

## SPATIAL ANALYSIS OF COVID-19 SPREAD PATTERN USING KERNEL DENSITY METHOD IN SURAKARTA

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**Abstrak:** Pandemi COVID-19 yang disebabkan oleh virus SARS-CoV-2, yang menyebar melalui sistem pernapasan dan dapat menyebabkan masalah pernapasan. Pandemi ini dimulai di Wuhan, Cina, pada Desember 2019, dan dengan cepat menyebar ke seluruh dunia, termasuk Indonesia. Kota Surakarta mengalami peningkatan kasus yang signifikan pada bulan April hingga Juni 2021 karena faktor seperti perayaan Idul Fitri. Penulis menggunakan metode Kernel Density untuk memetakan distribusi spasial kasus COVID-19 di Surakarta dan untuk meneliti hubungan antara tingkat vaksinasi dan kasus positif. Metodologi melibatkan studi deskriptif kuantitatif menggunakan data sekunder dari Dinas Kesehatan Surakarta pada bulan Mei 2021. Berdasarkan penelitian ditemukan bahwa tidak ada korelasi antara capaian vaksinasi dosis pertama dengan jumlah kasus terkonfirmasi COVID-19 di Kota Surakarta dan tingkat penyebaran Covid-19 lebih dipengaruhi oleh aktivitas yang dilakukan masyarakat pada fasilitas umum atau di luar ruangan serta taat mematuhi protokol kesehatan yang diberikan pemerintah.

**Kata kunci:** COVID-19, Kernel Density, vaksinasi

**Abstract:** The COVID-19 pandemic caused by the SARS-CoV-2 virus, which spreads through the respiratory system and can cause respiratory problems, began in Wuhan, China, in December 2019 and quickly spread worldwide, including Indonesia. Surakarta experienced a significant increase in cases from April to June due to factors such as the celebration of Eid al-Fitr. The author used the Kernel Density method to map the spatial distribution of COVID-19 cases in Surakarta and to investigate the relationship between vaccination rates and positive patients. The methodology involved a quantitative descriptive study using secondary data from the Surakarta Health Agency in May 2021. Based on the research, it was found that there was no relationship between the achievement of the first dose of vaccination and the number of confirmed COVID-19 cases in the city of Surakarta. The spread of COVID-19 was more influenced by activities carried out by the community in public facilities or outdoor spaces, as well as compliance with the health protocols provided by the government.

**Keywords:** COVID-19, Kernel Density, vaccination

### A. INTRODUCTION

The coronavirus, or SARS-CoV-2, is a new type transmitted to humans through the respiratory system (Kemenkes, 2020). This virus infection results in a disease known as Covid-19. This disease can cause mild respiratory system disturbances, severe lung infections, and even fatal outcomes. The

virus can affect various age groups, including babies, children, adults, the elderly, pregnant women, and nursing mothers.

The first case of Covid-19 appeared in Wuhan, China, on December 31, 2019, and quickly spread worldwide. This spread became an international health emergency (Lai et al., 2020). The

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first positive case of Covid-19 was detected in Indonesia on March 2, 2020, when two people were infected after contact with a Japanese citizen (Ciotti et al., 2020). The level of Covid-19 cases in Indonesia is among the highest in Southeast Asia, with an increase in Covid cases among those under 18 years old at 12.6% and a death rate of 1.2% (Unicef, 2021). The Covid-19 infographic data for Surakarta city on April 30, 2021, showed that there were 109 positive cases of Covid-19 in Surakarta. However, in June, it was recorded that 687 households were exposed to Covid-19 (Surakarta.go.id, 2022).

From April to June, there was a tendency for an increase in Covid-19 cases in Surakarta city every month. The increase in the number of positive Covid-19 cases did not happen overnight. Still, several contributing factors, such as the celebration of Eid al-Fitr, impacted the city's population's mobility. Therefore, Covid-19 prevention measures such as PPKM, mask-wearing, and social distancing did not work effectively.

Based on this understanding, this research identifies two problems to be investigated, namely: (1) how is the spatial distribution pattern of Covid-19 incidence rate using the kernel density method in Surakarta city, and (2) what is the relationship between the first dose vaccination coverage and the number of positive Covid-19 cases in Surakarta city.

The researcher aims to identify the pattern and level of spatial clustering of Covid-19 incidence in Surakarta city using the Kernel Density technique because the spread of Covid-19 in Surakarta city has been increasing from April to June.

The kernel Density Estimation (KDE) method effectively maps spatial patterns as points (Cai et al., 2013). The KDE method will be combined with Geographic Information System (GIS), which can handle Covid-19, focusing on spatiotemporal analysis (Franch-Pardo et al., 2020). By using GIS and spatial statistics, the handling of Covid-19 can be improved by finding and identifying spatial correlations with other variables that can be considered in formulating policies for the prevention and control of Covid-19, as well as future outbreaks of similar diseases.

The reference in the study entitled "Designing a Model for Analyzing Prospective Student Data Using Optimized Hot Spot Analysis and Kernel Density: A Case Study of FTI UKSW" discusses the problem of the lack of targeted school references, which results in ineffectiveness and inefficiency in the promotion system. Researchers used two methods in Geographic Information Systems (GIS), Optimized Hotspot Analysis and Kernel Density, to identify schools' hotspots and FTI UKSW students' locations from previous years.

The research findings show that information about which schools have the highest number of students enrolling in FTI UKSW can be obtained using Optimized Hotspot Analysis. The Optimized Hotspot Analysis and Kernel Density methods can be used to find potential school references for promotion (Santoso & Papilaya, 2019).

The other research used as a reference, titled "Dynamics of Population Distribution in Central Java: Formulating Regional Policies with Kernel Density Method," investigates the patterns of population distribution in a region intending to provide a basis for regional and urban planning. In this study, the Kernel Density method was used to understand the population density pattern in Central Java. Geographic Information Systems (GIS) was also an analytical tool used to study population phenomena in a spatial context (Handayani & Rudiarto, 2011).

Both studies used the Kernel Density method in analyzing data and spatial dimensions. The research resulted in a distribution pattern of specific cases, namely the schools used as references and population density in the Central Java region.

## **B. METHOD**

This research is a quantitative descriptive study that uses secondary data. The data includes the number of COVID-19 patients in Surakarta city in

May 2021 and the achievement of the first stage of vaccination in the same month. This data was obtained directly from the Surakarta Health Department.

This study uses KDE to map the spatial distribution pattern of COVID-19 cases in Surakarta City. Kernel Density Estimation (KDE) is a non-parametric statistical method used to estimate the density of data points. This method is often used in spatial analysis to analyze the distribution pattern of disease cases in a particular area. This methodology is based on data points, so information needs to be connected to specific points in space to estimate the density of points at a particular location. Using KDE, a pattern of COVID-19 spread can be produced that is useful for making prevention and control policies (Silverman, 1986).

The Spearman Rank method is a non-parametric method used to test the relationship between two variables. This method is used to determine the strength of the two variables' linear relationship by comparing each variable's ranks (Supranto, 2000).

In this study, Rank Spearman is used to find the relationship between the number of COVID-19 cases and the achievement of the first stage of vaccination in Surakarta City. Because Rank Spearman does not require assumptions about data distribution, this method is suitable for use on non-

normally distributed data. Using Rank Spearman, researchers can determine whether there is a relationship between the number of COVID-19 cases and the level of achievement of the first stage of vaccination in Surakarta City.

## **C. RESULT AND DISCUSSION**

### **C. 1. Result**

The result of data processing in the form of Covid-19 case data in May 2021, May Vaccination Achievement, and Public Facilities & Health Facilities location data through ArcGIS Pro, Google Maps, and Spearman Rank produced three outputs as follows:

#### **C.1.1.Map of Covid-19 Case Distribution.**

The map of Covid-19 case distribution is the result of processing Covid-19 case data, Surakarta city administrative boundaries (sub-district, village, and RT/RW boundaries), and public facilities & health facilities location data.

Firstly, in the data processing process, it is necessary to create a shape file of the Surakarta city administrative boundaries in the form of sub-district, village, RT, and RW boundaries that are made according to the indicative limits of the Indonesian Topographic Map, Scale 1:25,000, the Year 2017, provided by the National Geospatial Information Agency. After successfully creating the administrative boundary shape file, the next step is to generate data points for the

location of public facilities & health facilities.

Then, one by one, patient address data is converted into coordinate points containing latitude and longitude through Google Maps. After obtaining the coordinate points, the data is directly inputted into ArcGIS to be processed through its available features.

After all of this data is processed according to the data format required by ArcGIS, which is Point and Shape File, the data is inputted into the ArcGIS system, resulting in an output map of the Covid-19 case distribution in Surakarta.

In this map, information is displayed in the form of Covid-19 positive case location points, the location of health facilities and public facilities, and the sub-district administrative boundaries in Surakarta. The information can be further seen in Figure 1.

#### **C.1.2.Map of Spatial Distribution Patterns of Positive COVID-19 Cases in Surakarta.**

This map results from the next stage in processing the Map of Covid-19 Case Distribution. The data that has been prepared, which has been converted into a file format as shown in the Map of Covid-19 Case Distribution, is then processed again through the spatial analyst feature on ArcGIS, namely Kernel Density, to estimate the density of Covid-19 cases. This data processing generates an output as a Map of Spatial

Distribution Patterns of Positive COVID-19 Cases in Surakarta. The map contains information on positive Covid case levels and distribution patterns. The data can be further seen in Figure 2.

### C.1.3. The Relationship Between Vaccination and Positive Covid-19 Cases.

In this research, in addition to using ArcGIS as a data processing tool, there is one application used, which is SPSS. SPSS here functions to process the Vaccination Achievement data with the Number of Covid-19 Cases through the Rank Spearman calculation feature to test the relationship between these two variables. The result of the test shows that there is no significant relationship

between Vaccination and Covid-19 cases. This information can be seen further in Table 2.

## C.2. DISCUSSION

### C.2.1. Map of Covid-19 Case Distribution.

The data processed in this stage is the occurrence of positive COVID-19 cases in Surakarta City in May 2021, with 618 instances distributed in various districts and neighborhoods. Banjarsari District recorded the highest number of positive COVID-19 cases in Surakarta City, with 246 points. Meanwhile, Serangan District had the lowest number of cases, with only 43 confirmed cases of COVID-19.

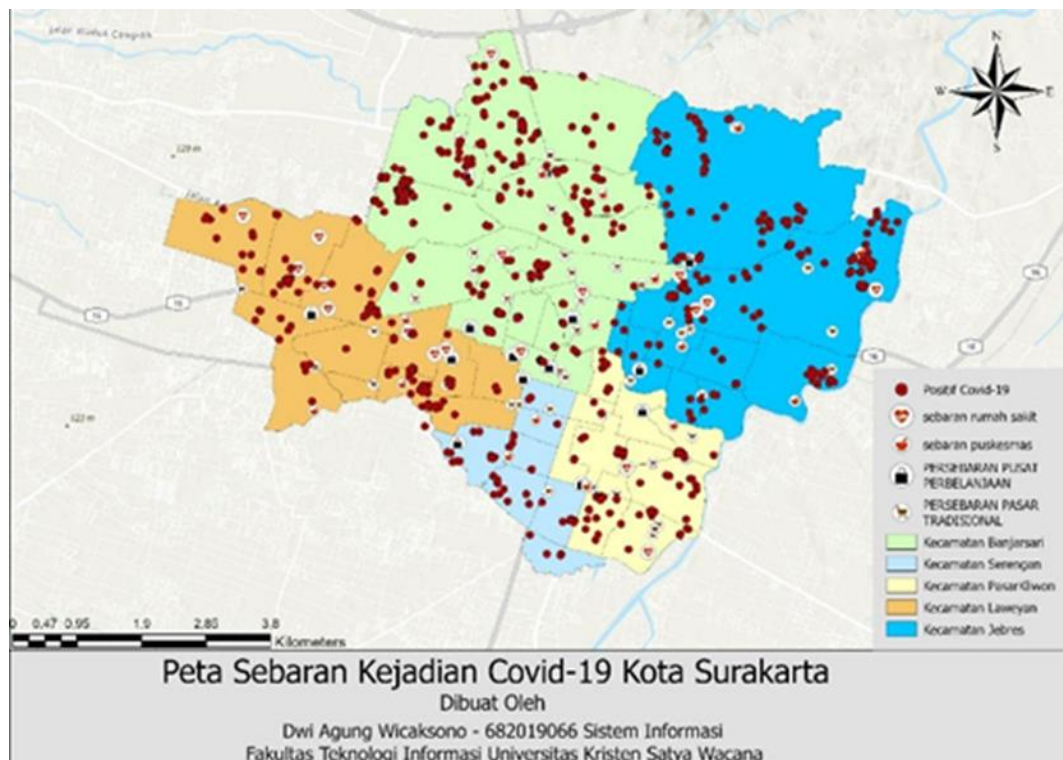


Figure 1. Map of Covid-19 Case Distribution. Source : data analysis

In Figure 1 above, the processed data shows the distribution of positive COVID-19 cases through coordinate points on the map. However, those coordinate points are not the actual location of the positive COVID-19 cases but are still within the same RT & RW area of the place. This is done to maintain the confidentiality of the COVID-19 patients' identities and prevent unwanted incidents.

It is also apparent that positive COVID-19 cases in Surakarta City are clustered in a location found in almost all districts. This happens because, as we know, COVID-19 spreads through the air and attacks the respiratory system. If one person is infected, there is a high chance that those around them are also at risk. The virus is transmitted through droplets produced when an infected person coughs, sneezes, or talks. These droplets can spread nearby, less than 1 meter, and affect those around them. Thus, the map shows that the COVID cases concentration is clustered in specific locations, such as Banjarsari and Jebres districts, which have the highest number of positive cases. Then this is also influenced by preventive measures such as maintaining distance, wearing masks, and frequently washing hands that have yet to be effectively implemented in the community. It becomes the cause of the spread of COVID-19 because when

someone infected with the coronavirus is in public places and does not comply with health protocols such as maintaining a physical distance of at least 1-2 meters, wearing a mask properly, and regularly washing hands with soap and running water or hand sanitizer, the risk of spreading the coronavirus in public places can increase.

The opinion is not unfounded as it is in line with other research titled "The transmission and diagnosis of 2019 novel coronavirus infection disease (COVID-19): A Chinese perspective," which concludes that "Individuals at the highest risk of contracting this disease are those who have close contact with Covid-19 patients, including those who care for patients. Generally, patients infected with Covid-19 will show symptoms such as cough, difficulty breathing, and fever."(Han & Yang, 2020)

In addition to those factors, this situation is also caused by the high level of community activity in the area, which is influenced by many public facilities such as traditional markets, shopping centers, health centers, and hospitals. The location of these public facilities can trigger an increase in positive COVID-19 cases as it can cause crowds of people in one place. In addition, in public places such as markets, shopping centers, offices, and places of worship, there is often poor or less optimal ventilation,

making the air inside the room less clean and susceptible to transmitting the virus in droplets.

The opinion is not baseless because it is in line with another study titled "COVID-19 transmission—up in the air," which concludes that "The risk of contracting Covid-19 can increase when engaging in outdoor activities if necessary precautions, such as maintaining physical distance, wearing masks, and implementing hygiene protocols, are not properly followed. The Covid-19 virus can spread through droplets from coughing, sneezing, or talking. Therefore, it is important to take these preventative measures when engaging in activities outside the home"(Medicine, 2020)

#### **C.2.2.Map of Spatial Distribution Patterns of Positive COVID-19 Cases in Surakarta.**

Figure 2 shows the Map of Spatial Distribution Patterns of COVID-19 Incidents in Surakarta City, divided into 5 classes: shallow, low, moderate, high, and very high. The spatial distribution pattern can be observed from the map, which tends to cluster around shopping centers and community health centers. This is consistent with the characteristics of COVID-19 transmission, which spreads more quickly in places that can create crowds, especially in health facilities such as community health

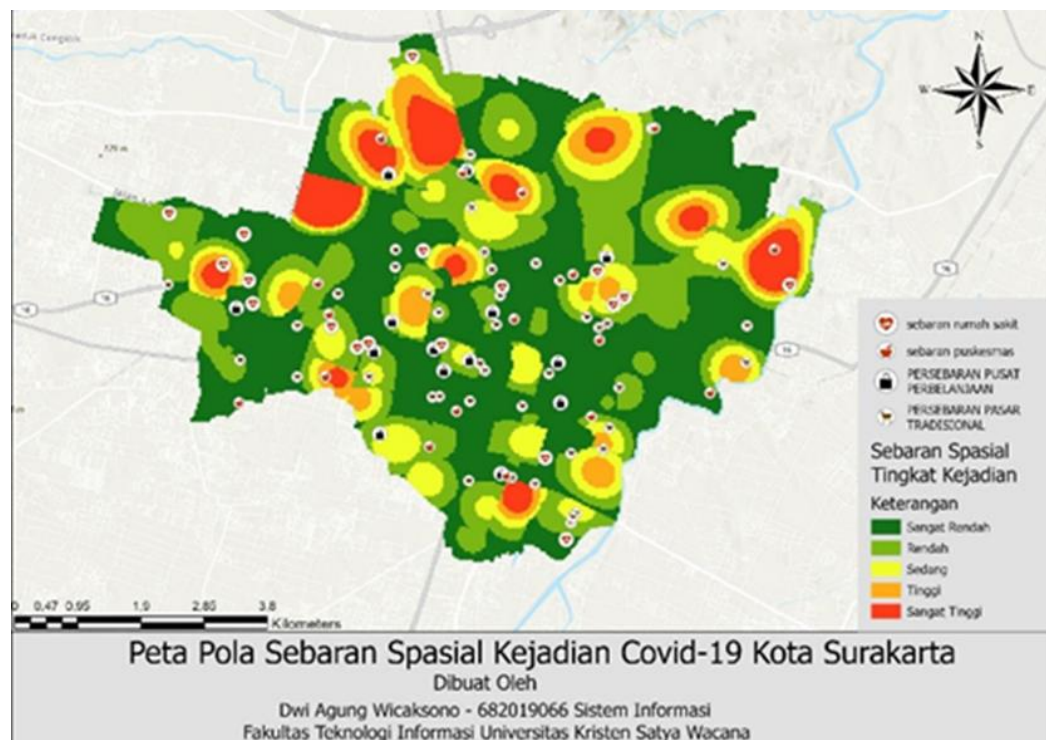
centers, where many people come and go, including those infected with COVID-19 or those who want to get vaccinated. The same goes for shopping centers, which are places where people gather and have a lot of social interaction, such as buying necessities, and are also influenced by the lax implementation of health protocols and the lack of strict health protocol management in these places, such as providing hand washing facilities, hand sanitizers, temperature detectors, etc.

The opinion is not unfounded as it aligns with another study entitled "The Character and Spread of Covid-19 in Indonesia", which concluded that "the characteristic of Covid-19 spread is faster in places that can create crowds of people" (Philips & Wicaksono, 2020). Then it can also be seen where areas that are further away from the center of crowds tend to have lower levels of COVID incidence, but that does not mean that the potential for contracting COVID-19 becomes small. Still, we must see that the further away from health centers such as health centers or hospitals, the level of public understanding about information regarding COVID-19 symptoms, COVID-19 testing (antigen test, swab test, etc.), COVID-19 symptoms, and prevention methods may be lacking because of complex dissemination of information due to distance from health facilities because better socialization



regarding COVID-19 can increase public awareness of the importance of maintaining distance, wearing masks,

washing hands, and avoiding crowds and physical interactions that have the potential to transmit the virus.



**Figure 2. Map of Spatial Distribution Patterns of Positive COVID-19 Cases in Surakarta.**

In addition, socialization can help the public understand accurate and reliable information about COVID-19, so they can avoid false or misleading information that can worsen the situation and spread unnecessary fear. Therefore, adequate and continuous socialization about COVID-19 is crucial to help break the chain of virus transmission in the community.

The opinion is not without basis as it is consistent with another research titled "The Urgency of Covid-19 Vaccination Education Program Based on Minister of Health Regulation

Number 10 of 2021," which concludes that "Socialization activities of the Covid-19 vaccine through community service have succeeded in increasing the awareness, enthusiasm, and understanding of the community towards the Covid-19 vaccine and can combat the spread of hoax news."(Larasati & Sulistianingsih, 2021)

In addition to that information, we can also see that in Surakarta City, the neighborhoods with High-Density classes are located in Mojosongo, Jebres, Sumber, Banyuanyar, Joglo, Kadipiro, and Nusukan. The districts with the



highest positive cases are in areas with health facilities and public facilities such as markets, shopping centers, universities, and schools. Neighborhoods with Medium Density classes are located around areas with High-Density classes, such as Karangasem, Kerten, Mangkubumen, Mojo, Pajang, Penularan, Pucang Sawit, Semanggi, Tipes, Baluwarti, Banjarsari, Bumi, Gilingan, Jajar, and Joyosuran. Low-Density classes are evenly distributed across all neighborhoods in Serangan, Pasar Kliwon, Laweyan, Jebres, and Banjarsari.

### **C.2.3. Vaccine coverage**

The vaccination program in Surakarta City is being carried out gradually to all layers of society using various types of vaccines such as Sinovac, Biofarma, Moderna, Pfizer, Astra Zeneca, and Sinopharm. The administration of the first vaccination dose is an essential part of the vaccination program to protect the community from COVID-19 infection and reduce the risk of death. The vaccination program is also the responsibility of all Indonesian citizens in creating public health, as emphasized by the government through the Deputy Minister of Law and Human Rights (Gandryani & Hadi, 2021).

The first vaccination dose aims to stimulate the production of antibodies or

the first immune response. One of the main objectives of the vaccination program is to achieve herd immunity among the population, which is when vaccination coverage reaches around 80% across the region to reduce the spread of the disease (Arina, 2021).

The first dose of the vaccination program still targets healthcare workers (doctors, nurses, midwives, and medical staff), public servants (government employees, police officers, teachers, public transport workers, etc.), and the elderly.

The Surakarta City Government has organized the distribution of the first phase of the COVID-19 vaccine through various health centers throughout the Surakarta region. Each health center has been assigned a specific coverage area to ensure all districts receive vaccination services. This distribution plan is crucial in protecting the entire community against the virus. It is a well-organized and thoughtful plan demonstrating the government's commitment to ensuring everyone's safety and health. The success of the vaccine distribution relies on the community's continued cooperation, and it is crucial that everyone takes advantage of the opportunity to receive the vaccine as it becomes available in their area.

The achievement of the first dose of vaccination in Surakarta City by health centers can be seen in Table 1.

**Table 1 Vaccination Achievement in Surakarta City in May 2021**

No	Puskesmas	Jumlah
1	Pajang	555
2	Penumping	262
3	Purwosari	225
4	Jayengan	402
5	Kratonan	357
6	Gajahan	390
7	Sangkras	441
8	Purwodiningratan	338
9	Ngoresan	1649
10	Sibela	526
11	Pucangsawit	425
12	Nusukan	513
13	Manahan	324
14	Gilingan	298
15	Banyuanyar	402
16	Setabelan	262
17	Gambirsari	229
<b>Total</b>		<b>7598</b>

Source : Surakarta City Health Department

From Table 1 above, we can gather the information that each health center has implemented the vaccination program comprehensively in each area of Surakarta City, with each health center having different achievements. In May, various health centers in an area have distributed the first dose of the vaccine to

their communities. The distribution ranges from 225 to 1649 of the total available vaccines, with Ngoresan Health Center having the highest distribution rate. These numbers indicate that while some health centers have been successful in their vaccine distribution efforts, others have room for improvement. It is important to continue monitoring and increasing vaccine distribution to protect the community against COVID-19.

#### **C.2.4. The Relationship Between Vaccination and Positive Covid-19 Cases.**

Table 2 shows the results of the Spearman Rank analysis, indicating no significant correlation between vaccination coverage and the number of confirmed COVID-19 cases in Surakarta City. The significance value (2-tailed Sig) is 0.784, which is greater than 0.05, indicating that vaccination coverage does not significantly impact the number of confirmed COVID-19 cases (Latief, 2013). Although people who have received the vaccine still have a risk of infection, hospitalization, and death, it tends to be lower than those who have not been vaccinated (Evayanti, 2022).

That is true if the entire population has been vaccinated comprehensively. However, in reality, in May 2021 in Surakarta City, not all of the people had received the first dose of the vaccine comprehensively, as the first dose was still prioritized for health workers

(doctors, nurses, midwives, and medical staff), public officials (government employees, police, teachers, public transportation staff, etc.), and the elderly.

**Table 2. Correlation Test Results of Vaccination Rate with the Distribution of Positive COVID-19 Cases.**

<b>Correlations</b>				
			Vaksinasi	Covid-19
<b>Spearman's rho</b>	Vaksinasi	Correlation Coefficient	1,000	0,072
		Sig. (2-tailed)		0,784
		N	17	17
	Covid-19	Correlation Coefficient	0,072	1,000
		Sig. (2-tailed)	0,784	
		N	17	17

Source : Data analysis

The number of people in these three groups is not more significant than the total number of the other population groups, so the vaccine's effectiveness has not been maximum, and herd immunity has not yet appeared. Additionally, there is a chance of getting infected by the new omicron variant, which spreads five times faster than the delta variant. Therefore, although there is an increase in the number of people who have been vaccinated, there is no correlation with the increase or decrease in the number of confirmed COVID-19 cases.

The findings of this research align with the results of a study in 31 regions in France, which showed no correlation between COVID-19 data and the level of vaccination for doses I and II. The higher the vaccination rate, the lower its relationship with COVID-19 cases.

Although vaccination has successfully reduced the number of deaths and hospitalizations of COVID-19 patients, it is ineffective in preventing the spread of the SARS-CoV-2 variant. Several factors that can cause this include decreased vaccine efficacy over time, lower effectiveness against the rapid transmission of new COVID-19 variants, advances in medical treatment for COVID-19 patients, and significant developments in natural immunity (Bouanane, 2021).

In addition to the emergence of new, more dangerous variants, COVID-19 transmission occurs through droplet infection. This means that information can occur in various places such as homes, workplaces, during travel, places of worship, tourist destinations, and other places where many people interact.

The effectiveness of vaccines also depends on other factors, such as individual-level preventive measures. Therefore, the role of the community is crucial in the efforts to prevent and control COVID-19. The community must adhere to prevention principles, such as wearing masks, maintaining physical distance, regularly washing hands, avoiding crowds, and complying with established rules and guidelines. By being actively involved, the community can help break the transmission chain and prevent new transmission sources (Yuliana, 2020).

#### **D. CONCLUSION**

Based on the available data from May 2021, the conclusion from the statistical test results regarding the achievement of the first dose of vaccination and the number of confirmed COVID-19 cases in Surakarta is that there is no relationship between the two.

Patterns of COVID-19 cases tend to be concentrated in areas with access to public facilities like markets, shopping centers, hospitals, and health centers. The distribution patterns can also be influenced by the extent to which the community adheres to health protocols.

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