bouldin Index
K = 2	0.3034407
K = 3	0.3214384
K = 4	0.3614302
K = 5	0.3100584

the smallest DBI value is K=2 with a value of 0.3034407. Therefore, the clustering plot used for grouping the districts/cities in South Sulawesi is shown in Figure 3, which results in a total of 2 clusters. This clustering plot is based on the variables used.

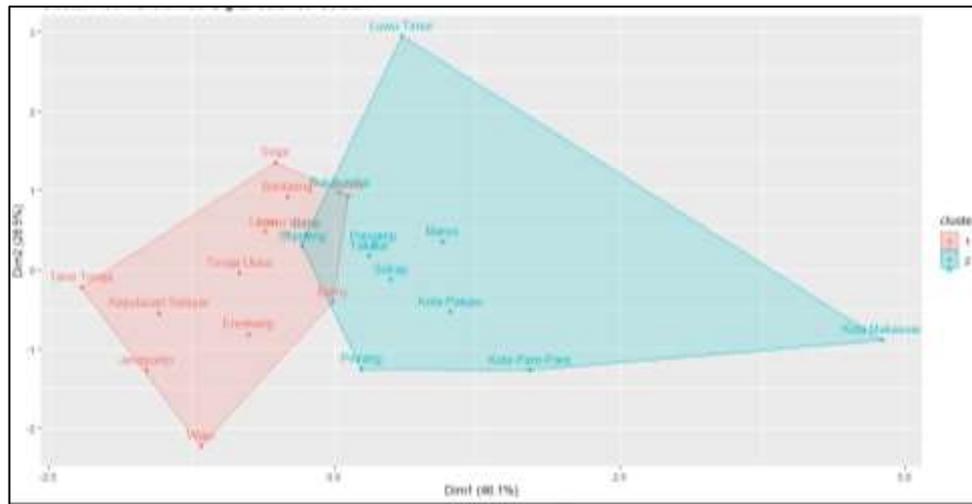


Figure 3. Cluster Plot Formed

Table 4. Clustering Results for Each District/City in South Sulawesi

District/Regency	Cluster	District/Regency	Cluster	District/Regency	Cluster
Kepulauan Selayar	1	Luwu	1	Bone	2
Bantaeng	1	Tana Toraja	1	Soppeng	2
Jeneponto	1	Luwu Utara	1	Sidrap	2
Gowa	1	Toraja Utara	1	Pinrang	2
Sinjai	1	Bulukumba	2	Luwu Timur	2
Barru	1	Takalar	2	Kota Makassar	2
Wajo	1	Maros	2	Kota Pare-pare	2
Enrekang	1	Pangkep	2	Kota Palopo	2

Table 4 shows the clustering results for each district/city in South Sulawesi using the K-Medoids method according to the clustering plot formed. The results indicate that, in terms of quantity, each cluster contains the same number of districts/cities, with 12 districts/cities in both Cluster 1 and Cluster 2.

Table 5. Average Values of Each Variable for the Clusters Formed

Variabel	Mean	Cluster 1	Cluster 2
Internet Users	64.6642	60.24	69.0883
E-Commerce Users	4.179	1.858	6.5
IKM Using Internet	25.986	17.334	34.638
Economic Growth	4.2404	4.025	4.4558
4G/LTE Villages	99	96	101
Productive-age Population	182962	168830	197094
Invesment	671237819	429759124.3	912716513.8
Amount of IKM	5403	5548	5259

Table 5 shows the average values of the variables from the clustering results. It can be observed that Cluster 2, which includes districts and cities in South Sulawesi, has better values for almost all variables compared to the districts/cities in Cluster 1. Generally, Cluster 2 dominates all the variables used, whereas Cluster 1 only performs better in the variable related to the number of IKM.

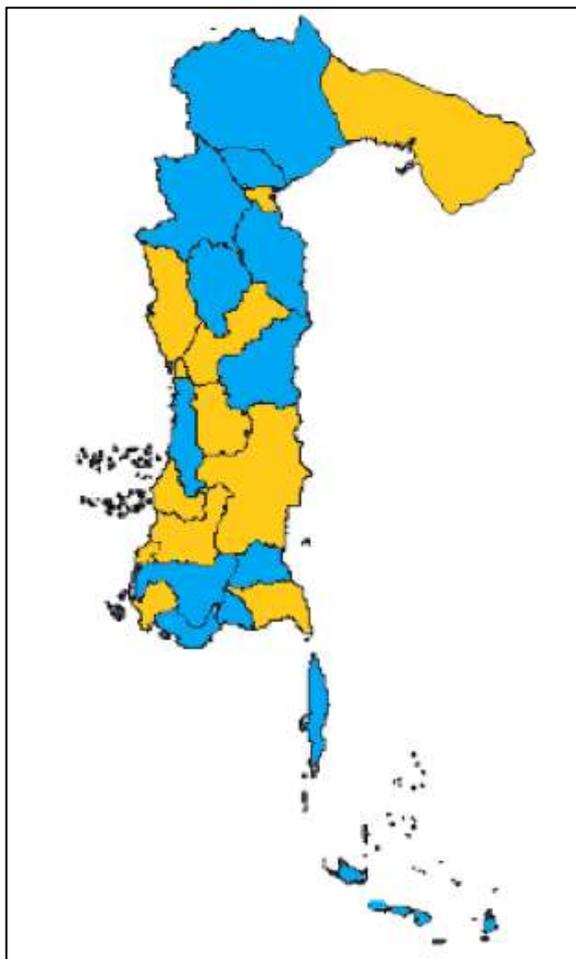


Figure 4. Final Clustering Results for Digital Transformation in South Sulawesi

Based on Figure 4, it can be identified that districts/cities in Cluster 2, which have better digital transformation indicators, are clustered in the central part of South Sulawesi and are located around the administrative city areas. This indicates that digital transformation tends to focus more on regions with high economic activity and dense population.

Discussion

This research explores the opportunities and strategies for accelerating digital transformation in South Sulawesi by analyzing spatial distribution and clustering using the K-Medoids method. Digital transformation is recognized as a key driver for economic growth and enhancing the efficiency of the real sector, including downstream programs and a more conducive business competition environment. The study results show that the distribution of internet users and e-commerce users varies greatly across South Sulawesi, with the highest concentrations in administrative cities such as Makassar, Palopo, and Pare-pare.

The high number of internet users in urban areas indicates that these regions have significant potential to drive economic growth through digitalization. The concentration of internet users in administrative cities not only reflects faster technology adoption but also better digital infrastructure. However, this also highlights a significant digital divide between urban and rural areas, which requires special attention from local governments to ensure that the benefits of digital transformation are felt more evenly.

Spatial distribution analysis shows that e-commerce users are concentrated in Makassar, which dominates with nearly 60% of the total users in South Sulawesi Province. This large gap indicates that although there is significant potential for e-commerce growth in the province, many areas are still lagging in technology adoption. There is a need for specific efforts to improve access and digital literacy in underdeveloped areas so they can participate in the digital economy.

On the other hand, internet use by Small and Medium Enterprises (SMEs) has started to become more widespread, with Bulukumba showing a high percentage of internet use by SMEs. However, some districts such as Tana Toraja, Jeneponto, Kepulauan Selayar, and Wajo still exhibit low levels of utilization. Local governments should focus on providing the necessary infrastructure and training to encourage digital technology adoption among SMEs in these areas.

The clustering results indicate that districts/cities in Cluster 2 perform better in digital transformation compared to those in Cluster 1, except in terms of the number of SMEs. This suggests potential for improvement in digital technology use in Cluster 1 regions. It indicates that areas with high economic activity and dense populations tend to be more advanced in digital transformation. To accelerate digital transformation across South Sulawesi Province, strategies should consider enhancing digital infrastructure in peripheral and rural areas.

In evaluating these findings, it is important to consider the broader context of digital transformation in Indonesia and relevant previous research. While South Sulawesi has significant potential for digital transformation, especially in cities like Makassar, Palopo, and Pare-pare, the digital divide between urban and rural areas remains a significant challenge. Previous studies have shown that rural areas often lag in digital technology adoption due to limited accessibility and infrastructure.

Additionally, the research notes that internet use for e-commerce is still highly centralized in Makassar, with a significant gap between this city and other areas. This suggests that there are barriers that need to be addressed to promote e-commerce penetration across the province. The risks associated with the digital divide and the concentration of economic activity in major cities have also been identified in the literature, highlighting the importance of creating an inclusive environment for digital economic growth.

Furthermore, it is important to consider the implications of these findings for economic and social development in South Sulawesi Province. Increasing access and adoption of digital technology has the potential to enhance the efficiency of the real sector, expand market access for SMEs, and create new job opportunities in the digital economy. However, realizing this potential requires cross-sector and interdisciplinary cooperation, as well as significant investments in infrastructure and human resource development.

Finally, the clustering results reveal a geographical pattern in digital transformation in South Sulawesi Province, with Cluster 2 being located in the central part of the province and

near administrative city areas. This finding underscores the importance of understanding local and geographical factors influencing technology adoption and tailoring policy strategies to the unique characteristics of each region. Thus, this research provides a crucial foundation for developing more targeted and effective policies to support digital transformation in South Sulawesi Province.

4. Conclusion

This research examines the opportunities and strategies for accelerating digital transformation in South Sulawesi based on spatial distribution analysis and the results of clustering regencies/cities in South Sulawesi Province. Based on the discussion provided, it can be concluded that spatially in South Sulawesi Province, the distribution of internet users, e-commerce service users, and internet-using SMEs shows a similar pattern, with a tendency to cluster in administrative city areas and noticeable disparities among regencies/cities, especially concerning e-commerce service users.

Clustering results using the K-Medoids method reveal that the regencies/cities in South Sulawesi form two clusters, with each cluster comprising 12 regencies/cities. It can be observed that Cluster 2, which includes regencies and cities in South Sulawesi, has better values in almost all variables compared to those in Cluster 1. Generally, Cluster 2 dominates all the variables used, whereas Cluster 1 is only superior in one variable.

Based on the research findings highlighting the condition of digital transformation in South Sulawesi, local governments can take a series of strategic steps to accelerate digital transformation in the region. Firstly, the government needs to prioritize investment in better telecommunications infrastructure, particularly in rural and peripheral areas with limited access. Developing 4G/LTE network infrastructure and providing affordable internet access will help bridge the digital divide between urban and rural areas and promote the adoption of digital technology across the province.

Additionally, digital literacy training and education programs should be evenly expanded throughout South Sulawesi. This includes organizing workshops, courses, and seminars on the benefits and use of digital technology for the community and local businesses. Technical support and assistance in developing digital skills will help accelerate technology adoption and enhance the skills of the local workforce, thereby creating an environment conducive to digital economic growth.

Collaboration between local governments, the private sector, and civil society is also crucial in accelerating digital transformation in South Sulawesi Province. The government can encourage public-private partnership initiatives to expand the coverage of internet services and digital infrastructure in underserved areas. These initiatives may include providing incentives for technology companies and internet service providers to invest in needy areas, as well as support for startups and local businesses in developing innovative solutions to address digital transformation challenges. With a coordinated and collaborative policy strategy, South Sulawesi Province can achieve significant acceleration in digital transformation and improve overall community welfare.

The limitations of this study include the narrow focus on spatial analysis and clustering, which may not cover all relevant factors in digital transformation in South Sulawesi Province.

Although the analysis provides valuable insights into spatial patterns and performance differences between regions, other aspects such as social, cultural, and economic factors may also play a significant role in local technology adoption. Additionally, the data used in this study may be limited in scope and accuracy, affecting the precision and generalizability of the findings. Therefore, further research involving multi-method approaches and more comprehensive datasets could provide a more comprehensive understanding of the dynamics of digital transformation in South Sulawesi Province.

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