

Analysis Of The Contribution Of Weather Modification Technology To The Gross Regional Domestic Product (Grdp) Of Purwakarta Regency West Java, Indonesia

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Abstract

Since the establishment of the Center for Weather Modification Technology (WMTC) in 1985, Weather Modification Technology (WMT) flight operations have been carried out in various regions in Indonesia, such as in Sumatra, Java, Kalimantan, Sulawesi, West Nusa Tenggara, and Bali. However, from 1979 until now, the research on the economic benefits of implementing Weather Modification Technology (WMT) has never been analyzed, and its influence on the economy or Gross Regional Domestic Product (GRDP) has not been evaluated. The indicator of economic growth is the increase in production capacity and services over a certain period of time. Generally, economic growth is defined as an increase in the ability of a country's or region's economy to produce goods and services (GDP/GRDP). Water generated from Weather Modification Technology activities can make a significant contribution to the regional economy, especially in relation to water availability for various needs such as hydroelectric power generation, drinking water, industrial water, and agriculture. This research aims to analyze and evaluate the contribution of WMT to the economy of the Purwakarta Regency in West Java. The scope of

the research is focused on the Purwakarta Regency, analyzing the impacts of the implementation of WMT for the purpose of filling the Citarum River Basin (Jatiluhur Reservoir). The research data consists of secondary data collected from operational reports of CWTMC, the Central Bureau of Statistics (Central and Purwakarta Regency Statistics Office), and the Office of the Department of Food Crops and Agriculture of Purwakarta Regency. The data analysis technique used is multiple regression modeling with the response variables (Y/Electricity and Drinking Water Sector of GRDP) and predictor variables: Electricity Production (X_1), PDAM Water Supply (X_2), Industrial Water Supply (X_3), and Agricultural/Rice Field Water Supply (X_4). By using multiple linear regression modeling, it can be explained that the additional rainwater contribution to Electricity Production (X_1), P DAM Water Supply (X_2), Industrial Water Supply (X_3), and Agricultural/Rice Field Water Supply (X_4) contributes 93.12% to the Electricity and Drinking Water Sector GRDP of Purwakarta Regency from the additional water provided by the WMT activities carried out by WMT.

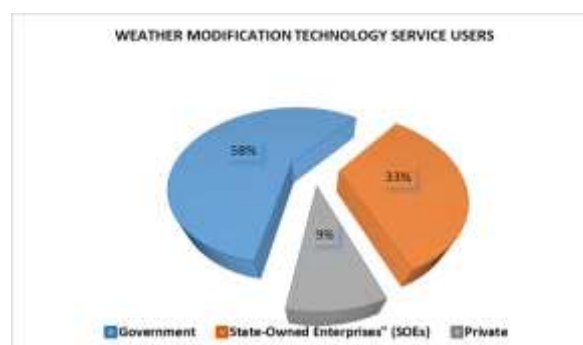
Keywords: Weather Modification Technology, Gross Regional Domestic Product (GRDP) Electric and Drinking Water Sector), Linier Regression.

1. INTRODUCTION

1.1. Background

Center for Weather Modification Technology (Balai Besar Teknologi Modifikasi Cuaca/BB-TMC) is a unit within the Agency for the Assessment and Application of Technology (BPPT) under the coordination of the Deputy Head of the Natural Resources Technology Development (TPSA) Department. Previously, BB-TMC was known as the Technical Implementation Unit for Artificial Rain (UPT-HB). The change in nomenclature from UPT-HB to BB-TMC was based on the Head of BPPT Regulation No. 10 of 2015, in line with the reorganization agenda that was part of the Bureaucratic Reform in BPPT.

The history of the establishment of BB-TMC (previously known as UPT-HB) began with the idea of President Soeharto (the President of Indonesia at that time) who wanted to implement artificial rain



activities in Indonesia to support the agricultural sector, as has been

done in Thailand, one of Indonesia's neighboring countries. This idea was responded to by Prof. Dr. Ing. BJ Habibie (the Minister of State for Research and Technology of the Republic of Indonesia at that time) by conducting artificial rain experiments in 1977 in the Bogor, Sukabumi, and Solo areas under the assistance of Prof. Devakul from Royal Rainmaking Thailand.

Initially, from 1976 to 1978, Artificial Rain was under the Directorate of Agronomy in the Advanced Technology Division of Pertamina, and its activities were still experimental. In 1977, the experimental status was upgraded to the Artificial Rain Project under the Directorate of Agronomy in the Advanced Technology Division of Pertamina. In 1978, the Agency for the Assessment and Application of Technology (BPPT) was established, and the Artificial Rain Project was under the Directorate of Natural Wealth Development (PKA). According to the organizational changes in BPPT in 1982, the Directorate of Natural Wealth Development became the Deputy of Natural Wealth Development, and the Artificial Rain Project was under the Directorate of Natural Resource Inventory.

In December 1985, the status of the Artificial Rain Project was elevated to the Technical Implementation Unit for Artificial Rain based on the Decree of the Minister of State for Research and Technology/Head of the Agency for the Assessment and Application of Technology No: SK/342/KA/BPPT/XII/1985 dated 3 December 1985, which was then renamed Balai Besar Teknologi Modifikasi Cuaca on 19 October 2015 based on the Head of BPPT Regulation (Perka) No. 10 of 2015.

Based on the BPPT Regulation No. 10 of 2015, BB-TMC has the task of implementing Weather Modification Technology (TMC) services, one of which is providing TMC services to government and private institutions.

In accordance with its duties and functions, since the 1970s, BB-TMC has served numerous government and private/state-owned enterprises (BUMN) in need of additional rainfall. Government agencies such as the National Disaster Management Agency (BNPB), the Ministry of Public Works, and Regional/Provincial Governments are the most frequent users of TMC services, utilizing TMC for various purposes of disaster mitigation caused by climate and weather factors, such as droughts, forest and land fire haze disasters, or floods. Meanwhile, the next sector of TMC service users includes state-owned enterprises (such as PT. PLN Persero, Perum Jasa Tirta, PT. INALUM) and private companies (PT. VALE) that use TMC as an integrated part of water resource management practices within the scope of their business operations.

Figure 1 1. TMC Service User Sector
(Source: BBTMC-BPPT)

Initially, the implementation of TMC in Indonesia, which began in 1977, was mainly aimed at addressing the negative impacts of drought disasters, such as filling strategic reservoirs for irrigation and hydropower plant (PLTA) needs. However, since the 2000s, TMC has also been utilized for handling land and forest fire disasters that occur

almost every year during the dry season. The statistics on the number of TMC activities in Indonesia based on their purposes are presented in Figure 1.2.



Figure 1 2. TMC Activity Statistics in Indonesia by Purpose (Source: BBTMC BPPT)

During the peak period of the rainy season, TMC can be utilized for the anticipation and mitigation of flood disasters. During the transition from the rainy season to the dry season, TMC is often used for drought disaster anticipation, while during the peak of the dry season, TMC is frequently employed for mitigating haze disasters caused by forest and land fires. Broadly speaking, the scope of TMC activities and their implementation period involves anticipating various disasters caused by climate and weather factors in Indonesia.

Broadly speaking, the utilization of TMC in Indonesia can be categorized into three main objectives, namely:

Cloud seeding for rain enhancement aimed at filling reservoirs to meet irrigation water needs, hydropower plants (PLTA), and raw water for public purposes.

Cloud seeding for rain reduction aimed at flood and landslide disaster mitigation or minimizing rainfall in mining areas.

Cloud seeding to thin out haze from forest and land fires aimed at extinguishing fire hotspots, improving visibility in airport areas to support commercial flight operations.

Since 1997 until now, "Research on the Economic Benefits of Weather Modification Technology (TMC) Implementation has not been thoroughly analyzed and evaluated for its contribution or economic benefits to the regional economy or Gross Regional Domestic Product (GRDP).

The domestic/regional concept here refers to provinces or districts/cities that produce goods and services within a certain period. The economic transactions to be counted are transactions that occur within the domestic territory of an area, regardless of whether the transactions are carried out by residents of that area or non-resident individuals. All goods and services resulting from economic activities operating within the domestic territory, regardless of whether the production factors originate from or are owned by the inhabitants of that area, constitute the domestic product of that region. Income arising from such production activities is considered

domestic income. The reality shows that some of the production factors used in production activities in an area originate from other areas or from abroad, and conversely, production factors owned by the inhabitants of that area participate in the production process in other areas or abroad. This leads to the value of the domestic product in an area not being equal to the income received by the residents of that area. With the flow of income between these regions (including from and to abroad), which generally takes the form of wages/salaries, interest, dividends, and profits, a distinction arises between domestic and regional products (Central Statistics Agency, 2023).

Economic growth indicates an increase in the capacity of production and services within a specific period. Generally, economic growth is defined as the enhancement of a country's ability to produce goods and services (GDP/Gross Regional Domestic Product). Michael P. Todaro explains that economic growth is a favorable process involving an increase in production capacity within an economy over time, capable of generating increased national income (Michael P. Todaro, 1983). Weather Modification Technology (TMC) can be categorized as an economic activity that serves as a service function.

The study or research that will serve as the model for the economic benefits of TMC research is in the Purwakarta Regency, West Java (Jatiluhur Reservoir, Citarum River Basin) because TMC implementation is most frequently conducted in this area. Variables to be studied include the dependent variable (Y/GRDP) and the independent variables, including Electricity Production (X1), Water Supply from the Regional Water Company (PDAM X2), Industrial Water Supply (X3), and Agricultural/Rice Field Water Supply (X4).

By using Multiple Regression modeling, it is expected to determine the contribution of additional rainfall, represented in the notation of independent variables, which influences the economy (GRDP in the Electricity and Drinking Water Sectors) of Purwakarta Regency, West Java, in relation to the economic benefits as an impact of TMC flight operations conducted by BB-TMC BPPT.

Formulation of the problem

Based on the explanation provided in the background, the research on the economic benefits of TMC has not been conducted in-depth, often leading to questions from TMC stakeholders about the extent of the economic benefits to the economy. To answer these questions, it is undoubtedly challenging to provide an accurate explanation. On the other hand, research on the economic benefits of TMC requires costs and time, resulting in the Balai Besar Teknologi Modifikasi Cuaca (BB-TMC) never having conducted research on the economic benefits of TMC to the economy of a region.

Research objectives

The research aims to collect, process, and formulate an analysis demonstrating the evidence of the influence of water obtained from Weather Modification Technology (TMC) operations contributing significantly to economic activities in the Purwakarta Regency of West

Java. This study is designed to ascertain whether there are economic benefits from TMC activities, as previously formulated in the research question.

Scope of research

Based on the formulated problem, the scope or limitations of this research can be determined, including:

The case study that is the object of this research is the TMC operations in the Citarum River Basin (Jatiluhur Reservoir) in Purwakarta Regency, West Java.

Water data entering the Jatiluhur Reservoir resulting from TMC activities from 1979 to 2021.

The conversion of water from TMC activities for electricity production per 1 Kwh requires 6 cubic meters of water, which is then channeled for other water needs to the Regional Water Company (PDAM) (cubic meters), Industry (cubic meters), and Agriculture (cubic meters) in quantities according to Table 1.2. The TMC-derived water is transformed into the Indonesian Rupiah currency unit for correlation and regression against the Gross Regional Domestic Product (GRDP) in the Electricity and Drinking Water Sectors because the GRDP, as the unit of goods and services production, is valued in Indonesian Rupiah. The water supply for agricultural needs will be converted into dry rice production with the calculation that the water requirement for 1 hectare of paddy fields is 11 cubic meters from the planting season to the harvest season (3 months) with a yield of 6 tons of dry rice per hectare (Purwakarta Regency Department of Food Crops and Agriculture, 2023). To perform this transformation, the unit prices of electricity, the Regional Water Company, Industry, and Agriculture must be multiplied by the unit prices in each year, resulting in values in Indonesian Rupiah. The unit prices refer to the unit values from 1979 to 2021 for evaluating Electricity, the Regional Water Company, Industry, and Agriculture. The price units are displayed in Table 1.3.

Table 1. 1. Cloud Seeding Operation on Jatiluhur Reservoir in 1979-2021

Year	Cloud Seeding Activities	Location
1979	reservoir inundation	Citarum River Basin (Jatiluhur Reservoir)
1980	reservoir inundation	Citarum River Basin (Jatiluhur Reservoir)
1981	reservoir inundation	Citarum River Basin (Jatiluhur Reservoir)
1982	reservoir inundation	Citarum River Basin (Jatiluhur Reservoir)
1983	reservoir inundation	Citarum River Basin (Jatiluhur Reservoir)
1987	reservoir inundation	Citarum River Basin (Jatiluhur Reservoir)
1988	reservoir inundation	Citarum River Basin (Jatiluhur Reservoir)
1989	reservoir inundation	Citarum River Basin (Jatiluhur Reservoir)
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1997	reservoir inundation	Citarum River Basin (Jatiluhur Reservoir)
1998	reservoir inundation	Citarum River Basin (Jatiluhur Reservoir)
2001	reservoir inundation	Citarum River Basin (Jatiluhur Reservoir)
2003	reservoir inundation	Citarum River Basin (Jatiluhur Reservoir)
2004	reservoir inundation	Citarum River Basin (Jatiluhur Reservoir)
2007	reservoir inundation	Citarum River Basin (Jatiluhur Reservoir)
2011	reservoir inundation	Citarum River Basin (Jatiluhur Reservoir)
2012	reservoir inundation	Citarum River Basin (Jatiluhur Reservoir)
2021	reservoir inundation	Citarum River Basin (Jatiluhur Reservoir)

Source: BBTMC BPPT

Table 1. 2. The TMC-derived water for Electricity Production, Regional Water Company, Industrial Water, and Agricultural 1979-2021

Year	The Water Entering Jatiluhur Reservoir (Unit in cubic meters - m3)	Power Plant (Unit in Kilowatt-hour - kWh)	Regional Water Company (Unit in cubic meters - m3)	Industrial Water (Unit in cubic meters - m3)	Agricultural Water (Unit in cubic meters - m3)
1979	118.000.000	19.666.667	6.671.034	2.481.909	737.344
1980	142.000.000	23.666.667	13.342.068	4.963.818	1.474.689
1981	179.000.000	29.833.333	20.013.102	7.445.728	2.212.034
1982	244.000.000	40.666.667	26.684.136	9.927.637	2.949.379
1983	48.000.000	8.000.000	33.355.170	12.408.547	3.686.724
1987	103.221.216	17.203.536	60.039.306	22.337.185	6.636.103
1988	268.000.000	44.666.667	66.710.340	24.819.094	7.373.448
1989	104.700.000	17.450.000	73.381.374	27.301.004	8.110.793
1990	264.000.000	44.000.000	80.052.408	29.782.913	8.848.138

Year	The Water Entering Jatiluhur Reservoir (Unit in cubic meters - m3)	Power Plant (Unit in Kilowatt-hour - kWh)	Regional Water Company (Unit in cubic meters - m3)	Industrial Water (Unit in cubic meters - m3)	Agricultural Water (Unit in cubic meters - m3)
1991	263.700.000	43.950.000	86.723.442	32.264.823	9.585.482
1992	138.000.000	23.000.000	93.394.476	34.746.732	10.322.827
1993	101.000.000	16.833.333	100.065.510	37.228.642	11.060.172
1994	107.700.000	17.950.000	106.736.544	39.710.551	11.797.517
1995	102.820.000	17.136.667	113.407.578	42.192.461	12.534.862
1997	662.070.000	110.345.000	126.749.646	47.156.280	14.009.551
1998	366.950.000	61.158.333	133.420.680	49.638.189	14.746.896
2001	214.000.000	35.666.667	153.433.782	57.083.918	16.958.931
2003	116.406.000	19.401.000	166.775.850	62.047.737	18.433.621
2004	110.860.000	18.476.667	40.728.725	13.894.360	4.988.752
2007	716.920.000	119.486.667	96.385.966	58.838.761	22.643.127
2011	340.000.000	56.666.667	91.433.757	37.320.113	12.677.087
2012	285.900.000	47.650.000	54.459.093	18.961.344	310.236.330
2021	529.500.000	88.250.000	57.151.578	22.772.973	240.634.137
Location	Sub-district. Sukasari	Sub-district. Sukasari	Sub-district. Sukasari	Sub-district. Sukasari	Sub-district. Sukasari

Source: BBTMC BPPT, Perum Jasa Tirta II (PJT II).

Table 1. 3. Unit Price of Electricity (kWh), Regional Water Company (m3), Industrial and Agricultural Water (Rice/Ton) 1979-2021

Year	Price per kWh (in Rp)	Water Price per M ³ Regional Water Company (in Rp)	Water Price per M ³ for Industrial Water (in Rp)	Price per kg of Paddy/Rice (in Rp)
1979	20,00	17,00	12,92	139,76
1980	23,82	22,16	17,28	279,52
1981	27,64	27,31	21,64	419,27
1982	31,46	32,47	26,00	559,03
1983	35,28	37,63	30,36	698,79
1987	50,56	58,26	47,80	1.257,81
1988	54,38	63,41	52,15	1.397,57
1989	58,20	68,57	56,50	1.537,33
1990	62,02	73,73	60,87	1.677,08
1991	65,84	78,88	65,23	1.816,84
1992	69,66	84,04	69,59	1.956,60
1993	73,48	89,20	73,95	2.096,35
1994	77,30	94,35	78,31	2.236,11
1995	81,12	99,51	82,67	2.375,87
1997	88,76	109,83	91,39	2.655,38

Year	Price per kWh (in Rp)	Water Price per M ³ Regional Water Company (in Rp)	Water Price per M ³ for Industrial Water (in Rp)	Price per kg of Paddy/Rice (in Rp)
1998	92,58	114,98	95,75	2.795,14
2001	104,04	130,45	108,83	3.214,41
2003	111,68	140,77	117,50	3.493,92
2004	115,50	145,92	121,91	3.633,68
2007	180,00	161,39	134,98	4.052,95
2011	180,00	182,00	152,42	4.911,11
2012	257,50	187,18	224,71	5.382,33
2021	338,00	272,50	224,71	4.540,72

Source: BBTMC BPPT, PJT II, BPS.

1.2. Benefits of research

The results of the research in the form of scientific manuscripts will undoubtedly provide a significant contribution to the development of science, especially to stakeholders such as Higher Education Institutions, Technology TMC Service Users, Government Agencies, Students and Scholars, as well as the general public.

With the disclosure of the economic benefits of TMC, all stakeholders become aware of the benefits of TMC. In the future, it is expected that TMC stakeholders, especially research institutions and universities, can develop TMC to optimize service functions for users.

2. LITERATURE REVIEW

2.1. Weather Modification Technology (Cloud Seeding)

Weather Modification Technology (Cloud Seeding), known to the Indonesian public as Artificial Rain Technology, is an effort by humans to manipulate weather by dispersing or seeding clouds with seeding materials such as table salt powder (NaCl Powder) and Silver Iodide (AgI). NaCl is delivered by cloud seeding aircraft (Cloud Seeder Aircraft) based on powder, while AgI is dispersed through a Flare-based aircraft (burned) where AgI can take the form of a Hygroscopic Flare.

The system for delivering seeding materials into the body of the clouds operates through two methods. Firstly, through aircraft flying at altitudes of 3000 – 5000 feet (Hygroscopic Flare) and 9000-12000 feet using NaCl Powder as the seeding material. Secondly, through Ground-Based Generators (GBG) towers built on hills, using Hygroscopic Flare as the seeding material (National Agency for Meteorology, Climatology, and Geophysics, 2019).

The activities of Weather Modification Operations (TMC) are utilized to fill reservoirs in an effort to support Hydropower Plant (HPP) operations, as well as to supply water for industrial, Drinking Water (PAM), and Agricultural (Paddy Field) purposes. In the structure of Gross Domestic Product (GDP), where Hydropower Plants (HPP), industrial water supply, Drinking Water (PAM), and Agriculture (Paddy Fields) are elements calculated in measuring or calculating GDP.

The development of TMC globally continues to advance to obtain increasingly sophisticated technology. The development of this technology continues to progress in several countries such as the United States, Canada, Australia, Greece, South Africa, India, Thailand, and also in Indonesia.

There are three purposes of utilizing TMC (National Agency for Meteorology, Climatology, and Geophysics, 2019) as follows:

- Cloud seeding to increase rainfall (rain enhancement), commonly used for the purpose of reservoir filling to meet the needs of Hydropower Plant (HPP), and water supply for industry, Drinking Water (PAM), and Agriculture (Paddy Fields).
- Cloud seeding to decrease rainfall (rain reduction) used for flood disaster mitigation or to minimize rainfall in mining areas.
- Cloud seeding to thin out haze from forest and land fires (fire suppression) used for extinguishing forest and land fire hotspots, improving visibility at airports, reducing respiratory disease, and reducing the potential for complaints from neighboring countries due to haze caused by forest and land fires in the regions of Sumatra and Kalimantan Islands.

This research will focus on explaining the results of TMC activities for rain enhancement, commonly used for reservoir filling purposes, as depicted in the graph below.

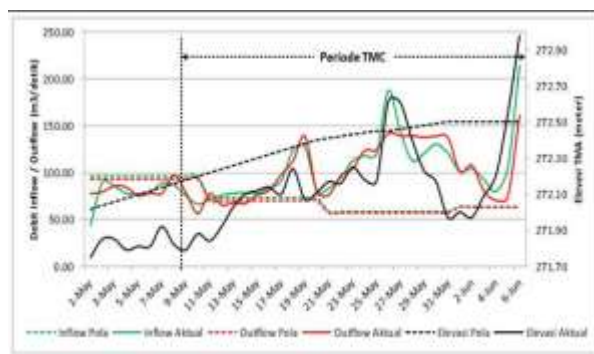
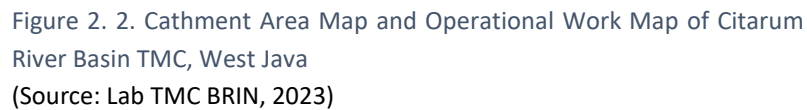


Figure 2. 1. Hydrology Graph of Sutami Reservoir During Cloud Seeding Activities; Pattern vs Actual

(Source: Perum Jasa Tirta I dan BBTMC-BPPT, 2013)

2.2. The parameters of TMC water output to be analyzed.



The literature review conducted on the theoretical foundations related to Statistical Literature, Multiple Regression, and Economics will enhance the strength and precision in data processing and the conclusion of scientific research. This is particularly pertinent to the economic benefits related to the contribution of TMC to the economic activities of a region, especially in Purwakarta Regency, West Java.

According to Sadono Sukirno (1981:52), the total value of production (goods and services) created in a country in a particular year is called National Income. Therefore, National Income is defined as the value of all finished goods and services produced by a country in a particular year. In the calculation of National Income, there are three terms that provide an

overview of the National Income of a country. These three terms are Gross National Product (GNP), Gross Domestic Product (GDP), and National Income. Gross National Product is the national income calculated by the expenditure approach. Gross Domestic Product is the national income calculated by the production of goods and services. Meanwhile, National Income is the National Income calculated by income. Here are the 11 Sector Components of Gross Domestic Product (Gross National Product) calculated based on the production sector, as shown in Table 2.1.

Table 2.1. GDP Elements in Rupiah

Sectors:	GDP (in Rp) in year to, n
1. Agriculture	xxx
2. Mining	Xxx
3. Industry	xxx
4. Electricity, Gas, and Drinking Water.	xxx
5. Building	xxx
6. Wholesale and Retail Trade	xxx
7. transportation and communication	xxx
8. Banking	xxx
9. House Rent	xxx
10. Government and Defense	xxx
11. Other services	xxx
Gross Domestic Product	xxx

2.4. Gross Regional Domestic Product (GRDP)

Gross Regional Domestic Product (GRDP) is the total value of final goods and services produced by all economic units in 11 sectors in a particular region and at a specific time. This research examines the influence of Weather Modification Technology (TMC) in producing water that enters the reservoir of the Citarum River Basin (Jatiluhur Reservoir), which is capable of generating electricity (X_1), supplying water to the Regional Drinking Water Company/PDAM (X_2), supplying water to industries (X_3), and supplying water to agriculture/paddy fields (X_4), which can have a positive impact on the total GDP of the Electricity and Drinking Water sector in Purwakarta Regency, West Java Province.

2.5. Linear regression

A regression model can be used to study the relationship between two or more variables for empirical analysis. However, sometimes a simple

regression model is suitable as an empirical tool. Interpreting a simple regression model is a good basis for delving into the application of multiple regressions (Jeffrey M. Wooldridge, Michigan State University, 2015). The form of a simple linear regression can be written as follows:

$$Y = \beta_0 + \beta_1 X + \mu \quad (2.1)$$

Y = variable response

β_0 = Constanta or intercept

X = Predictor variable

β_1 = Coefisien of linier regression

μ = error

In the context of research to find the cause-and-effect relationship of several predictor variables on a response variable, the mathematical equation that can be applied is, of course, using multiple linear regression equations. This equation has the ability to analyze, evaluate, and explain the relationships of several predictor variables included in multiple linear regression modeling on the response variable, which will be tested through modeling. The suitability of the variables or parameters to be included and used in multiple linear regression modeling must all meet the requirements of classic regression tests, and if they do not meet the criteria, these variables cannot be used in multiple regression modeling.

2. Multiple Linear Regression Equation

Based on the problem formulation and research objectives, this study falls under quantitative research using a multiple regression model approach. The regression model is intended to determine the contribution of the independent variables ($X_1 \dots X_4$) to the dependent variable, namely variable Y (GDP) of Purwakarta Regency, West Java Province. Conceptually, the multiple regression model equation is constructed as follows:

$$Y = \beta_0 + \beta_1 X_1 + \dots + \beta_n X_n + \mu_i, i = 1, 2, 3, \dots, n \quad (2.2)$$

where;

Y = Response variable

β_0 = Intercep

β_i = Coefisien of Regression

X_i = Predictor variable

μ_i = Error

The data processing technique that will be used to calculate the dependent and independent variables in this study is Minitab Version 18.

2.5.1 Coefisien of Corellation

Correlation coefficient analysis is used to determine the strength or weakness of the relationship between predictor (independent) variables and the response (dependent) variable.

2.5.2 Data Analysis Methodology

In constructing a regression model, there is a need for analytical requirements, namely the model must be BLUE (Best Linear Unbiased Estimation). Therefore, before conducting a regression model analysis, it is necessary to test the analytical requirements through classic assumption tests. This classic assumption test is performed to assess whether there are problems with classic assumption in an Ordinary Least Square (OLS) linear regression model. The classic assumption tests used in this research include tests for normality, multicollinearity, heteroskedasticity, autocorrelation, and linearity.

2.5.3 Classic Assumption Test/Variable Parameter Test

a. Normality Test

The normality test aims to examine whether in the regression model, the disturbance variable or residual has a normal distribution. A good regression model has normally distributed residual values. The normality test uses the One Sample Kolmogorov-Smirnov Test. Using a significance level of $\alpha = 5\%$, the decision criteria for the test results are as follows:

- If the Sig. (significance) value ≥ 0.05 , it indicates that the data are normally distributed;
- If the Sig. (significance) value < 0.05 , it indicates that the data are not normally distributed.

b. Multicollinearity test

The multicollinearity test is intended to observe the presence of high correlation between independent variables in a multiple regression model. A good regression model is one in which there is no correlation between the independent variables. If there is high correlation between the independent variables in the model, the relationship between the independent variables and the dependent variable will be disrupted. To test for multicollinearity, the variance inflation factor (VIF) values are used as indicators. The decision-making basis for the multicollinearity test by analyzing the tolerance coefficient and VIF values is as follows:

- If the tolerance value > 0.10 , it indicates that there is no multicollinearity in the regression model.
- If the tolerance value < 0.10 , it indicates that there is multicollinearity in the regression model.
- If the VIF value < 10.00 , it indicates that there is no multicollinearity

in the regression model.

- If the VIF value > 10.00 , it indicates that there is multicollinearity in the regression model.

C. Heteroscedasticity Test

The Heteroskedasticity test is intended to observe or test whether there is inequality in pairs of residuals between one observation and another in the regression model. A good model that meets the analysis requirements will have no equal variance of residuals. The statistical tests that can be used to identify heteroskedasticity include the Glejser test parameter and the White test rank Spearman. Using a significance level of $\alpha = 5\%$, the applicable test criteria are as follows: if the significant test value > 0.05 , this result indicates that the residual variance is the same (homoskedasticity) or that there is no heteroskedasticity. If the significant test value < 0.05 , it indicates that the test result concludes that there is heteroskedasticity in the model.

d. Linearity Test

The linearity test is used to determine whether the constructed model has a linear relationship or not. The linearity test is used to confirm whether the linear nature between two theoretically identified variables corresponds with the existing observational results. The linearity test can use the Durbin-Watson test.

e. Autocorrelation Test

The Autocorrelation Test is necessary in this research. Considering that the data being studied uses time series data closely related to time periods (TMC activities from year to year). The purpose of this test is to ensure that the independent variables do not have correlations with each other, so that the independent or predictor variables have good accuracy in predicting the response variable. The autocorrelation test that will be used is the Durbin Watson (DW) test with the approach of the Durbin Watson table, which has lower limit (dL) and upper limit (dU) values with the following rules: $DW < dL$ = indicates positive correlation.

1. $dL < DW < dU$ = no conclusion can be drawn.
2. $dU < DW < 4 - dU$ = no positive or negative correlation.
3. $4 - dU < DW < 4 - dL$ = no conclusion can be drawn.
4. $DW > 4 - dL$ = indicates negative correlation.

f. Hypothesis Testing Partial Test

Partial testing is intended to test the significance of the influence of independent variables on the dependent variable individually. To test the coefficients of the independent variables partially, the t-test is used. The t-statistic value is equal to the sample slope divided by the standard error slope. Mathematically, the formula for the t-test is:

$$t_i = \frac{b_i}{sb_i} \quad (2.3)$$

where:

t = calculated t-value

b_i = coefficient value of the i-th variable

Sb_i = standard error of the coefficient of the i-th variable

The proposed hypotheses are as follows: H_0 : The independent variables do not have a significant influence on the dependent variable. H_a : The independent variables have a significant influence on the dependent variable. Using a significance level of $\alpha=5\%$, the decision in this test is:

- If the test result has a significance probability value > 0.05 , then H_0 is accepted and H_a is rejected. This means that there is no significant influence between the independent variables and the dependent variable.
- If the test result has a significance probability value < 0.05 , then this result accepts H_a and rejects H_0 . This means that there is a significant influence between the independent variables and the dependent variable.

g. Coefisien of Determination

The Coefficient of Determination (CD) is used to determine the level of influence (%) of changes in the value of X on changes in the value of Y. The Coefficient of Determination (R^2) is used to determine the percentage of the influence of the independent variables on the dependent variable. The value of the determinant coefficient measures the ups and downs of the dependent variable influenced by its independent variables, and the rest is influenced by other variables not included in the model. Mathematically, the formula for the coefficient of determination is:

$$R^2 = 1 - \frac{RSS}{TSS} \quad (2.4)$$

where:

R^2 = determinant Coefficient value

RSS = Sum of square of residual

TSS = Total sum of square

- h. The research data used is secondary data. Additional data on Water from the results of TMC conducted by BBTMC and data on Electricity Production, PDAM Water Supply, Industrial Water Supply, and Agricultural/Rice Field Water Supply are used. The GDP data is obtained from relevant institutions and the Central Bureau of

Statistics of Purwakarta Regency and Perum Otorita Jatiluhur (POJ) as well as from several publications.

2.6. Previous Research

In this subsection, a summary of journals or scientific articles regarding the economic benefits of TMC reviewed by the author is presented as a reference or comparison that will be conducted by the author in this research. Previous research is presented in table 2.1.

Table 2. 1. Previous Economic/Benefit Research of Cloud Seeding

Title	Writer/ Researcher	Year	Type of Research	Object ive of Research
Economic impacts of cloud seeding	Hydro Tasmania and West Coast Council, Australia	2008	Cloud Seeding Report	Cloud Seeding (Weather Modification)
Overview of ground-based generator towers as cloud seeding facilities to optimize water resources in the Larona Basin	Anom Prasetyo, Bambang L. Widjiantoro, Aulia MT Nasution	2019	National Journal	Weather Modification
Kajian Distribusi dan	Anom Prasetyo	2019	Thesis	Weather

Title	Writer/ Researcher	Year	Type of Research	Objective of Research
Lokasi Menara Ground Base Generator Sebagai Sarana Cloud Seeding Guna Optimalisasi Pengelolaan Sumber Daya Air Di Das Larona				Modification
Operation and Water Management of Dam Cascade System	Anom Prasetyo, Abu Ashar	2022	National Journal Nasional	Weather Modification

Hydro Tasmania and West Coast Council Australia, 2008, in the report "Economic impacts of cloud seeding" stated that the economic benefits of Cloud Seeding activities conducted in West Coast Tasmania, Australia. An increase in rainfall per cloud seeding activity resulted in an additional $\approx 20\%$ of rainfall at a cost of AUS \$1.5 million per cloud seeding activity. The estimated economic benefit of the additional water from Cloud Seeding for hydroelectric power production is at least AUS \$4 million or equivalent to 20 MW.

Anom Prasetyo, Bambang. L. Widjiantoro, Aulia MT Nasution, 2019, in the research "Overview of ground-based generator towers as cloud seeding facilities to optimize water resources in the Larona Basin" in the River Basin area (Larona River Basin) with a river basin area of 2477 km²,

including three tiered lakes, namely Lake Matano, Mahalona, and Towuti. This area is a strategic river basin that serves as a water source for three hydroelectric power plants that supply 420 Megawatts of electricity for the nickel processing plant and its supporting facilities, and meet the electricity needs of the surrounding community. The maximum and minimum operating heights of Lake Towuti are 319.6 meters above sea level (asl) and 317.45 meters asl, respectively. The water storage capacity between the two heights is 1,231,500 m³. Currently, the average flow rate from Lake Towuti to the power plant is 130.1 m³/second, resulting in a total annual flow volume of 4,103,000 m³. By comparing the flow volume with the water storage volume, it is clear that the current water storage capacity has limitations in addressing the difference in capacity between wet and dry years. In dry years, the water flow decreases to 100 m³/second. Therefore, optimizing water resource management in the Larona River Basin is essential to meet energy production needs. To address the decrease in the lake water level, Cloud Seeding technology is needed to generate rain to increase the water volume in the lakes. The estimated cost is around US\$11,133,258.36 if the company uses Diesel Power Plants and Steam Power Plants as more expensive alternatives compared to cloud seeding technology.

Anom Prasetyo (2019), in the study "Study of Distribution and Location of Ground-Based Generator Towers as Cloud Seeding Facilities to Optimize Water Resources in the Larona Basin," in this research explained the Weather Modification process to increase the amount of rainfall can be continuously carried out when favorable weather conditions and can be used to maintain the water level in the lakes, especially during the dry season. In this study, the economic benefits are calculated and analyzed, including the cost data incurred for the water addition work through weather modification technology and the costs incurred if the water level decreases so that it cannot meet the water needs for the operation of the hydroelectric power plant. The operational economic benefits of weather modification technology are analyzed from the aspects of operational and capital costs of Weather Modification Technology (TMC) compared to the costs incurred when using Steam Power Plants, Diesel Power Plants, and MBDGs in thermal. After calculating the benefit cost ratio analysis, it can be seen that TMC is quite effective and efficient for increasing the water flow.

Anom Prasetyo (2019), Benefit Cost Ratio Analysis is calculated and analyzed to determine the economic feasibility of TMC operational activities at PT. Vale Indonesia (PTVI) can be measured by the Benefit Cost Ratio (B/C) indicator. In the benefit cost ratio analysis by considering the cost of using thermal power plants and the expenditure used to finance the TMC program. Thus, the B/C ratio value of TMC operational activities can be calculated and compared so that the clear benefits of the TMC program can be known. Thus, from the above cost analysis, namely: the cost of thermal electricity compared to the TMC program, \$ 7,675,224.25

/ \$380,733.14 = 20.16/1. If TMC uses an airplane, the cost required is \$1,300,000, so if compared between the cost of the thermal plant and the TMC using the aircraft, the B/C is \$7,675,224.25 / \$1,300,000 = 5.9/1.

3. RESEARCH METHODOLOGY

In the implementation of this research, a systematic method design is required to conduct the stages of the research process. The intended method serves as a basis for the author to carry out the research stages to achieve the expected research objectives. The formulated method consists of stages of research activities conducted by the author and presented in the diagram in Figure 3.1 below.



Figure 3. 1. Research Flowchart Diagram

3.1. Description of Research

The activity of Weather Modification Technology (TMC) operations has long been carried out in Indonesia, as in other parts of the world. TMC activities in Indonesia are utilized for filling reservoirs, reducing rainfall for flood mitigation, and suppressing forest and land fires. In other parts of the world, TMC is used to fill reservoirs for hydropower generation, as well

as for snow decomposition (hail suppression) at airports to avoid disrupting flights.

The description of the issue regarding the implementation of TMC in Indonesia has not yet included an analysis and evaluation of the impact of the water entering the Jatiluhur reservoir in relation to the GDP of the Electricity and Drinking Water sectors. This has led many parties to question the extent of the benefits or contributions of TMC to the GDP of the Electricity and Drinking Water sectors.

In calculating the Gross Regional Domestic Product (GRDP) of Purwakarta Regency based on constant prices, there are 11 sectors of business fields involved in the calculation. The GRDP figures in these 11 sectors of business activities indicate economic activities or growth in a country or region and serve as an indicator in measuring the level of community welfare (income per capita). To explain the issues in this research, it can be illustrated in the following diagram.

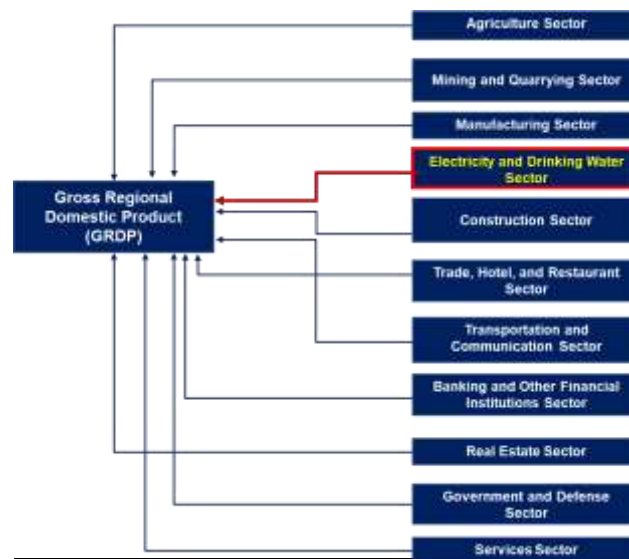


Figure 3. 2. Diagram of Business Sector Elements in GRDP

Based on the diagram in Figure 3.2, the water output from TMC that enters the Jatiluhur reservoir has never been analyzed, evaluated, or tested for its relationship with the GDP of the Electricity and Drinking Water sectors using multiple linear regression equations.

3.2. Data Collection

The data needed and collected for this research are classified into five groups, including:

3.2.1 Gross Regional Domestic Product (GRDP)

The data required for this study are the Gross Regional Domestic Product (GRDP) of Purwakarta Regency, West Java Province, specifically from the Electricity and Water Supply sector. The required data is sourced from the Central Statistics Agency (BPS) Central, BPS Purwakarta Regency, Perum Jasa Tirta (PJT II) Jatiluhur Purwakarta, and the Purwakarta Regency Department of Food Crops and Agriculture.

3.2.2 Water from Weather Modification Technology Activity

The water produced from Weather Modification Technology activities conducted by the Weather Modification Technology Center under the Agency for the Assessment and Application of Technology (currently the Weather Modification Technology Laboratory under the National Research and Innovation Agency).

The water resulting from TMC activities that enters the Jatiluhur Reservoir (Perum Jasa Tirta II) in Purwakarta, West Java, is utilized for Hydroelectric Power Plants, Industrial Water Supply, Drinking Water Supply (PAM), and for Agriculture (Paddy Fields).

The collected data refers to the Gross Regional Domestic Product (GRDP) of the Purwakarta Regency, specifically related to the analysis and evaluation during the years of TMC operations in the Citarum River Basin (Jatiluhur Reservoir) in the years 1979, 1980, 1981, 1982, 1983, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1997, 1998, 2001, 2003, 2004, 2007, 2011, 2012, and 2021.

The data will be examined concerning their correlation and contribution to the four predictor variables (electricity, water supply to the industry, PAM water supply, and agriculture) on the GRDP of the Purwakarta Regency.

The water data supplied to the Jatiluhur Reservoir is obtained from cloud seeding operations conducted during the transitional seasons, namely, at the end of the rainy season but before the onset of the dry season. Conversely, cloud seeding is conducted at the end of the dry season and before the arrival of the rainy season. This is intended to expedite rainfall and ensure that the water availability in the Jatiluhur Reservoir is maintained for the purposes of electricity generation, drinking water supply, industrial water supply, and agricultural irrigation. This transitional season is depicted in Figure 3.3.

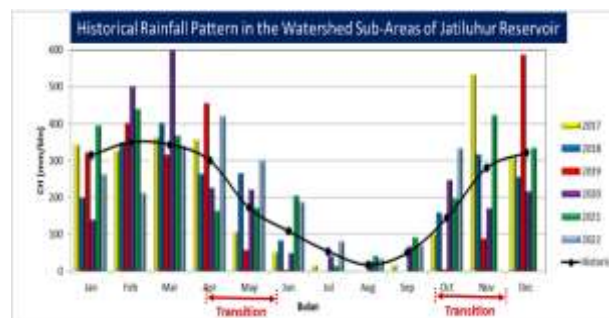


Figure 3.3. Historical Rainfall Pattern in the Watershed Sub-Areas of Jatiluhur Reservoir (Source: BBTMC BPPT)

To achieve optimal water output with maximum benefits, cloud seeding activities should preferably be conducted during this transitional period as it can increase the water availability in the Jatiluhur Reservoir before the reservoir naturally replenishes during the onset of the rainy season.

3.3. Data processing

Data processing of the dataset on the Hydroelectric Power Plant, Distribution of Water to the Industrial Sector, Drinking Water Supply (PAM), and for Agriculture (Paddy Fields) has been organized into the form of the Gross Regional Domestic Product (GRDP) of Purwakarta Regency from the Electricity and Clean Water Business Sector (Y) and the rainwater resulting from the TMC activities, converted with the Production of Electricity (X_1), Supply of PDAM Water (X_2), Industrial Water Supply (X_3), and Agricultural/Paddy Field Water Supply (X_4). The dataset, which has been structured accordingly, will be processed using the Minitab version 18 application. The output from the multiple regression calculations in the Minitab application will be subjected to validation, analysis, and interpretation in accordance with the research objectives.

3.4. Building a regression model

Building a regression model will be obtained from the output calculation of the Minitab version 18 Application Program. The output from the Minitab application will provide information on response and predictor parameters to build the Multiple Regression Model. From the intended calculation information, it is possible to build a Multiple Regression Model in accordance with the research objectives. In constructing a multiple regression model, there are several conditions that must be considered, such as variable analysis and statistical tests to validate parameters suitable for constructing a linear regression equation.

In constructing the regression model equation, the established steps must be followed systematically and adhered to based on scientific principles. This is important to ensure that the process of building the regression model equation can provide accurate analysis and information on the independent variables analyzed. Errors in constructing the model or the process of constructing the regression model that is not carried out systematically will result in an invalid regression equation model, thus leading to an inability to achieve the expected result prediction and obtaining erroneous and biased results.

Therefore, to obtain a good and valid regression equation model and to avoid errors in the model construction process, the author will follow steps as shown in the following diagram.

By validating suitable parameters for building a linear regression equation, the response variable (Gross Regional Domestic Product) measured over time (in years) is contributed or influenced by four predictor variables such as Electricity Production (X1), PDAM Water Supply (X2), Industrial Water Supply (X3), and Agricultural/Rice Field Water Supply (X4) as represented in Table 3.1.

Table 3. 1. Response and Predictors Variable

Regression Variable	Description	Data Type
Gross Regional Domestic Product	The total production of goods and services within a specific year.	Numeric
Electric Hydro Power Generation Product Supply	Electricity Production from - generated Water by Cloud Seeding	Numeric
Regional Drinking Water Supply Company	Drinking Water from Cloud Seeding Activities	Numeric
Industry Water Supply	Industrial Water from Cloud Seeding Activities	Numeric
Agriculture Water Supply	Water for Agriculture Needs from Cloud Seeding Activities	Numeric

By conducting the data processing, validation, and statistical tests, the model that will be developed is $Y = \beta_0 + \beta_1 \text{Electricity Production Water} + \beta_2 \text{PDAM Water Supply} + \beta_3 \text{Industrial Water Supply} + \beta_4 \text{Agricultural Water} + \mu_i$ where Y represents the Gross Regional Domestic Product (GRDP) of the Electricity and Drinking Water Sector in Kabupaten Purwakarta influenced by the cloud seeding operations in the Citarum River Basin, West Java.

3.4.1 Regression Model Validity Testing

The crucial stage in the analysis using multiple linear regression equations is the testing of validity and statistics. The testing aims to obtain accuracy in determining the predictor parameters in the model. With valid predictor parameter validity, it will determine the accuracy in predicting the dependent variable (GRDP)

3.4.2 Error Calculation

Standard error is a test of predictor parameters to determine the smallest standard error or minimize the error, which means that the coefficient or predictor variable tends to approach the true value (Nachrowi D Nachrowi, Hardius Usman, 2006). The approach used to calculate the standard error is the use of Mean Square Error (MSE) or the R2 Coefficient.

4. ANALYSIS AND DISCUSSION

4.1. History of Weather Modification Technology

The history of research and development of rainmaking technology, known as cloud seeding in Indonesia, has a long history. The history and development of cloud seeding encompass methods and experiments throughout the evolution of this technology. The research and development of cloud seeding aim to control or modify the weather to manage atmospheric water resources to be precipitated as rain, addressing drought and supporting agriculture, especially in water-scarce areas. In Indonesia, aside from reservoir filling, cloud seeding is also utilized for forest fire suppression and reducing rainfall to mitigate floods (cloud dispersal). In the 19th and early 20th centuries, scientists began experiments using seeding chemicals such as salt (NaCl Powder) and smoke to trigger rain. Charles Hatfield was commissioned by the city of San Diego, United States, in 1915 to conduct rainmaking to alleviate the drought in the area, and his efforts were deemed successful (source: https://en.wikipedia.org/wiki/Charles_Hatfield).

In the mid-20th century, cloud seeding continued to be developed in several countries, using airplanes as carriers to introduce seeding agents into clouds, using chemicals like Silver Iodide (AgI). The goal was to expedite the process of collision and coalescence of water droplets in clouds to form larger raindrops. In the past decade, sophisticated technology has been used, with planes equipped with special equipment such as a flare rack and atmospheric instruments to identify clouds with the potential for seeding treatment. The modern development of cloud seeding also involves the use of sodium, not just NaCl and AgI, and has been carried out by several countries in America, Asia, Europe, Australia, and Africa. In China, rocket technology has been used to deliver seeding agents into cloud masses and applied for rain prevention (cloud dispersal) during the Beijing Olympics in 2008 (source: Antara News), (<https://www.antaranews.com/berita/112273/pembukaan-olimpiade-bebas-hujan-berkat-1000-roket>).



Figure 4. 1. Ejectable Flare Rack and Hygroscopic Flare Rack
(Source: Weather Modification Inc. Fargo North Dakota, USA)



Figure 4. 2. Ejectable Flare Rack and Hygroscopic Flare Rack (Source: Weather Modification Inc. Fargo, North Dakota, USA)

With the increasing development of TMC, many countries around the world are becoming interested in possessing and developing TMC for the purpose of enhancing rainfall (rain enhancement) and destroying snowstorms (hail suppression).

4.2. Description and Data Processing of the Research

Based on data from table 1.2 and table 1.3, the incoming water from TMC operations is converted into the Indonesian Rupiah currency to be regressed with the value of the Gross Regional Domestic Product for the Electricity and Clean Water Sectors (PDRBSektor Listrik dan Air Minum). The data processing from table 1.2 and table 1.3 results in table 4.1, which represents the dataset obtained from the multiplication of data from table 1.2 and table 1.3. In Chapter 4, the data processing stage and the analysis of parameters obtained from the input dataset in table 4.1 are performed using the Minitab version 18 application.

The purpose of this data processing is to analyze and determine the percentage contribution of the water resulting from TMC to the Gross Regional Domestic Product for the Electricity and Clean Water Sectors of Purwakarta Regency. The evaluation and analysis of the Gross Regional Domestic Product for the Electricity and Clean Water Sectors are based on constant prices and subsequently correlated with the water resulting from TMC operations from 1979 to 2021 (converted to Indonesian Rupiah), as presented in table 4.1.

Table 4.1. Dataset of Gross Regional Domestic Product for the Electricity and Clean Water Sectors, Electricity, Clean Water, Industry, and Agriculture Converted into Rupiah 1979-2021.

(In Rupiah)

Year	GRDP ^{Electricity and Drinking Water} (Y)	Electricity (X ₁)	Drinking Water/PDAM (X ₂)	Industry (X ₃)	Agriculture/Rice Field (X ₄)
1979	2.887.490.000	393.333.333,33	113.407.578,00	32.066.264,28	56.209.744,06
1980	3.847.970.000	563.740.000,00	295.660.226,88	85.774.775,04	224.839.128,70
1981	4.808.450.000	824.593.333,33	546.557.815,62	161.125.553,92	505.876.088,28
1982	5.768.930.000	1.279.373.333,33	866.433.895,92	258.118.562,00	899.340.732,20
1983	6.729.410.000	282.240.000,00	1.255.155.047,10	376.723.486,92	1.405.225.016,71
1987	10.571.330.000	869.810.780,00	3.497.889.967,00	1.067.717.443,00	4.552.885.480,60
1988	11.531.810.000	1.903.300.000,00	4.230.102.659,40	1.294.315.752,10	5.620.859.848,01
1989	12.962.090.000	1.015.590.000,00	5.031.760.815,18	1.542.506.726,00	6.801.253.856,01
1990	13.452.770.000	2.728.880.000,00	5.902.264.041,84	1.812.885.914,31	8.094.019.242,02
1991	15.619.680.000	3.845.165.733,00	6.840.745.104,96	2.104.634.404,29	9.499.247.518,30
1992	16.597.520.000	1.602.180.000,00	7.848.871.763,04	2.418.025.079,88	11.016.896.349,93
1993	36.105.000.000	5.640.993.909,00	8.925.843.492,00	2.753.058.075,90	12.646.904.493,93
1994	40.517.500.000	1.387.535.000,00	10.070.592.926,00	3.109.733.248,00	14.389.388.584,84
1995	44.930.000.000	1.511.499.226,00	11.285.188.086,78	3.488.050.750,87	16.244.292.316,33
1997	61.108.420.000	4.319.653.333,00	13.920.913.620,18	4.309.612.429,20	20.291.280.836,93
1998	57.102.610.000	5.662.038.500,00	15.340.709.786,40	4.752.856.596,75	22.483.439.392,06
2001	85.762.190.000	3.710.760.000,00	20.015.436.861,90	6.212.442.795,94	29.734.340.397,66
2003	80.673.990.000	2.166.703.680,00	23.477.036.404,50	7.290.609.097,50	35.130.325.682,36
2004	137.953.830.000	15.176.700.000,00	5.943.135.552,00	1.693.861.427,60	9.887.742.745,83
2007	146.010.480.000	7.284.000.000,00	15.555.731.052,74	7.942.055.959,78	50.057.160.858,90
2011	204.974.900.000	10.311.000.000,00	16.640.943.774,00	5.688.331.623,46	33.959.219.310,86
2012	214.262.700.000	12.269.875.000,00	10.193.653.027,74	17.184.135.699,71	910.796.894.208,49
2021	316.687.700.000	29.828.500.000,00	15.573.805.005,00	5.117.314.762,83	595.992.130.122,90

Source: Central Bureau of Statistics (BPS), Derived from Table 1.2 and Table 1.3.

Referring to Table 1 (descriptive statistics), each predictor variable and the response variable used in building the regression equation have reasonable statistical values. The Supply of TMC Water for Electricity

Generation, PDAM Water, and Industrial Water have reasonable mean, minimum, median, and maximum values, except for the maximum value of the dry grain yield from agricultural activities, which has increased sharply, indicating a data anomaly likely caused by high water supply for agricultural needs in 2012 and 2021, allowing for rice cultivation to be carried out 3-4 times per year. Additionally, the influence of agricultural intensification, such as fertilization, the selection of superior seeds, and pest control, also contributed to the significant increase in rice production in 2012 and 2021.

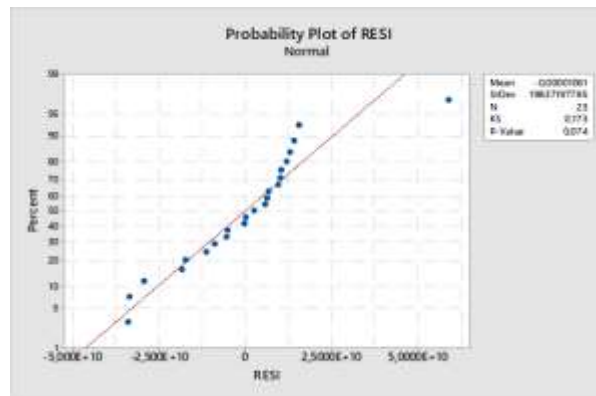
Tabel 4,2. Descriptive Statistic

Variable	Total Count	Mean	StDev	Minimum	Median
PDRBSektor Listrik dan Air Minu	23	66559424783	83592999332	2887490000	36105000000
Listrik (X1)	23	4981628920	6733579658	282240000	2166703680
PDAM (X2)	23	8842253848	6718977143	113407578	7848871763
Industri (X3)	23	3508519845	3801836166	32066264	2418025080
Pertanian (X4)	23	78273468346	218637000000	56209744	11016896350
Variable	Maximum				
PDRBSektor Listrik dan Air Minu	316688000000				
Listrik (X1)	29828500000				
PDAM (X2)	23477036405				
Industri (X3)	17184135700				
Pertanian (X4)	910797000000				

Data processing of table 4.1 also resulted in the multiple linear regression equation: **GRDP Electricity and Drinking Water Sector = -15591761971 + 10.17 Electricity (X₁) + 0.50 PDAM (X₂) + 8.88 Industry (X₃) - 0.0520 Agriculture (X₄)**. The above equation must undergo correlation and classical multiple linear regression tests to meet the requirements of a good model, namely fulfilling the Best Linear Unbiased Estimation (BLUE) or, in other words, meeting the requirements of the classical multiple regression test.

4.2.1. Correlation Test

Referring to Table 4.3 (correlation of predictor variables with the response variable), the output of the correlation test obtained from Minitab is displayed in Table 4.3. The correlation figures of the variables Electricity Supply (0.913), PDAM Supply (0.578), Industrial Water Supply (0.669), and Agricultural Water Supply (0.721) with GRDP Electricity and Drinking Water Sector show a strong and significant relationship, considering that all four variables have a P-value smaller than the value $\alpha = 0.05$ (5%). The electricity variable has a strong relationship with the PDRB Electricity and Drinking Water Sector. The correlation test indicates that water supply for hydroelectric power generation, PDAM, Industry, and for agricultural purposes has a positive relationship with economic activity (PDRB Electricity and Drinking Water Sector) in Purwakarta Regency.



Tabel 4.3 Correlations

	GRDP Electricity and Drinking Water Sector	Electricity (X1)	Drinking Water/PDAM (X2)	Industry (X3)
Electricity(X1)	0,913 0,000			
Drinking Water/PDAM (X2)	0,578 0,004	0,380 0,074		
Industry (X3)	0,669 0,000	0,418 0,047	0,632 0,001	
Agriculture (X4)	0,721 0,000	0,663 0,001	0,211 0,334	0,757 0,000

Cell Contents

Pearson correlation

P-Value

4.2.2. Normality Test

Based on figure 4.4 (Probability Plot of RESI), the residual variable has a normal distribution using the one-sample Kolmogorov-Smirnov test, where the P-Value is 0.074 (7.4%), which is greater than $\alpha = 0.05$ (5%). This indication suggests that the residuals of the four predictor variables in the multiple regression equation have a normal distribution, fulfilling one of the elements of the classical multiple regression test. The normality test of the residual can be clearly seen in the figure 4.4.

Figure 4.4 Probability Plot of RESI

4.2.3. Multicollinierity Test

Referring to Table 4.4 (Variance Inflation Factor/VIF), the VIF values for the four predictor variables are as follows: electricity (3.47), PDAM (4.36), Industry (8.98), and Agriculture (9.06). All four predictor variables have VIF values less than 10.

These VIF values suggest that the four predictor variables do not exhibit multicollinearity with each other. This confirms that each predictor variable has an influence on the PDRB sector of Electricity and Drinking Water.

Table 4.4 Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-1,55918E+10	7945515097	-1,96	0,065	
Listrik (X1)	10,17	1,29	7,87	0,000	3,47
PDAM (X2)	0,50	1,45	0,34	0,737	4,36
Industri (X3)	8,88	3,69	2,41	0,027	8,98
Pertanian (X4)	-0,0520	0,0644	-0,81	0,430	9,06

4.2.4. Heteroscedesity Test

Heteroscedasticity test is an important sequence in multiple regression classic tests, and the test is conducted based on two approaches, namely the Glejser Test (regressing Absolute Value Residual on the four predictor variables) and the Rank Spearman Test (Spearman Rho) by correlating the four predictor variables with the Absolute Value Residual.

Referring to the Table 4.5 (Absolute Value Residual). The calculated P-Values from the Minitab output using the Glejser Test approach indicate that the P-Values of the Electricity (0.029) and Agriculture (0.028) variables are smaller than the value of $\alpha = 0.05$ (5%).

This provides an indication that both predictor variables show heteroscedasticity in the constructed model.

The second test uses the Spearman Rho approach (Table 4.6), which shows that the predictor variables have P-Values; Electricity (0.386), PDAM (0.641), Industry (0.520), and Agriculture (0.562) are greater than the value of $\alpha = 0.05$ (5%). By using the Spearman Rho test, the Electricity and Agriculture predictor variables are free from heteroscedasticity indications, and with the statistical rules of this research, it can be continued.

Tabel 4.5 Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	10023324679	4571424595	2,19	0,042	
Listrik (X1)	1,766	0,744	2,37	0,029	3,47
PDAM (X2)	-1,204	0,836	-1,44	0,167	4,36
Industri (X3)	3,71	2,12	1,75	0,098	8,98
Pertanian (X4)	-0,0883	0,0370	-2,38	0,028	9,06

Table 4.6 Spearman Rho: Listrik (X1); PDAM (X2); Industri (X3); ... 4); ABS Residu

Correlations

	Listrik (X1)	PDAM (X2)	Industri (X3)	Pertanian (X4)
PDAM (X2)	0,722 0,000			
Industri (X3)	0,757	0,954		
	0,000	0,000		
Pertanian (X4)	0,805	0,948	0,986	
	0,000	0,000	0,000	
ABS Residu	0,190 0,386	-0,103 0,641	-0,141 0,520	-0,127 0,562

Cell Contents**Spearman rho****P-Value****4.2.5. Linierity Test**

The linearity confirmation test of the two variables is conducted using the linearity diagram of the variables (referring to the Figure 4.5, scatterplot linearity of predictor variables against the response variable). The output diagram from Minitab processing shows that the predictor variables (Electricity, PDAM, and Industry) have a linear relationship with the response variable, except for the Agriculture predictor variable, which is distant and does not follow the linear prediction line (irregular and not in the same direction).

Based on the above diagram, the scatter plot of the predictor variables (Electricity and Industry) is in line with the regression line. Meanwhile, the PDAM variable follows the direction of the regression line, but the data scatter points move further to the right away from the regression line.

Based on the linearity graph above, where the agricultural predictor variable's data scatter is not in line with its regression line and is trending upwards, this variable can be said to be non-linear with respect to the PDRB.

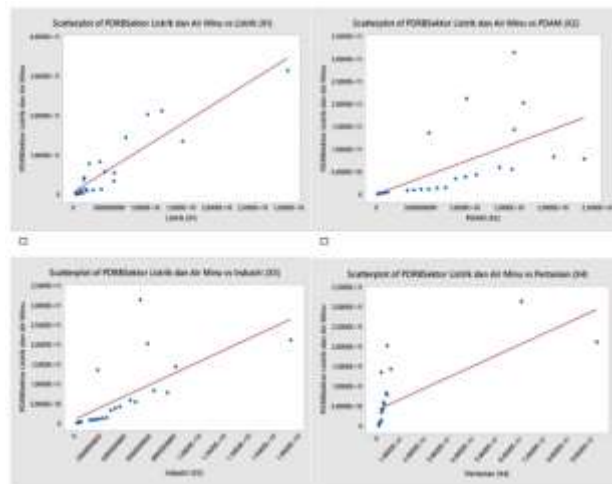


Figure 4.5 Linierity Graph

4.2.6. Auto Corellation Test

Considering the research data as time series, an autocorrelation test is necessary to examine whether there is autocorrelation in the multiple linear regression equation's predictor parameters. The Minitab calculation resulted in a Durbin Watson (DW) test value of 1.57640 and $4 - 1.57640 = 2.4236$. This figure must be compared with the Durbin Watson Table for $N = 23$ with the number of predictor variables = 4 at $\alpha = 0.05$ (5%). Thus, the

calculated values for dL are 0.99 and dU are 1.79 with a value of 4 - dL = 3.01. According to Nachrowi D Nachrowi, Hardius Usman, 2006, if $DW < dL$ (there is positive correlation) and $DW > 4-dL$ (there is negative correlation). The calculation results found the value of $dL < DW < dU$ ($0.99 < 1.57640 < 1.79$), thus unable to determine whether the residuals are correlated or not.

Regarding the heteroscedasticity test, a regression between the Absolute Value (ABS Resi) and the predictor variable has been conducted to obtain the Residual P-Value. The calculation results also yield a DW value of 2.13697 with $dL = 0.99$ and $dU = 1.79$ ($N=23$), resulting in the formulation of $dU < DW < 4-dU$ ($0.99 < 2.13697 < 2.21$), indicating that there is no autocorrelation in the multiple regression equation.

To complete the examination of the presence or absence of autocorrelation in the multiple linear regression equation, it can be supported by an examination with the graphical method (referring to Figure 4.6, residual versus observation order graph). The above figure shows that there is no specific similarity pattern in the residual data scatter plot, such as a continuously decreasing or increasing data trend, or a flat trend forming a specific pattern. Based on the graph, it can be concluded that there is no autocorrelation among the predictor variables in the regression equation.

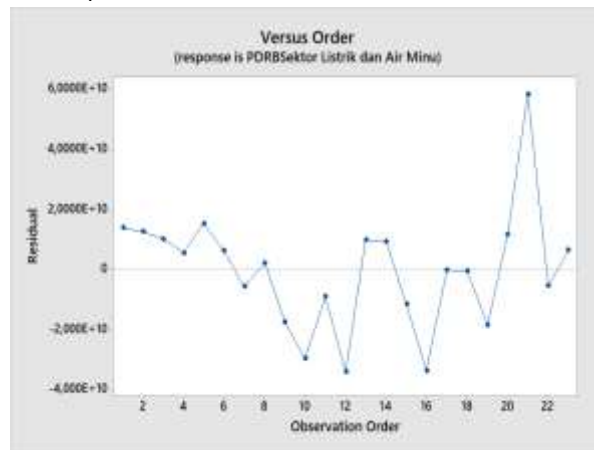


Figure 4.6 Auto Correlation Detection (Versus Order)

4.2.7. Hypothesis testing

Hypothesis testing is a classical series of tests that must be conducted and meet the requirements for the model's predictions to provide accurate predictions of the response variable by the predictor variables.

The calculation results show that the P-Value for Electricity (0.000) and Industry (0.027) are smaller than the $\alpha = 0.05$ (5%) value, indicating that both of these predictor variables have a significant influence on the response variable (referring to the Table 4.7 Analysis of Variance/ANOVA).

Furthermore, the P-Value for Water Supply (0.737) and Agriculture (0.430) are greater than the $\alpha = 0.05$ (5%) value, meaning that

both predictor variables do not have a significant impact on the response variable.

The P-Value of the regression equation has a value of 0.000, which is smaller than the $\alpha = 0.05$ (5%) value, indicating that the constructed regression equation has good validity.

Tabel 4.7 Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	4	1,45074E+23	3,62685E+22	75,41	0,000
Listrik (X1)	1	2,97758E+22	2,97758E+22	61,91	0,000
PDAM (X2)	1	5,61117E+19	5,61117E+19	0,12	0,737
Industri (X3)	1	2,79148E+21	2,79148E+21	5,80	0,027
Pertanian (X4)	1	3,14042E+20	3,14042E+20	0,65	0,430
Error	18	8,65732E+21	4,80962E+20		
Total	22	1,53731E+23			

4.2.8. Coefficient of Determination Test

The calculation of the coefficient of determination, obtained from the R² calculation, is 93.12%. This figure indicates that the influence of water resulting from TMC activities, represented for Hydroelectric Power Generation, Water Supply for PDAM, Industrial Water, and Water for Agricultural needs, collectively contributes positively by 93.12% to the Electricity and Drinking Water Sector GRDP.

Model Summary;

S	R-sqm	R-sq(adj)	R-sq(pred)
2,19308E+10	94,37%	93,12%	65,04%

4.3. Discussion

The processing of data from table 4.1 using Minitab version 18 yielded a regression model for PDRB Electricity and Drinking Water Sector (Y) as - 15591761971 + 10.17 Electricity + 0.50 PDAM + 8.88 Industry - 0.0520 Agriculture. The correlation test for the predictor variables, Electricity (0.913; P-Value 0.000), PDAM (0.578; P-Value 0.004), Industry (0.669; P-Value 0.000), and Agriculture (0.721; P-Value 0.000) shows a strong and moderate correlation with the response variable PDRB Electricity and Drinking Water Sector (Y).

The results of the multiple classic regression test, supported by other statistical tests (non-parametric), indicate that the built regression

equation model is considered to have good validity in examining the relationship between the Water from TMC activities utilized for power generation, water supply for PDAM, water supply for industry, and agriculture (paddy fields) with the economic activities of Purwakarta Regency in the Electricity and Drinking Water Sector.

The coefficients of the Electricity and Industry variables have a significant influence on the growth of the PDRB Electricity and Drinking Water Sector, evident from the coefficients' P-Value of electricity 0.000 and industry 0.027, both smaller than the $\alpha = 0.05$ (5%). Meanwhile, the coefficients of PDAM and Agriculture have P-Value values of 0.737 and 0.430, respectively, larger than the $\alpha = 0.05$ (5%), indicating that the influence of these two variables is not significant to the PDRB Electricity and Drinking Water Sector of Purwakarta Regency.

The intercept value of the regression equation is estimated to be minus Rp. 15591761971. This can be interpreted as an estimation that without the additional TMC water entering the Jatiluhur reservoir (Citarum River Basin) during the research period from 1979 to 2021 (TMC operation for Jatiluhur reservoir water addition), it is anticipated that during the dry season, it will not be able to cover the electricity production and the supply of water for industrial needs, resulting in a decrease in the value of the PDRB Electricity and Drinking Water Sector of Purwakarta Regency by Rp. 15591761971.

With an additional value of Rp. 1 of TMC water entering the Citarum River Basin (Jatiluhur Reservoir), it can contribute to increasing the value of the PDRB Electricity and Drinking Water Sector from electricity production by Rp. 10.17, Rp. 0.50 from PDAM, Rp. 8.88 from Industrial Water Supply, but it decreases by Rp. 0.0520 from Agricultural Water. However, the PDAM and Agriculture variables each have a P-Value (0.737) and (0.430), indicating that their influence is not significant on the PDRB Electricity and Drinking Water Sector.

Based on the graph in appendix 6, the linearity of PDAM to the PDRB Electricity and Drinking Water Sector shows that its data spread is increasingly diverging from the regression line, which is consistent with the P-Value of 0.737. On the other hand, the linearity graph of the agriculture variable to the PDRB, where its data spread does not follow the direction of the regression line, but rather diverges and points upwards. Therefore, it is suspected that the value of the Agriculture Water parameter in the multiple regression equation is negative, which should be positive towards the PDRB Electricity and Drinking Water Sector.

4.4. Aspects of Weather Modification Technology Development

Based on the analysis presented in the previous discussion, it is evident that Weather Modification Technology (WMT) plays a strategic role in replenishing the Jatiluhur reservoir (Citarum River Basin) and significantly influences the support of the economic activities (PDRB in the Electricity and Water Supply Sector) of Purwakarta Regency. Therefore, the

continued development of WMT is deemed necessary, considering that Indonesia possesses a Multi-Functional Reservoir for hydropower generation, drinking water supply, industrial, and agricultural purposes, all of which require the presence of WMT.

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

Based on the research results of the Analysis of the Contribution of Weather Modification Technology (WMT) to the Economy (GDP) of Purwakarta Regency, West Java, the following conclusions can be drawn:

1. Multiple linear regression model using Minitab version 18 can be used to analyze the contribution of Water from Weather Modification Technology activities in the Citarum River Basin (Jatiluhur Reservoir) for hydroelectric power generation, tap water supply (PDAM), water supply for industries, and water supply for agriculture (rice fields) that have an influence on the Economy (GDP of the Electricity and Water Supply Sector) of Purwakarta Regency.
2. The Water from WMT for hydroelectric power generation, tap water supply (PDAM), water for industrial needs, and water for agriculture that were studied, collectively have an influence on the economy or the GDP of the Electricity and Water Supply Sector of Purwakarta Regency, Indonesia by 93.12%.

5.2. Recommendations

Based on the research conclusions, some recommendations for the future can be suggested as follows:

1. Cloud seeding operations at the Jatiluhur Reservoir are best conducted during the transition season (Ref Figure 3.3). Operations during this season aim to maximize the reservoir's water storage to ensure an adequate water supply during the dry season. Conversely, it aims to accelerate rainfall before the rainy season arrives, intending to replenish the water supply at the Jatiluhur Reservoir.
2. The National Weather Modification Technology Center at the Agency for the Assessment and Application of Technology (TMC Lab BRIN) should further develop WMT, especially the utilization of flare-based WMT, and the addition of supporting equipment or instruments (cloud and atmospheric instruments), considering that Water from WMT provides significant benefits to the economy.
3. The government should implement WMT operations with precise timing in the Citarum River Basin (Jatiluhur Reservoir) to maintain water supply for power generation, drinking water, industrial water, and agriculture.

4. A more in-depth examination is needed to find the reasons why the PDAM variable (X_2) and the variable (X_4) have a non-significant P-Value (ANOVA) towards the GDP of the Electricity and Water Supply Sector, while both variables have a strong correlation with the GDP of the Electricity and Water Supply Sector.
5. Research on the analysis of the chain effect (multiplier effect) on a broader economic sector from the Water generated from WMT.

References

- Anto Dayan (1973), Pengantar Metode Statistik Jilid II (Cetakan I), LP3ES, Jakarta 1973, Hal 325-341.
- Anom Prasetyo, Bambang L. Widjiantoro, Aulia MT Nasution (2019), Overview of Ground-Based Generator Towers as Cloud Seeding Facilities to Optimize Water Resources in the Larona Basin, Department of Physics Engineering, ITS Surabaya, Indonesia.
- Anam Prasetyo (2019), Kajian Distribusi dan Lokasi Menara Ground Base Generator sebagai Sarana Cloud Seeding guna Optimalisasi Pengelolaan Sumber Daya Air di DAS Larona, Thesis TF185471, Departemen Teknik Fisika, Fakultas Teknologi Industri, ITS Surabaya.
- Anom Prasetyo, Abu Ashar (2022), Operation and Water Management of Dam Cascade System, Energy and Environment Department PT. Vale Indonesia.
- Balai Besar Teknologi Modifikasi Cuaca Badan Pengkajian Dan Penerapan Teknologi (2019), FEASIBILITY STUDY, Penguatan Armada Pesawat TEKNOLOGI MODIFIKASI CUACA Untuk Penanggulangan Bencana Hidrometeorologi, Peningkatan Produksi Pertanian dan Pengelolaan Sumberdaya Air.
- Background Report 4, Economic impacts of cloud seeding Hydro Tasmania and West Coast Council Australia, SGS Economics and Planning, April 2008.
- Christina Nebel, Cloud Seeding Operations Supervisor, Cloud Seeding in Tasmania 1964 to today, Hydro Tasmania, Australia, ASL Presentation – 1st July 2008.
- Damodar N. Gujarati (2006), Dasar Dasar Ekonometrika, United States Military Academy, West Point, Penerbit Erlangga, Jakarta.
- Donald R. Cooper, Pamela S. Schindler (2006), Metode Riset Bisnis, Volume 2, Penerbit Media Global Edukasi, Jakarta, McGrawHill.
- Jeffrey M. Wooldridge, Introductory Econometrics A Modern Approach, Sixth Edition, Michigan State University, (2015).

J. Supranto, Ekonometrik, (Buku I), Lembaga Penerbit FE UI, Jakarta 1983, Hal 97-98.

Lind, Marchal, Wathen (2007), Teknik-teknik Statistika dalam Bisnis dan Ekonomi, Penerbit Salemba Empat, McGrawHill.

Michael P. Todaro (1983), Pembangunan Ekonomi di Dunia Ketiga, Penerbit Ghalia Indonesia

Nachrowi D Nachrowi, Hardius Usman (2006), Ekonometrika Untuk Analisis Ekonomi dan Keuangan, Lembaga Penerbit Fakultas Ekonomi Universitas Indonesia.

Nazarullah Ibny (2022), Prediksi Kegagalan Komponen pada Pesawat A320-200 Dengan Menggunakan Metode Regresi, Thesis BM185407, SIMT ITS Surabaya.

Suliyanto (2011), Ekonometrika Terapan, Teori dan Aplikasi dengan SPSS, Penerbit Andi Yogyakarta.

Sadono Sukirno (1981), Pengantar Teori Makro Ekonomi, Lembaga Penerbit FE UI, Jakarta 1989.

Terrence W. Krauss (2005), Recent Advances in Cold and Warm Cloud Rain Enhancement Methods, Weather Modification Inc. Fargo, North Dakota, USA Red Deer, Alberta, Canada, International Workshop on Weather Modification and Cloud Seeding Technology for Rain Water Enhancement Hyderabad, India January 27, 2005

Keyne Robert, Economic growth, University of Washinton DC, 1990.

https://en.wikipedia.org/wiki/Charles_Hatfield

https://en-m-wikipedia-org.translate.goog/wiki/Cloud_seeding?_x_tr_sl=en&_x_tr_tl=id&_x_tr_hl=id&_x_tr_pto=tc

<https://www.antaranews.com/berita/112273/pembukaan-olimpiade-bebas-hujan-berkat-1000-roket>