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PREFACE

We would like to present, with great pleasure, the first issue of Matrix: Jurnal Manajemen Teknologi dan Informatika in Volume 13, Number 3, 2023. This journal is under the management of Scientific Publication, Research and Community Service Center, Politeknik Negeri Bali and is devoted to cover the field of technology and informatics management including managing the rapid changes in information technology, emerging advances in electrical and electronics and new applications, implications of digital convergence and growth of electronics technology, and project management in electrical, mechanical or civil engineering. The scientific articles published in this edition were written by researchers from Universitas Dinamika, Politeknik Negeri Jember, Universitas Amikom Yogyakarta, Politeknik Negeri Malang, Universitas Kahuripan Kediri, Universitas Islam Negeri Sunan Kalijaga Yogyakarta, and Politeknik Negeri Bali. Articles in this issue cover topics in the field of Lighter as Flame Control and Temperature Control in Milk Pasteurization System, Analysis Distribution and Segmentation of Micro, Small, and Medium Enterprises (MSMEs) in Kediri Residency Area: Implications for Local Economic Development, Analysis and Design of UI and UX of the Taring Application Using Goal-Directed Design and Cognitive Walkthrough Methods, The Impact of ChatGPT on the Critical Thinking Ability of UIN Sunan Kalijaga Students, and Modelling Spatio-Temporal Energy Consumption from Nighttime Radiance Satellite Dataset. Finally, we would like to thank reviewers for their efforts and hard work in conducting series of review phase thoroughly based on their expertise. It is our hope that the work of the authors in this issue will be a valuable resource for other researchers and will stimulate further research into the vibrant area of technology and information management in specific, and engineering in general.

Politeknik Negeri Bali, 29 November 2023

Editor-in-chief

Gusti Nyoman Ayu Sukerti, S.S., M.Hum.

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Lighter as flame control and temperature control in milk pasteurization system

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Abstract: Milk pasteurization involves heating milk at a specific temperature below its boiling point as a method to keep the resulting dairy product retaining the shape and taste characteristics of fresh milk. In several experiments, the use of fuzzy control systems has been tested to regulate the temperature in the milk pasteurization process and to time the ignition of the stove flame. However, this fuzzy approach still causes the system to give an unstable response and irregular stove flame. In order to study milk pasteurization, the Low Temperature Long Time (LTLT) method is used which is implemented automatically through a PID control system. This method serves to maintain nutritional quality by keeping the pasteurization temperature at a setpoint of 62°C. This control involves the use of servo actuators and electric lighters that are automatically regulated with the help of flame sensors. The flame sensor detects the presence of flame and ensures that the flame remains lit throughout the pasteurization process. At the end of the process, the flame sensor plays a role in breaking the flame by setting a certain threshold. This sensor operates within 10 CM of the flame source and will produce an analog output with a maximum value of 4000 when the flame is lit. When the flame is extinguished, the analog output of the sensor will reach a value of 4095. Testing of the milk pasteurization automation system is given a value for each PID resulting from the value of Kp = 31.8, Ki = 115.6, Kd = 4.4 and obtained a rise time value of 0.39 minutes, 0.61%, settling min of 60.88, and settling max of 62.38.

Keywords: DS18B20 sensors, lighter, milk, pasteurization, PIDs

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Introduction

To meet the community's nutritional needs for proper nutrition, it is undeniable that milk is one of the elements the community needs. In general, milk is essential as a source of animal protein for human health and growth due to its high nutritional content. Almost all the substances contained in milk are needed by humans, including proteins: fats, carbohydrates, minerals, and vitamins [1]. Animal protein processed products have better nutritional value than protein products from plants (vegetables) [2]. Milk also contains antibodies called immunoglobulins, which are good for the immune system of a growing child [3]. During the productive age of humans 15-65 years, the need for cow's milk encourages rapid growth and strengthens bones, preventing osteoporosis in old age. Osteoporosis is a disease characterized by low bone mass and structural damage to bone tissue, causing bone fragility and increasing the risk of fractures. Bone tissue is formed during puberty, so milk is very suitable for consumption during puberty [4]. The milk's nutrients include protein, calcium, vitamin A, vitamin B, vitamin D, amino acids, calories, fat, phosphorus, iodine, zinc, iron, copper, magnesium, vitamin E, and thiamine [5]. Milk contains high nutrition, which contains water (87.5%), carbohydrates (4.5%), fat (3.6%), protein (3.4%), and minerals (0.75%).

So that lactic acid bacteria do not attack and contaminate, it is necessary to do processing so that the milk does not spoil quickly. Although cow's milk has high nutritional value, it is susceptible to bacteria which causes cow's milk to have a short shelf life and spoil easily. One way to optimize milk is to use pasteurization and heating to prevent damage to the milk. Pasteurization

of milk is a way of preserving milk by heating it to a certain temperature below the boiling point of milk so that the processed product retains its shape and taste of fresh milk [6]. In several experiments, a fuzzy control system has been applied to regulate milk temperature in the pasteurizer and stove lighter with a timer. However, the fuzzy method still causes the system response to be unstable, and the flame of the stove lighter is uncertain [7].

Previous research [8] showed a model of an automatic milk pasteurization system with the ultimate goal of controlling the temperature value on the output side, (t), in such a way that the output value is at the LTLT pasteurization temperature, namely at a temperature of $y(t) \approx 64$ °C. The servo motor is a load (plant) that functions as a regulator of the size of the flame in the heating furnace to increase or decrease the milk temperature. In that study, there was no flame sensor so the system could not know the on and off of the fire in the heating system. Whereas in this research a flame sensor is added to detect the flame in the heating system. With the flame sensor when the condition must cool the temperature of the milk the fire on the heater must be turned off by turning the servo to the minimum position and the flame sensor is used to detect the extinguishing of the fire. And vice versa if from the position of the fire extinguished the PID control system wants to raise the temperature then the heating system must be turned on. The step taken to turn on the heating fire is to rotate the servo to open the gas and then light the fire with a match when lighting the fire a flame sensor is used to detect the success of the match in lighting the fire. If the fire is detected to be unlit, it must light the match again until the fire is confirmed to be lit. That is the novelty of this system compared to the system from previous research.

For this reason, referring to the data presented, the researcher wants to improve this milk pasteurization system by applying PID control and flame sensor, to achieve a more stable control level. In its application concept, PID control works in a fairly simple way, where the error value is used as system feedback to determine the next control value.

Methodology

Pasteurization

Pasteurization is a high-temperature heating system designed to kill bacteria, microbes, and some microorganisms while minimizing damage to proteins. There are two pasteurization methods, namely Low-Temperature Long Time (LTLT) at 62°C for 30 minutes and High-Temperature Short Time (HTST) at 72°C for 15 seconds. The next pasteurization process is a cooling process with a temperature of 4°C to extend the shelf life of the milk. In the pasteurization of milk, pasteurization is used to destroy pathogenic microorganisms [8].

Proportional Integral Derivative Control (PID Control)

PID (Proportional Integral Derivative) is a regulatory system used to control an instrument system by utilizing feedback from the system. The PID controller consists of three main components namely Proportional, Integral, and Derivative. These three components can work together or separately, depending on the desired response of the device. In designing a PID control system, the goal is to adjust the parameters P, I, or D so that the system output response to a particular input is as desired. PID is usually used in closed-loop control systems as shown in Figure 1.

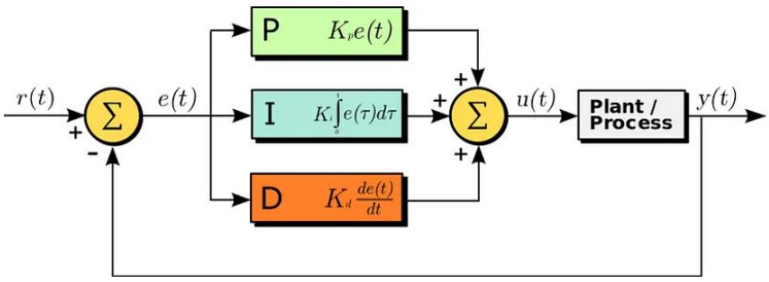


Figure 1. PID Control System

The PID controller equation is:

$$r(t) = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{de(t)}{dt} \quad (1)$$

Description:
Kp = Proportional gain, tuning parameters
Ki = Integral Gain, tuning parameters
Kd = Derivative Gain, tuning parameters
e = Error
t = time
τ = Variabel integrasi; nilainya diambil dari waktu nol sampai *t*.

Ziegler-Nichols Method

The Ziegler-Nichols method consists of the first method and the second method. The first method has two parameters, namely L and T, then is used to find the values of Kp, Ki, and Kd. These two parameters are obtained from the inflection point of the S curve, which is obtained from the tangents to the x and y axes. The second method also has two parameters, namely Ku and Tu. Ku is the critical value of Kp when the system is properly oscillating. Tu is the distance between the crests of the wave in seconds. The equations for finding Kp, Ki, and Kd values based on L and T parameter values are shown in Table 1. The equations for finding Kp, Ki, and Kd values based on Ku and Tu parameter values are shown in Table 2 [9].

Table 1. Kp, Ti, and Td values based on L and T values

Controller	Kp	Ti	Td
P	T/L	∞	0
PI	0.9 T/L	L/0.3	0
PID	1.2 T/L	2L	0.5L

Table 2. Kp, Ti, and Td values based on Ku and Tu values

Controller	Kp	Ti	Td
P	Ku/2	-	-
PI	2Ku/5	4Tu/5	-
PID	3Ku/5	Tu/2	3Tu/25

ESP32 DEVKIT V1

The ESP32 module is a compact prototyping microcontroller that can be easily programmed through the Arduino IDE. This module was introduced and developed by Espressive Systems. The ESP32 chip has been equipped with a WiFi module that supports the development of Internet of Things (IoT) applications. One of the application systems is ESP32. The ESP32 DEVKIT V1 has two 32-bit processor cores that make it more advanced compared to the ESP8266 series. The advantage of the ESP32 DEVKIT V1 microcontroller is a low-cost, low-power, system-integrated microcontroller chip with Bluetooth dual mode and power-saving features that make the ESP32 DEVKIT V1 microcontroller compatible with mobile devices [10].

DS18B20 Temperature Sensor

DS18B20 is a type of temperature sensor that produces a digital signal as its output. One of the advantages of this sensor is its high level of accuracy, reaching 0.5°C over a temperature range of -10°C to +85°C. Temperature sensors generally require an Analog-to-Digital Converter (ADC) and several port pins on the microcontroller to communicate, but the DS18B20 does not depend on ADC and only requires one cable to connect to the microcontroller. The ground and Vdd pins are connected to Vcc, while the DQ pin is connected to the microcontroller I/O pins. The data output is digital data with an accuracy value of 0.5°C [11].

Flame Sensor

A flame sensor is a device that detects the presence of flame and smoke using an infrared transducer. It can detect wavelengths between 760 nm to 1100 nm, which is used to identify flames. The structure of this sensor consists of four important pins: VCC, GND, AO (Analog Output), and DO (Digital Output). The AO pin is responsible for providing an analog output that can give an indication of the position or direction of the flame, as it has a reading angle of 60°. This sensor has 5 LEDs (Light Emitting Diode) which are useful as detection indicators. The flame sensor is a sensor that can detect fire and change its representation to an analog quantity. The parameter measured by the flame sensor is temperature, while the temperature measured by the flame sensor is the wavelength of light [12].

MG995 Servos

A servo motor is an electromechanical component designed as an actuator in a system. It generates torque and speed based on the applied electric current and voltage. Servo motors are commonly used in closed control systems, which allow setting the speed and acceleration of the motor with a high degree of accuracy. In contrast to DC motors, servo motors do not move continuously. They only move at a certain angle and stop at that angle. There are two types of servo motors, namely standard servo motors and continuous servo motors. A continuous servo motor can move a full 360^{O}, but a normal servo motor can only move half a turn, ie. 180^{O} [13].

DC Motors

A direct current motor (Direct Current) is a device that converts electrical energy into kinetic energy or motion. DC motor speed is around 3000 to 8000 RPM (revolutions per minute) with an operating voltage of about 1.5 to 24 volts. A DC motor uses the concept of an electromagnet for its motion [14].

Relay

A relay is an electrical device that functions as an electrically operated switch. This component consists of two main parts, namely the electromagnet coil and mechanical (a set of switch contacts). The working principle of the relay is to move the switch contacts through an electromagnet so that a small electric current can control the flow of electricity that has a higher voltage.

LCD (Liquid Crystal Display) 16x2

LCD (Liquid Crystal Display) is a display device that uses liquid crystal as its main element, which is capable of displaying characters and images. Inside the LCD there is a microcontroller in charge of controlling the display of characters on the screen. LCD screens have been used in various fields, such as electronic devices such as televisions, calculators, or computer screens. LCD applications use a dot matrix LCD with a 2x16 character count. The LCD screen functions as a display device which is then used to indicate the working status of a tool [15].

System Block Diagram

Figure 2 below is a hardware design with input in the form of DS18B20 temperature sensor values and Flame Sensor. The input will be displayed through the LCD (Liquid Crystal Disk) and then processed by the ESP32 DEVKIT V1 microcontroller system and sent a command to the servo as an actuator on the gas stove to light the stove using an electric lighter through a relay so that heating occurs.

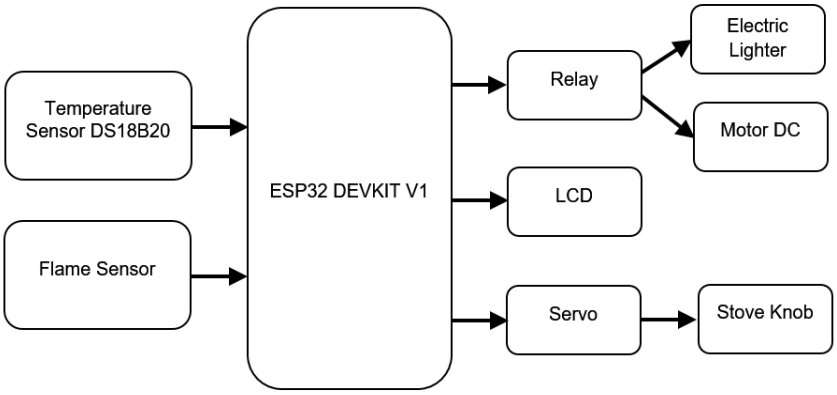


Figure 2. System Block Diagram

DS18B20 Temperature Sensor Design

Figure 3 below is a DS18B20 temperature sensor design used to read temperature values in the range of -10 to +85 degrees Celsius. This sensor can work with serial communication with one data line and one ground or what is commonly called one wire. In the DS18B20 sensor, there are 3 pins used, namely the data signal line, ground, and 5 Volt VCC power supply line. VCC and signal data pins are connected to the ESP32 DEVKIT V1 microcontroller, but a pull-up resistor of 4.7k is added.

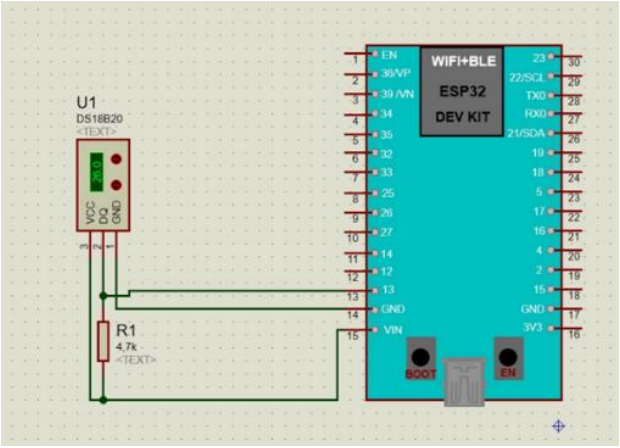


Figure 3. DS18B20 Temperature Sensor Design

Flame Sensor Design

The image below shows the design of the flame sensor circuit. This fire sensor has four pins, namely VCC, GND, AO (analog output), and DO (digital output). The AO pin can detect the location of the fire because the reading angle is 60°. The analog pin input voltage is 5V, and the digital pin is 3.3V. When the VCC voltage at the analog output of this sensor is less than 3.3V, the fire detection becomes unstable, and an error occurs at the output. In a milk pasteurization system, the analog output is used to set the threshold value on the stove fire. Figure 4 below describes the Fire Sensor Design.

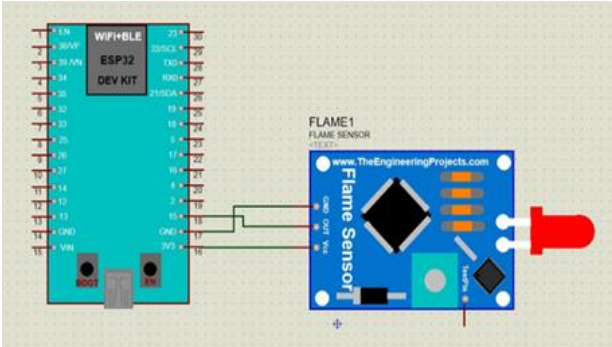
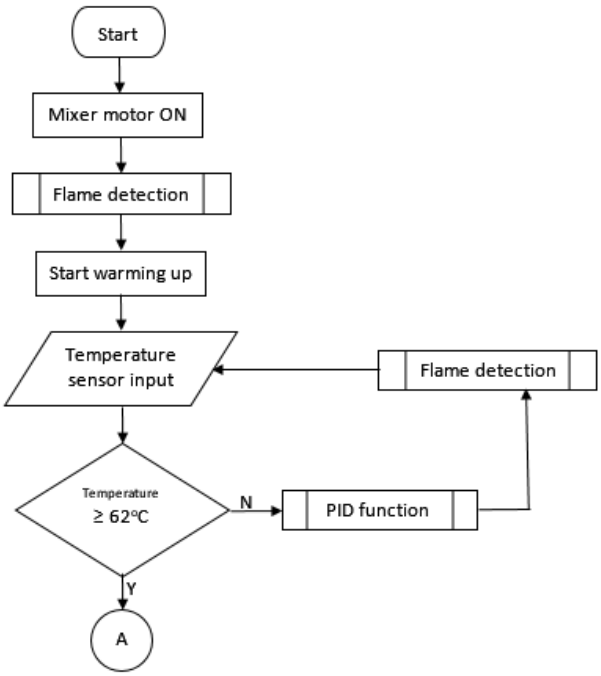


Figure 4. Flame Sensor Design

Overall System Flowchart



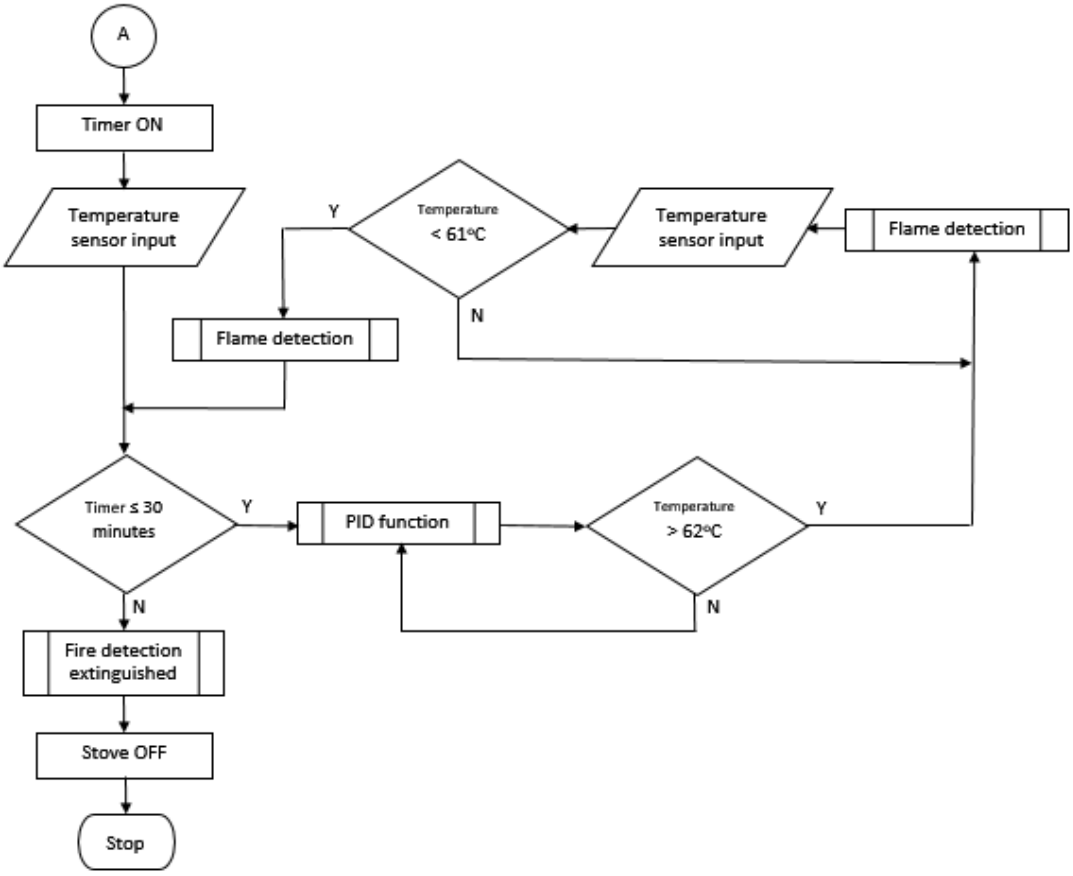


Figure 5. Overall System Flowchart

Judging from Figure 5 that has been presented, it can be explained that when the system is activated, the stirring motor will operate. After that, the lighter will be turned on to ignite the flame. The next process involves the flame sensor which will detect the presence of the flame. In the milk pasteurization stage, the temperature sensor detects the temperature of the milk being cooked. If the detected milk temperature value is still below 61 degrees Celsius, the microcontroller will control the flame level on the stove by moving the servo that regulates the flame control knob using PID logic. After the milk temperature reaches above 61 degrees Celsius, the timer on the stove will be activated to start the cooking process with a duration of 30 minutes. During this cooking stage, the temperature sensor continues to monitor to keep the temperature of the cooked milk stable, so that the milk can be cooked with the right consistency. The sensor instructs the microcontroller to control the flame intensity by moving the servo connected to the stove's flame control knob. After 30 minutes have passed, the timer will stop and the microcontroller will turn off the stove to end the milk pasteurization process.

PID System Flowchart

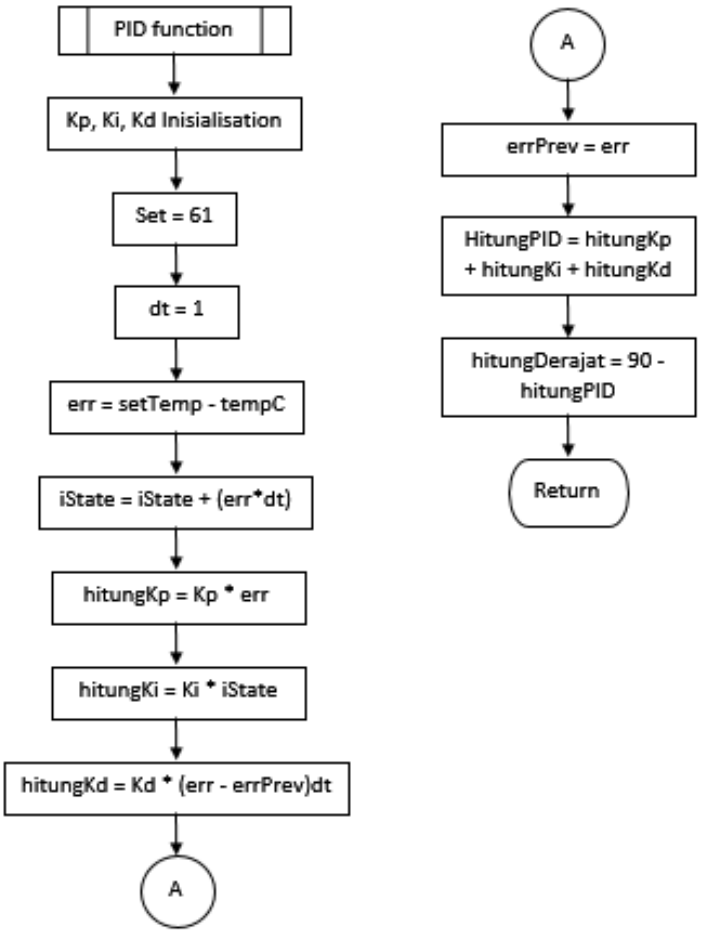


Figure 6. PID System Flowchart

The PID control stage is illustrated in Figure 6. At the start of the process, initial values are initialized for the Kp, Ki, and Kd parameters. The desired temperature setpoint is set at 62°C, and the variable dt representing the time change is set at a value of 6. Before the PID formula can be applied, calculations are performed for the integral error value stored in the variable 'iState'. Initially, the 'iState' value is initialized with zero, assuming that the integral process starts at time 0. The 'iState' value is updated by adding the previous 'iState' value with the latest error value (variable 'err'). The next step in the PID system is to calculate the PID value itself, by calculating the Kp, Ki, and Kd values separately. This calculation involves the following formulas: Kp = Kp * err, Ki = Ki * iState, and Kd = Kd * (err - errPrev)/dt.

Mechanical Design

This section describes the design of the installation of components consisting of a DS18B20 temperature sensor, flame sensor, servo motor, and DC motor, and the placement of the ESP32 DEVKIT V1 microcontroller so that it can run as desired. Figure 7 below is a mechanical design for the milk pasteurization system:

Figure 7. Mechanical Design of the System

Results and Discussions

Results

DS18B20 Temperature Sensor Test Results

This test is carried out to display sensor readings and process status on the pasteurization device. This test aims to ensure that the 16x2 LCD screen functions properly and is able to display data sent by the microcontroller during the process.

Table 3. DS18B20 sensor test results

No	DS18B20 Temperature Sensor (in degrees)	Digital Thermometer (in degrees)	Measurement Difference (in degrees)	Errors (in %)
1	29.95	29.41	0.54	1.84
2	30.76	30.70	0.06	0.20
3	31.21	31.40	0.19	0.61
4	36.21	35.20	1.01	2.87
5	30.61	29.80	0.81	2.72
6	31.85	31.00	0.85	2.74
7	30.13	30.80	0.67	2.18
8	30.13	29.50	0.63	2.14
9	33.31	33.60	0.29	0.86
10	32.82	32.10	0.72	2.24
11	32.82	32.60	0.22	0.67
12	34.76	34.60	0.16	0.46
13	38.61	38.10	0.51	1.34
14	40.81	40.80	0.01	0.02
15	43.39	43.30	0.09	0.21
16	45.82	45.10	0.72	1.60
17	47.81	47.00	0.81	1.72
18	49.89	49.60	0.29	0.58
19	53.89	52.80	1.09	2.06
20	56.20	56.50	0.30	0.53
21	57.41	57.50	0.09	0.16
22	59.20	59.10	0.10	0.17
23	62.39	61.80	0.59	0.95
24	63.17	63.60	0.43	0.68
25	61.14	61.20	0.06	0.10
26	60.95	60.80	0.15	0.25
27	60.70	60.50	0.20	0.33
28	60.39	59.50	0.89	1.50
29	60.01	60.50	0.49	0.81

No	DS18B20 Temperature Sensor (in degrees)	Digital Thermometer (in degrees)	Measurement Difference (in degrees)	Errors (in %)
30	59.76	59.50	0.26	0.44

Flame Sensor Test Results

The next step in the test is to check the performance of the flame sensor as a stove lighter detector in the milk pasteurization system. This test is intended to verify whether the flame sensor is able to detect the presence of fire through analog output and produce output data that can be displayed on the 16x2 LCD screen.

Table 4. Testing Results of Flame Sensors (Flame Sensors)

Distance (in cm)	Flame sensor analog output	Description	Accuracy Percentage (in %)
10	3823	Succeed	100
	3547	Succeed	
	3623	Succeed	
	3551	Succeed	
	3509	Succeed	
15	3959	Fail	40
	4071	Fail	
	4027	Fail	
	4079	Succeed	
	3775	Succeed	
20	3791	Succeed	20
	4079	Fail	
	4095	Fail	
	4095	Fail	
	4095	Fail	
25	4095	Fail	0
	4095	Fail	
	4095	Fail	
	4095	Fail	
	4095	Fail	
30	4095	Fail	0
	4095	Fail	
	4095	Fail	
	4095	Fail	
	4095	Fail	
35	4095	Fail	0
	4095	Fail	
	4095	Fail	
	4095	Fail	
	4095	Fail	
40	4095	Fail	0
	4095	Fail	
	4095	Fail	
	4095	Fail	
	4095	Fail	
45	4095	Fail	0
	4095	Fail	
	4095	Fail	

Distance (in cm)	Flame sensor analog output	Description	Accuracy Percentage (in %)
	4095	Fail	
	4095	Fail	
50	4095	Fail	0
	4095	Fail	
	4095	Fail	
	4095	Fail	
	4095	Fail	

Further testing was done with an approach where the flame sensor was placed in a fixed position at a distance of 10 CM from the stove flame. The results of the test were recorded as follows:

Table 5. Testing the Flame Sensor at a Distance of 10 cm

No	Time (in minutes)	Distance (in cm)	Value Analog Output	Description
1	01:00	10	3824	Succeed
2	02:00	10	3548	Succeed
3	03:00	10	3624	Succeed
4	04:00	10	3552	Succeed
5	05:00	10	3510	Succeed
6	06:00	10	3384	Succeed
7	07:00	10	3264	Succeed
8	08:00	10	3478	Succeed
9	09:00	10	3456	Succeed
10	10:00	10	3404	Succeed
11	11:00	10	3284	Succeed
12	12:00	10	3428	Succeed
13	13:00	10	3424	Succeed
14	14:00	10	3380	Succeed
15	15:00	10	3392	Succeed
16	16:00	10	3384	Succeed
17	17:00	10	3408	Succeed
18	18:00	10	3368	Succeed
19	19:00	10	3262	Succeed
20	20:00	10	3372	Succeed
21	21:00	10	3280	Succeed
22	22:00	10	3380	Succeed
23	23:00	10	3352	Succeed
24	24:00	10	3328	Succeed
25	25:00	10	3452	Succeed
26	26:00	10	3352	Succeed
27	27:00	10	3282	Succeed
28	28:00	10	3528	Succeed
29	29:00	10	3347	Succeed
30	30:00	10	3420	Succeed

MG995 Servo Trial Results

The following test results reflect the evaluation of the MG995 servo motor with rotation angle as a comparison applied as a stove knob control device in the temperature control system. This test is intended to assess whether the MG995 servo can function properly by displaying its output results through the 16x2 LCD screen.

Table 6. MG995 Servo Trial

No	Servo Degrees (in degrees)	Protractor (in degrees)	Measurement Difference (in degrees)	Accuracy Percentage
1	10	10	0	0 %
2	10	10	0	0 %
3	10	10.1	0.1	0.99 %
4	10	10	0	0 %
5	10	10	0	0 %
6	30	29.9	0.1	0.33 %
7	30	29	1	3.44 %
8	30	30	0	0 %
9	30	30	0	0 %
10	30	30	0	0 %
11	40	40	0	0 %
12	40	40	0	0 %
13	40	40	0	0 %
14	40	40	0	0 %
15	40	40	0	0%
16	45	45	0	0 %
17	45	45.1	0.1	0.22 %
18	45	45	0	0 %
19	45	45	0	0 %
20	45	45.1	0.1	0.22 %
21	60	60	0	0 %
22	60	60	0	0 %
23	60	60	0	0 %
24	60	60	0	0 %
25	60	60	0	0 %
26	90	90	0	0 %
27	90	90	0	0 %
28	90	90	0	0 %
29	90	90	0	0 %

Overall System Test Results

In this test, tests were carried out for the entire system that has been integrated on the ESP32 DEVKIT V1 Microcontroller. This test aims to test the function of the entire system which includes temperature settings, fire sensors, servo motors, electric lighters, and stirring motors in the context of milk pasteurization. In the milk pasteurization test, the Low Temperature Long Time (LTLT) method is used which requires the temperature to reach 62°C for 30 minutes during the pasteurization process. From the temperature value, it can be observed how the servo motor responds to reach the balance point by utilizing the Kp, Ki, and Kd parameters generated through the Ziegler-Nichols 2 method. In this test, Kp, Ki, and Kd have been given certain values, namely Kp = 31.8, Ki = 115.6, and Kd = 4.4. Furthermore, the test was conducted by setting the temperature at various different levels, with the temperature setpoint fixed at 61°C.

Table 7. Testing the Whole System

No	Temperature	Fire sensor analog results	State of the electric lighter	Stove state	Servo degree
1	62.19	4095	0	0	0 degrees
2	61.80	4095	0	0	0 degrees

No	Temperature	Fire sensor analog results	State of the electric lighter	Stove state	Servo degree
3	61.38	4095	0	0	0 degrees
4	60.88	3527	1	1	90 degrees
5	61.13	3875	0	0	90 degrees
6	62.38	4095	0	0	0 degrees
7	62.13	4095	0	0	0 degrees
8	61.80	4095	0	0	0 degrees
9	61.55	4095	0	0	0 degrees
10	61.34	4095	0	0	0 degrees
11	61.19	4095	0	0	0 degrees
12	61.13	4095	0	0	0 degrees
13	61.06	4095	0	0	0 degrees
14	60.94	4095	1	1	90 degrees
15	61.19	3356	0	1	90 degrees
16	61.50	3419	0	1	90 degrees
17	61.94	3650	0	1	90 degrees
18	62.00	4095	0	0	0 degrees
19	61.88	4095	0	0	0 degrees
20	61.55	4095	0	0	0 degrees
21	61.34	4095	0	0	0 degrees
22	61.13	4095	0	0	0 degrees
23	61.06	4095	0	0	0 degrees
24	60.88	4095	1	1	90 degrees
25	61.34	3231	0	1	90 degrees
26	61.50	3547	0	1	90 degrees
27	61.94	3854	0	1	90 degrees
28	62.00	4095	0	0	0 degrees
29	62.13	4095	0	0	0 degrees
30	61.88	3991	0	0	0 degrees

Information:
1. Electric lighter status = 0, which means the lighter does not work (does not ignite).
2. Stove status = 0, which means the stove is off.
3. Electric lighter status = 1, which means the lighter is working (igniting).
4. Stove status = 1, which means the stove is on.

Discussions

In the experiments shown in Table 3 using the DS18B20 temperature sensor and a thermometer for comparison, it can be seen that there is a difference in the value of 0.44°C and an average percentage error of about 0.01%. From the experimental results, it can be concluded that the DS18B20 sensor is reliable in the milk pasteurization control system.

From Table 4 listed above, it can be stated that the flame sensor test results show that the reading success rate is 100% at a distance of 10 CM. At a distance of 15 CM, the success rate is 40%, while at a distance of 20 CM, the success rate is 20%. However, for distances between 25 CM to 50 CM, the accuracy percentage reaches 0%, which indicates that at these distances, the analog output of the flame sensor cannot detect the presence of fire.

In Table 5 listed above, the test was carried out by placing the flame sensor in a fixed position at the same distance in each experiment, which is 10 CM from the stove flame. The results of the test showed a success percentage of 100%, where the flame sensor was able to detect the analog output value of the flame for 30 minutes.

Based on Table 6 above, it can be concluded that the average angle difference between the servo motor and the arc angle is about 0.04°, with an average error percentage of about 0.17%.

Table 7 shows the results of testing the milk pasteurization control system over 30 minutes by applying the Low-Temperature Long Time (LTLT) method. Data was taken at one-minute intervals to record the temperature values during the pasteurization operation. From the experiments on the milk pasteurization system for 30 minutes, the results were obtained for a rise time of about 0.39 minutes, less than 1% error value (overshoot) at a settling time of about 60.88, and a maximum settling value of 62.38.

Conclusion

The conclusions based on the research conducted are: (1) In the actuator test using the MG995 servo, the servo-operated well. When the temperature reaches the setpoint value of 62°C, the servo will rotate at an angle of 0°; (2) From testing the DS18B20 temperature sensor, the average measurement difference is 0.44°C and the average percentage error is 0.011%; (3) In testing the milk pasteurization automation system, the PID parameters that have been generated with values of Kp = 31.8, Ki = 115.6, and Kd = 4.4 are applied. The test results show a rise time value of 0.39 minutes, an overshoot percentage of 0.61%, a minimum settling time of 60.88, and a maximum settling time of 62.38; (4) In testing the activation of the stove using an electric lighter and flame sensor, the threshold value imposed in the range of 1000 to 4000 for the analog output is used to detect the flame at a fixed distance of 10 CM. The purpose of this test is to ensure that the stove ignites successfully at a percentage of 100% when the flame sensor detects the flame; (5) In testing the electric lighter and flame sensor, it can be concluded that the time required to light the stove when the electric lighter is on is 2 seconds, and when the stove is lit, the electric lighter will turn off within 1 second.

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Analysis distribution and segmentation of micro, small, and medium enterprises (MSMEs) in Kediri Residency Area: implications for local economic development

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Abstract: Micro, Small, and Medium Enterprises (MSMEs) are critical drivers of economic growth, especially in developing nations like Indonesia. This study focuses on the specific case of Kediri Residency, using 2018 data from the Central Bureau of Statistics of East Java Province to uncover insights for sustainable local economic development. Our methodology involved data acquisition, parsing, mining, filtering, and representation/ interaction. This process yielded a dataset of 168 data points, providing a nuanced view of MSMEs in Kediri Residency. Our analysis highlighted significant trends. Kediri Regency, for example, excelled in the Food and Beverage Industry (270 MSMEs) and Wood Industry (260 MSMEs). Blitar Regency thrived in the Wood Industry (235 MSMEs) and the Food and Beverage Industry (230 MSMEs). Tulungagung Regency showed strength in the Wood Industry (219 MSMEs). These findings have strategic implications for local economic development, such as sectoral strengthening, enhancing competitiveness, forming business clusters, and tailoring policies to MSMEs' unique needs. Comparing Kediri City to Kediri Regency and Blitar City to Blitar Regency revealed disparities and opportunities, highlighting the role of local policies and infrastructure in MSME development. In conclusion, our research provides actionable insights to formulate policies, develop infrastructure, improve financing access, and enhance skills training programs. These actions will catalyze MSME growth, promoting regional economic development and stability.

Keywords: data analysis, local economic development, local governments, MSMEs report

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Introduction

Micro, Small, and Medium Enterprises (MSMEs) play a vital role in the economic growth of a country [1]. These enterprises are characterized by their small-scale operations, limited resources, and relatively low workforce [2]. Despite their modest size, MSMEs make significant contributions to the national economy [3], [4], particularly in developing countries like Indonesia. In Indonesia, MSMEs make significant contributions to the national economy by creating jobs, increasing income for the population, and driving local economic development [5]. Due to their decentralized nature, MSMEs are often located in rural and semi-urban areas, where large-scale industries may have a limited presence [6]. By providing employment opportunities, MSMEs contribute to reducing unemployment rates, alleviating poverty, and promoting inclusive growth [7].

Data visualization is like a magic wand that turns raw data into clear and understandable pictures [8]. It's a way of presenting information visually, using charts, graphs, and other visual elements that make it easier for our brains to process and understand complex data [9]. In today's world, where data is abundant and often overwhelming, data visualization is a crucial tool for

making sense of it all [10]. When we look at raw data, such as long lists of numbers or rows and columns in a spreadsheet, it can be difficult to see the patterns and insights hidden within [10]. That's where data visualization comes in. It takes this raw data and transforms it into visual representations that we can easily grasp and interpret [11]. It's like putting on a pair of glasses that make everything clearer.

This highlights the importance of analyzing the distribution and segmentation of MSMEs in specific regions, such as the Kediri Residency, to gain insights into their characteristics, distribution patterns, and potential for local economic advancement with data visualization. Through the analysis of MSME distribution and segmentation, a comprehensive understanding of the conditions and prospects for local economic development in the Kediri Residency can be obtained. This knowledge will serve as a basis for local governments, financial institutions, and industry players to devise more effective and efficient strategies for economic development. By comprehending the distribution and segmentation of MSMEs, targeted initiatives can be implemented, including tailored assistance, training, market access, or financing to meet the specific needs of different MSME segments.

In the context of local economic development, the findings from the analysis of MSME distribution and segmentation in the Kediri Residency hold significant implications. These implications involve identifying opportunities to strengthen specific MSME sectors, enhancing business competitiveness in particular market segments, forming business clusters, and developing infrastructure and supportive policies that align with the unique characteristics and requirements of MSMEs in each locality.

This scientific article aims to conduct an analysis of MSME distribution and segmentation in the Kediri Residency, utilizing data from the Central Bureau of Statistics of East Java Province in 2018. The objective is to explore strategic implications that can foster sustainable local economic development. The research is expected to contribute to the formulation of policies and concrete measures that promote inclusive and sustainable MSME growth, while also bolstering long-term regional economic stability.

Methodology

The research methodology employed in the data processing process is illustrated in Figure 1. The data visualization undergoes five stages using the method presented by Ben Fry [12], namely acquire, parse, mine, filter, represent/ refine, and interact.

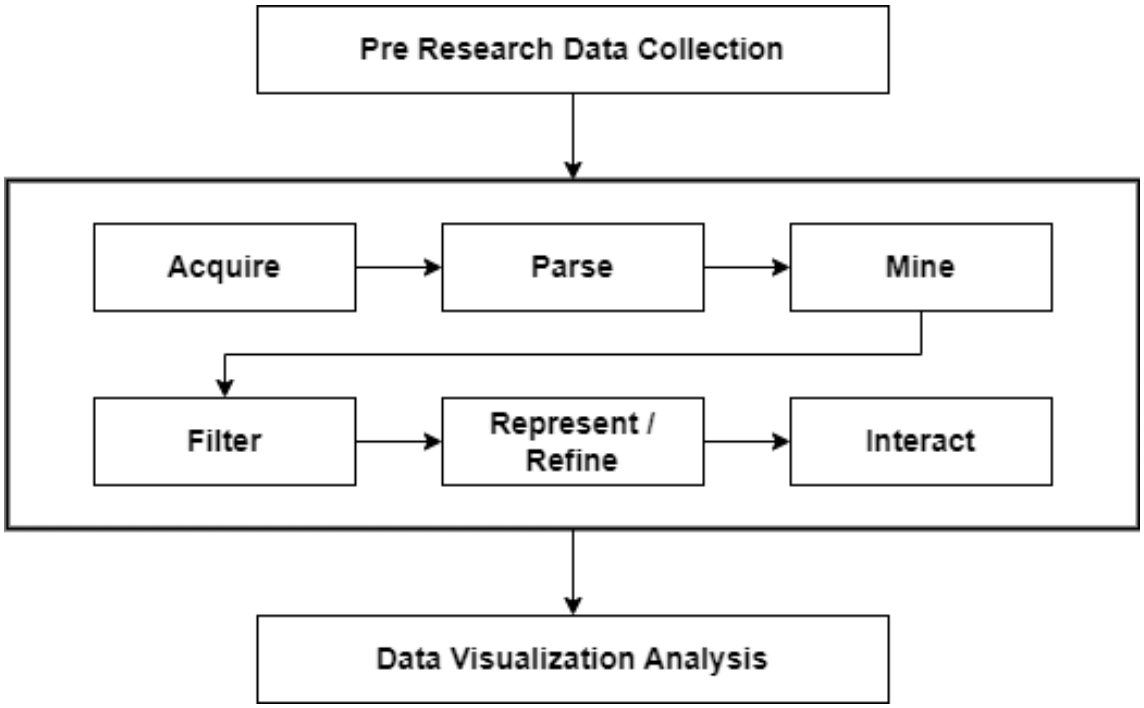

Figure 1. Data Processing Methodology

The pre-research data collection process was conducted to gather the necessary information to achieve the research objectives. After going through the pre-research process, the following steps were undertaken to acquire, parse, mine, filter, represent/refine, and interact. In simple terms, acquiring data means gathering information from different sources. It could involve conducting surveys, interviews, or accessing existing databases or online resources to collect the necessary data for analysis [13]. Parsing is like breaking down the acquired data into smaller, manageable parts [14]. It's like organizing the data and making sure it's in the right format for further analysis. This step helps in cleaning up the data and making it easier to work with. Data mining is all about exploring the data to find interesting patterns or relationships within it [15]. It's like digging deep into the data to discover valuable insights and hidden information that can help in understanding trends or making predictions. Filtering is about refining the data by removing unnecessary or irrelevant information. It's like separating the wheat from the chaff, keeping only the data that is important for the analysis. Filtering helps in focusing on the relevant aspects and getting rid of any noise that might affect the results [16]. Representing or refining the data means transforming it into visualizations or summaries that are easier to understand. It's like creating charts, graphs, or other visual representations that make it simpler to grasp the key findings and trends present in the data. Refining the data may also involve further analysis or processing to improve its quality or accuracy. Interacting with the data means being able to explore and play around with the visualizations or representations [17]. It's like having the ability to zoom in, filter out specific data points, or ask questions about the data. Interactivity allows users to have a hands-on experience with the data and gain deeper insights by actively engaging with it. After going through the process, an analysis was conducted based on the visualization of the obtained data for the scientific article.

Results and Discussions

The raw data for this study was obtained from the Central Bureau of Statistics of East Java Province, titled "Number of Villages by Existence and Type of Micro and Small Industries in Districts/Cities in 2018." The initial raw data consisted of MSME data from all districts/cities in East Java. However, since this research focuses on the MSMEs in the Kediri Residency, only the data from this specific region, including Kota Kediri, Kota Blitar, Kabupaten Kediri, Nganjuk, Tulungagung, Trenggalek, and Blitar, was used.

The available data consists of MSME data for the year 2018, with a data structure comprising 304 rows and 3 columns with a total of 912 data. This research focuses on the MSMEs in the Kediri Residency, then we utilize 56 rows and 3 columns with a total of 168 data. The columns contain the names of the districts/cities, the types of industries, and the number of MSMEs. There are eight types of MSMEs listed in the "Type of Industries" column, including Leather Industry, Wood Industry, Precious Metals and Metal Materials Industry, Pottery/Ceramics/Stone Industry, Fabric/Textile Industry, Food and Beverage Industry, and Other Industries.

Once the data was obtained, a data pre-processing step known as data editing was performed. During this stage, the data was cleaned, ensuring that it matched the respective columns. Redundant and duplicate data were also eliminated. In this case study, we assigned a value of 0 to any empty data cells.

Using the Python programming language and charts, we were able to analyze the predominant types of industries among the residents of the Kediri Residency. This analysis allowed us to understand the relationship between the types of businesses and the potential of each area.

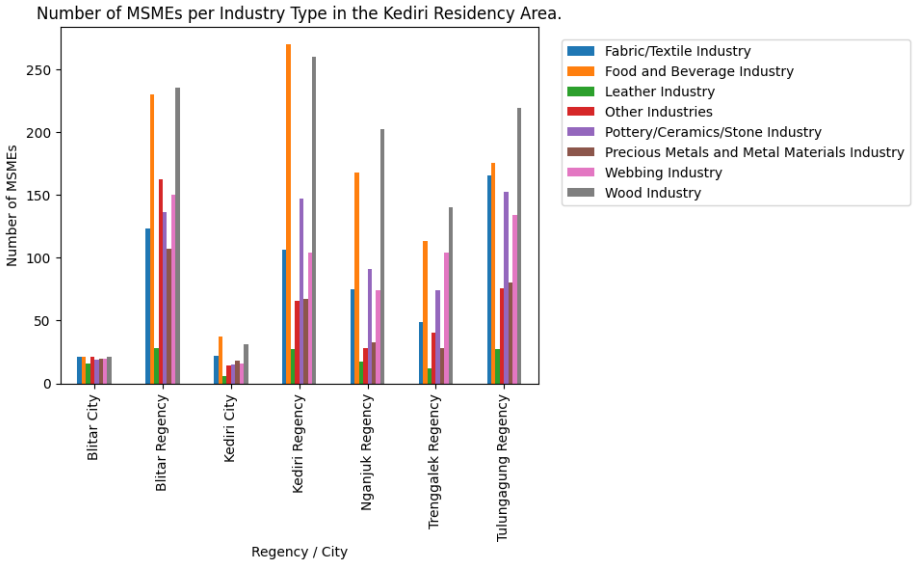

Figure 2. Data distribution of the Number of MSMEs per Industry Type in the Kediri Residency

Table 1. Top five prevalent types of businesses operating within the Kediri Residency Area

Regency/ City	Types of Industry	Number of MSMEs in 2018
Kediri Regency	Food and Beverage Industry	270
Kediri Regency	Wood Industry	260
Blitar Regency	Wood Industry	235
Blitar Regency	Food and Beverage Industry	230
Tulungagung Regency	Wood Industry	219

Figure 2 shows the data distribution of the Number of MSMEs per Industry Type in the Kediri Residency. To enhance the readability of Figure 2, a complementary Table 1 has been created, presenting the top five prevalent types of businesses operating within the Kediri Residency Area. In the provided data, several regency cities have the largest number of micro, small, and medium enterprises (MSMEs) in specific industries. In Kediri Regency, the Food and Beverage Industry has a total of 270 MSMEs, while the Wood Industry has 260 MSMEs. This indicates that Kediri Regency has significant potential in the food and beverage sector as well as the wood industry. Moving on to Blitar Regency, the Wood Industry dominates with 235 MSMEs, while the Food and Beverage Industry has 230 MSMEs. Blitar Regency also shows significant potential in the wood industry and the food and beverage sector. Lastly, in Tulungagung Regency, the Wood Industry has a total of 219 MSMEs. This signifies that the wood industry also plays an important role in the economy of Tulungagung Regency.

This data provides an overview of industries with significant numbers of micro, small, and medium enterprises in each regency city. This information can be used to identify sectors with potential for further development and as drivers of economic growth in each region.

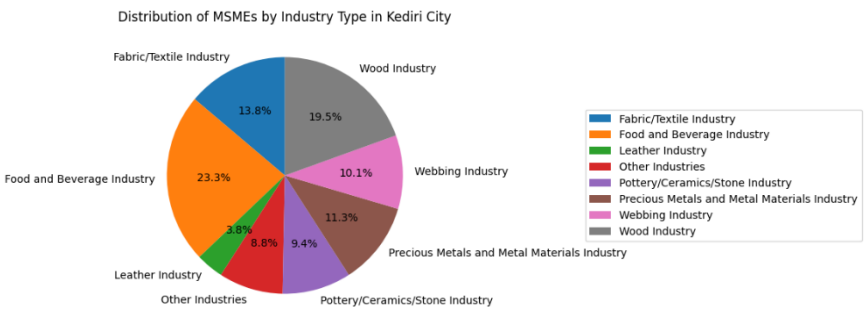

Figure 3. Distribution of MSMEs by Industry Type in Kediri City

Figure 3 shows in distribution of MSMEs by Industry Type in Kediri City. Analyzing the data provided for Kediri City, we can observe the distribution of micro, small, and medium enterprises (MSMEs) across various industries. The Fabric/Textile Industry represents 22 MSMEs, accounting for 13.8% of the total MSMEs. The Food and Beverage Industry comprises 37 MSMEs, which make up 23.3% of the MSMEs. The Leather Industry encompasses 6 MSMEs, equivalent to 3.8% of the total. Other Industries include 14 MSMEs, representing 8.8% of the MSMEs. The Pottery/Ceramics/Stone Industry consists of 15 MSMEs, accounting for 9.4% of the total. The Precious Metals and Metal Materials Industry comprises 18 MSMEs, making up 11.3% of the MSMEs. The Webbing Industry encompasses 16 MSMEs, equivalent to 10.1% of the total. Lastly, the Wood Industry consists of 31 MSMEs, representing 19.5% of the MSMEs. The cumulative number of MSMEs in Kediri City amounts to 159.

In summary, the data highlights the distribution of MSMEs across different industries in Kediri City, showcasing the diverse economic landscape of the region. The Food and Beverage Industry and the Wood Industry emerge as the prominent sectors with the highest number of MSMEs. This indicates their significance in the local economy and potential for further growth. Conversely, the Leather Industry exhibits a smaller presence, suggesting the need for targeted support and development initiatives. The data provides valuable insights for policymakers and stakeholders to formulate strategies that promote the growth and sustainability of MSMEs in Kediri City.

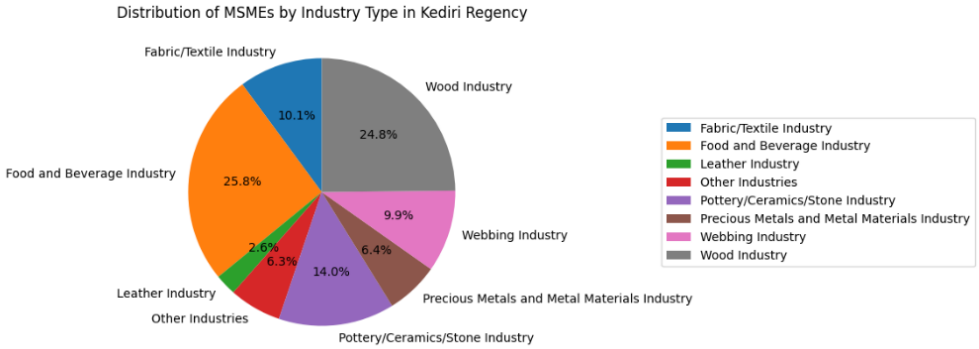

Figure 4. Distribution of MSMEs by Industry Type in Kediri Regency

Figure 4 looks at the distribution of MSMEs by Industry Type in Kediri Regency. Analyzing the provided data for Kediri Regency, we can observe the distribution of micro, small, and medium enterprises (MSMEs) across different industries. The Fabric/Textile industry comprises 106 MSMEs, representing 10.1% of the total MSMEs. The Food and Beverage industry encompasses 270 MSMEs, accounting for 25.8% of the MSMEs. The Leather industry consists of 27 MSMEs, equivalent to 2.6% of the total. Other industries encompass 66 MSMEs, representing 6.3% of the MSMEs. The Pottery/Ceramics/Stone industry consists of 147 MSMEs, making up 14% of the total. The Precious Metals and Metal Materials industry comprises 67 MSMEs, accounting for 6.4% of the MSMEs. The Webbing industry encompasses 104 MSMEs, equivalent to 9.9% of the total. Lastly, the Wood industry consists of 260 MSMEs, representing 24.8% of the MSMEs. The cumulative number of MSMEs in Kediri Regency amounts to 1047.

Upon analysis, the Food and Beverage industry and the Wood industry emerge as the largest sectors in terms of MSME numbers and their impact on the local economy. The Fabric/Textile industry also plays a significant role in manufacturing. However, the Leather industry has a smaller presence, indicating room for targeted support. The diverse industries, including Pottery/Ceramics/Stone, Precious Metals and Metal Materials, and Webbing, contribute to Kediri Regency's economic vibrancy. Policymakers can use this data to identify sector-specific strengths and weaknesses, promoting sustainable MSME growth and overall economic development.

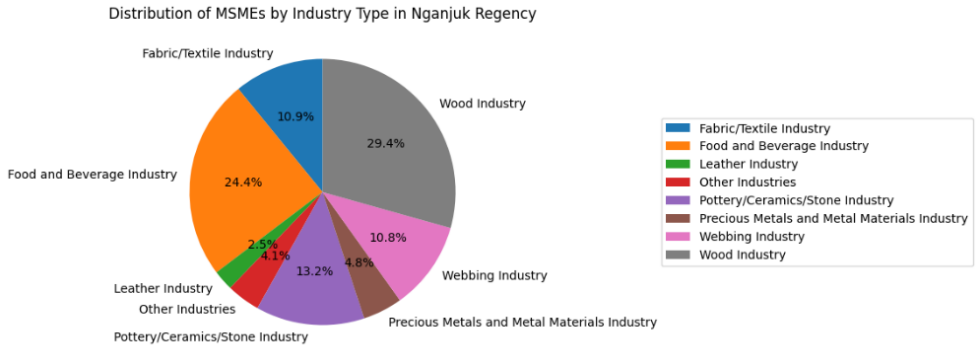

Figure 5. Distribution of MSMEs by Industry Type in Nganjuk Regency

Figure 5 illustrates the distribution of MSMEs by Industry Type in Nganjuk Regency. The data presented provides an overview of the distribution of micro, small, and medium enterprises (MSMEs) across different industries in Nganjuk Regency. The Fabric/Textile industry accounts for 75 MSMEs, representing 10.9% of the total MSMEs. The Food and Beverage industry comprises 168 MSMEs, making up 24.4% of the MSMEs. The Leather industry consists of 17 MSMEs, representing 2.5% of the MSMEs. Other industries encompass 28 MSMEs, accounting for 4.1% of the MSMEs. The Pottery/Ceramics/Stone industry comprises 91 MSMEs, representing 13.2% of the MSMEs. The Precious Metals and Metal Materials industry consists of 33 MSMEs, representing 4.8% of the MSMEs. The Webbing industry encompasses 74 MSMEs, accounting for 10.8% of the MSMEs, and the Wood industry consists of 202 MSMEs, representing 29.4% of the MSMEs. The total number of MSMEs in Nganjuk Regency amounts to 688.

The data suggests that Nganjuk Regency possesses significant potential for MSME development, particularly in the Food and Beverage and Wood industries. By formulating targeted strategies and providing comprehensive support, the government can nurture a conducive environment for MSMEs, leading to economic growth, job creation, and sustainable development in Nganjuk Regency.

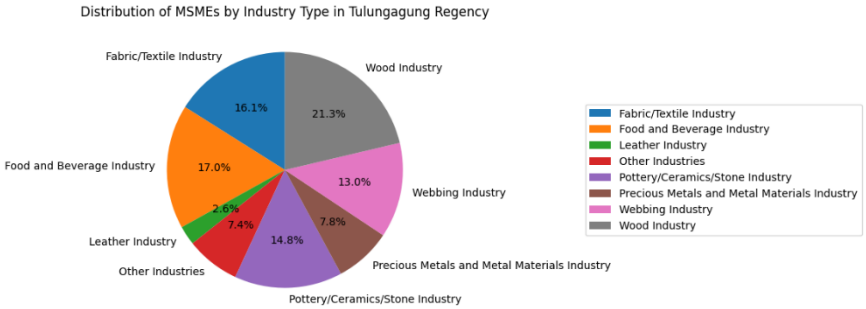

Figure 6. Distribution of MSMEs by Industry Type in Tulungagung Regency

Figure 6 describes the distribution of MSMEs by Industry Type in Tulungagung Regency. In Tulungagung Regency, the provided data reveals the distribution of micro, small, and medium enterprises (MSMEs) across various industries. The Fabric/Textile industry comprises 165 MSMEs (16.1%), the Food and Beverage industry encompasses 175 MSMEs (17%), the Leather industry consists of 27 MSMEs (2.6%), the other industries encompass 76 (7.4%) MSMEs, the Pottery/Ceramics/Stone industry consists of 152 MSMEs (14.8%), the Precious Metals and Metal Materials industry comprises 80 MSMEs (7.8%), the Webbing industry encompasses 134 MSMEs (13%), and the Wood industry consists of 219 MSMEs (21.3%). The cumulative number of MSMEs in Tulungagung Regency amounts to 1028.

Based on the data analysis, the government of Tulungagung Regency should consider specific measures to foster the growth and development of certain industries. Given the significant number of MSMEs in the Fabric/Textile, Food and Beverage, Pottery/Ceramics/Stone, and Wood industries, policymakers could prioritize targeted support in terms of infrastructure development,

access to financing, and skills training programs. By focusing on these industries, the government can create an enabling environment that encourages entrepreneurship, enhances productivity, and stimulates job creation, ultimately contributing to the overall economic progress and welfare of Tulungagung Regency.

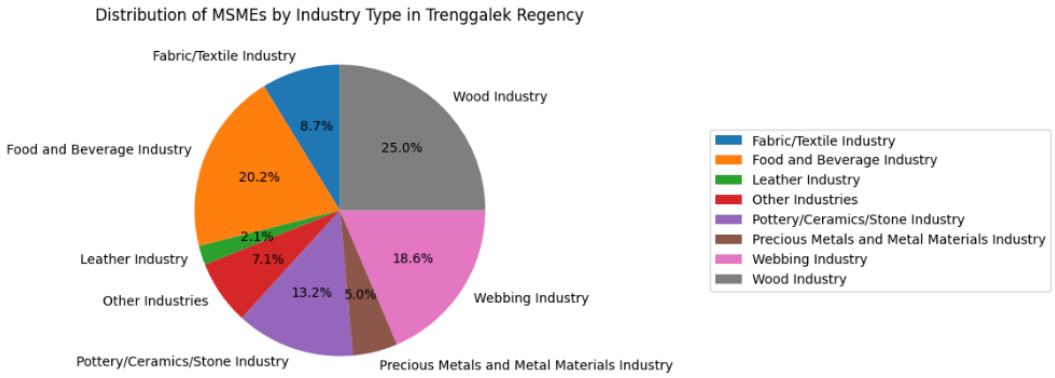

Figure 7. Distribution of MSMEs by Industry Type in Trenggalek Regency

Figure 7 provided illustrates the distribution of micro, small, and medium enterprises (MSMEs) across various industries in Trenggalek Regency. The Fabric/Textile industry comprises 49 MSMEs (8.7%), the Food and Beverage industry encompasses 113 MSMEs (20.2%), the Leather industry consists of 12 MSMEs (2.1%), the other industries encompass 40 MSMEs (7.1%), the Pottery/Ceramics/Stone industry consists of 74 (13.2%) MSMEs, the Precious Metals and Metal Materials industry comprises 28 MSMEs (5%), the Webbing industry encompasses 104 MSMEs (18.6%), and the Wood industry consists of 140 MSMEs (25%). The cumulative number of MSMEs in Trenggalek Regency amounts to 560.

Upon analysis of the data, that the Wood industry has the highest number of MSMEs, indicating its significance in the local economy. The Food and Beverage industry also demonstrates a considerable presence, followed by the Fabric/Textile industry. Conversely, the Leather industry has the lowest number of MSMEs. These findings suggest that the Wood industry holds potential for growth and further investment, while the Leather industry may require additional support and development initiatives. Additionally, the presence of MSMEs in diverse industries highlights the economic diversity within Trenggalek Regency, contributing to employment opportunities and overall economic stability.

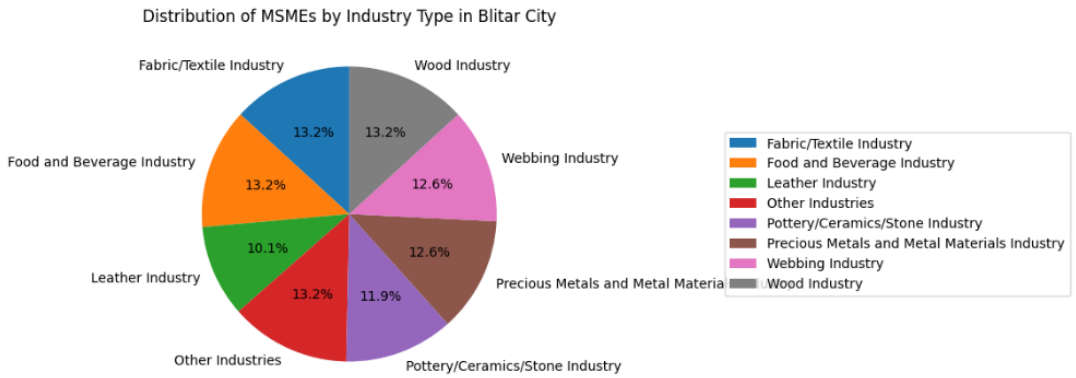

Figure 8. Distribution of MSMEs by Industry Type in Blitar City

Figure 8 given data reveals the distribution of micro, small, and medium enterprises (MSMEs) across various industries in Blitar City. The data provided indicates that the Fabric/Textile and Food and Beverage industries have the highest number of MSMEs, with 21 businesses each,

accounting for 13.2% of the total. The Leather industry has a smaller representation with 16 MSMEs (10.1%), while the Pottery/Ceramics/Stone industry has 19 MSMEs (11.9%). The Precious Metals and Metal Materials industry and the Webbing industry both consist of 20 MSMEs (12.6%), and the Wood industry also has 21 MSMEs (13.2%). In total, there are 159 MSMEs in Blitar City.

Analysis of the data reveals a balanced distribution of MSMEs across various industries, with the Fabric/Textile and Food and Beverage sectors leading the way. These findings suggest the potential for growth and investment in these industries. The Leather industry may require additional support and development initiatives due to its smaller representation. The presence of MSMEs in diverse industries highlights the economic diversity within Blitar City, contributing to employment opportunities and overall economic stability.

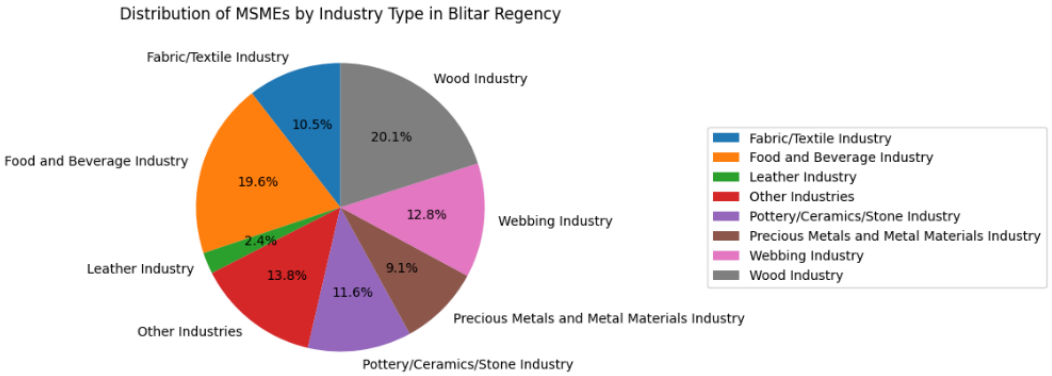

Figure 9. Distribution of MSMEs by Industry Type in Blitar Regency

Figure 9 provided data showcases the distribution of micro, small, and medium enterprises (MSMEs) across various industries in Blitar Regency. Among the different industries, the Wood industry stands out with the highest number of MSMEs, totaling 235 (20.1%). This indicates the significant presence and contribution of the Wood industry to the local economy.

Following closely behind is the Food and Beverage industry with 230 MSMEs (19.6%), highlighting its importance as well. The Fabric/Textile industry also demonstrates a substantial presence, comprising 123 MSMEs (10.5%). Additionally, the Other Industries category encompasses 162 MSMEs (13.8%), showcasing a diverse range of businesses in different sectors. The Pottery/Ceramics/Stone industry contributes 136 MSMEs (11.6%), while the Precious Metals and Metal Materials industry comprises 107 MSMEs (9.1%). The Leather industry accounts for 28 MSMEs (2.4%), and the Webbing industry includes 150 MSMEs (12.8%). Overall, the total number of MSMEs in Blitar Regency amounts to 1171.

This data indicates a vibrant entrepreneurial landscape and economic activity within the region. The findings suggest the significance of industries such as Wood, Food and Beverage, and Fabric/Textile, which may present opportunities for further growth and development initiatives. Moreover, the presence of MSMEs across various industries highlights the economic diversity and potential for employment generation in Blitar Regency.

We aim to compare data from adjacent areas, namely Kediri City and Kediri Regency, as well as Blitar City and Blitar Regency, to examine their similarities and differences.

Table 2. Comparison of MSME data for the Kediri City and Kediri Regency

Types of Industry	Number of MSMEs in 2018 in Kediri City	Number of MSMEs 2018 in Kediri Regency
Fabric/Textile Industry	22	106
Food and Beverage Industry	37	270
Leather Industry	6	27
Other Industry	14	66
Leather Industry	15	147

Precious Metals and Metal Materials Industry	18	67
Webbing Industry	16	104
Wood Industry	31	260

Table 2 describes MSME data for the Kediri City and Kediri Regency. The analysis of the data reveals significant differences in the distribution of micro, small, and medium enterprises (MSMEs) between Kediri City and Kediri Regency. Kediri Regency demonstrates a larger number of MSMEs in almost all recorded industry sectors compared to Kediri City. For instance, the Fabric/Textile Industry sector has 106 MSMEs in Kediri Regency, significantly higher than the 22 MSMEs in Kediri City. Similarly, the Food and Beverage Industry sector also exhibits a notable disparity, with 270 MSMEs in Kediri Regency and 37 MSMEs in Kediri City.

These variations can be attributed to factors such as economies of scale, market accessibility, and local government policies. Kediri Regency may possess better infrastructure and policy support for MSME development, thus attracting a larger number of businesses in specific industry sectors.

In addressing these disparities, the government's stance becomes crucial. The government needs to assess the potential and requirements of each industry sector in both areas and design appropriate strategies to strengthen underdeveloped sectors. For instance, for sectors with a lower number of MSMEs, such as the Leather Industry in Kediri City, the government can provide incentives and specialized development programs to stimulate sector growth. Additionally, the government should enhance infrastructure, market access, and skill training for entrepreneurs in both areas to enhance the competitiveness and productivity of MSMEs.

With a proactive approach and well-designed strategies, the government can foster balanced and sustainable growth for MSMEs in both Kediri City and Kediri Regency, creating a conducive environment for the development of micro, small, and medium enterprises to support overall regional economic growth.

Table 3. Comparison of MSME data for the Blitar City and Blitar Regency

Types of Industry	Number of MSMEs in 2018 in Kediri City	Number of MSMEs 2018 in Kediri Regency
Fabric/Textile Industry	21	123
Food and Beverage Industry	21	230
Leather Industry	16	28
Other Industry	21	162
Leather Industry	19	136
Precious Metals and Metal Materials Industry	20	107
Webbing Industry	20	150
Wood Industry	21	235

Table 3 describes MSME data for the Blitar City and Blitar Regency. The provided data showcases the comparison of micro, small, and medium enterprises (MSMEs) between Blitar City and Blitar Regency. The analysis reveals variations in the number of MSMEs across different industry sectors in the two areas.

In Blitar City, there are notable similarities in the number of MSMEs compared to Blitar Regency in the Fabric/Textile Industry, Food and Beverage Industry, Other Industries, and Wood Industry. However, differences emerge in specific sectors. The Leather Industry in Blitar City has 16 MSMEs, whereas Blitar Regency has 28 MSMEs. This suggests a potential for further development and support of the Leather Industry in Blitar City. Additionally, Blitar Regency demonstrates a stronger presence in the Pottery/Ceramics/Stone Industry and the Precious Metals and Metal Materials Industry, with higher numbers of MSMEs compared to Blitar City.

The data highlights the significance of the Food and Beverage Industry and the Wood Industry in both Blitar City and Blitar Regency, as they exhibit similar numbers of MSMEs in each

area. This indicates their importance in the local economy and their growth potential. To address the disparities observed, policymakers can consider implementing targeted measures. In Blitar City, efforts can focus on supporting and promoting the Leather Industry, while in Blitar Regency, nurturing the Pottery/Ceramics/Stone Industry and the Precious Metals and Metal Materials Industry can be prioritized.

Overall, this comparison of MSME data between Blitar City and Blitar Regency emphasizes the need for strategic policies to foster balanced development across industry sectors. By addressing sector-specific challenges and leveraging strengths, policymakers can promote the growth of MSMEs, stimulate economic activity, and generate employment opportunities in both Blitar City and Blitar Regency.

Conclusion

This scientific paper delves into a detailed examination of the distribution and segmentation of Micro, Small, and Medium Enterprises (MSMEs) within Kediri Residency. The data utilized for this analysis was sourced from the Central Statistics Agency of East Java Province, specifically from the year 2018. The data underwent a meticulous processing methodology, which encompassed five essential stages: editing, classification, verification, analysis, and, most notably, the formulation of conclusive findings.

The final determinations and crucial insights gathered from this exhaustive investigation of the MSME landscape in Kediri Residency. For instance, the data portrays the substantial presence of industries like Food and Beverage and Wood in both Kediri and Blitar Regency, underscoring their significance and potential for growth. Conversely, the Leather Industry exhibits a smaller presence, signaling a need for targeted support and development initiatives in Kediri City and Blitar City. The comparison tables between Kediri City and Kediri Regency, Blitar City, and Blitar Regency reveal significant differences in the distribution of MSMEs across various industry sectors, signaling the importance of regional policies and infrastructure in fostering these businesses. Industries like Fabric/Textile and Food and Beverage exhibit vast differences in MSME numbers between the city and regency areas, underlining the need for a nuanced approach to addressing these disparities.

The strengths lie notably in the dominance of the Food and Beverage industry, especially in Kediri Regency, along with the significant presence of the Wood industry across multiple areas, signifying a strong local economy and potential for further growth. However, weaknesses are evident in the smaller presence of certain industries like Leather and Webbing, indicating a need for focused support and development initiatives to bolster their growth. Identified potential areas for development and support encompass targeted interventions for the Leather Industry, investment in infrastructure, market accessibility, and skills training programs for industries like Fabric/Textile, Food and Beverage, and Wood to stimulate job creation and economic growth. These insights emphasize the necessity for strategic policymaking to balance growth and promote sustainable development across various sectors within the Kediri Residency.

During the editing phase, we diligently scrutinized the data to ensure its quality and reliability. Subsequently, in the classification stage, we organized this data into meaningful categories for a structured analysis. The verification phase followed, during which we meticulously cross-referenced and validated the data to ascertain its accuracy and fidelity. The analysis stage was pivotal, as it unearthed significant patterns and insightful revelations within the dataset. However, the culminating stage, the conclusion, played a crucial role in summarizing the findings and insights gleaned from our exhaustive analysis.

Employing Python programming, we harnessed a dataset comprising 56 rows and 3 columns, totaling 168 data points. This dataset served as the foundation for our comprehensive insights into the local economic landscape and the potential avenues for development within Kediri Residency. The knowledge thus acquired is of paramount importance, as it can be leveraged by various stakeholders such as local governments, financial institutions, and industry players to formulate more precise and efficient strategies for fostering economic growth.

Leveraging the comprehensive data gathered from various industries in Kediri Residency, it is crucial to provide stakeholders with strategic advice for sustainable development. Presenting this data is vital, but equally important is highlighting the necessity for targeted interventions. Stakeholders should concentrate on fortifying industries such as Food and Beverage and Wood,

acknowledged for their strength while implementing customized strategies to support sectors like Leather and Webbing, which exhibit comparatively lower representation. Diversification within the region's industrial landscape is pivotal for economic stability. Stakeholders should advocate policies that foster entrepreneurship, infrastructure development, and market access to enhance untapped sector potential. Prioritizing skill development programs and infrastructure for industries like Fabric/Textile, Food and Beverage, and Wood is critical for reinforcing their role in job creation and economic advancement. These recommendations, supported by relevant data, will guide stakeholders towards creating an environment conducive to the sustainable growth of micro, small, and medium enterprises in Kediri Residency.

With an intricate understanding of the distribution and segmentation of MSMEs in Kediri Residency, targeted interventions can be implemented with precision. These interventions may encompass tailored assistance programs, specialized training initiatives, enhanced market access opportunities, or optimized financing strategies. By aligning these interventions with the specific needs and characteristics of the local MSME landscape, we can catalyze sustainable economic development and prosperity in the region.

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Analysis and design of UI and UX of the Taring application using goal-directed design and cognitive walkthrough methods

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Abstract: Taring is a web-based application used for online administrative services for both Indonesian citizens and foreign nationals in the field of population administration. It is published by the Denpasar Population and Civil Registration Office. The taring application was released on June 8, 2020, and includes features such as managing Family Cards, e-IDs, Change of Residence Letters, and Legalization. Analysis and evaluation of the Taring application are necessary to improve usability, quality of use, and the provided information. This is achieved through the utilization of the Goal-Directed Design method and the Cognitive Walkthrough method in its process. The employed analysis and design method is Goal-Directed Design, which focuses on designing and developing interactive systems to make them more useful, with a focus on the diverse goals of the users. The evaluation methods used are the Cognitive Walkthrough and the System Usability Scale questionnaire, which assess usability and the application's usage based on observations of the users. The results of the Cognitive Walkthrough testing revealed 20 issues related to user interface and user experience, while the research findings indicated an increase in effectiveness and efficiency. The research also demonstrated an improvement in usability using the System Usability Scale method, with the score rising from 50.8 (E) to 88.9 (A).

Keywords: cognitive walkthrough, goal-directed design, system usability scale

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Introduction

The rapid development of websites has made human activities and needs easier. Various business processes can be carried out. Technology related to the Internet is widely utilized as a solution for the majority of existing needs, particularly those about effectiveness and efficiency in activities and procedures [1]. The design of a website is closely related to the comfort and user experience in using it, and it involves user interface and user experience. A well-designed interface can enhance easy and natural interaction between users and the system, improve user satisfaction, and encourage repeat visits to the website. The process of design is intricate and consists of multiple steps that require skills such as logical thinking, innovative ideas, strategic planning, and effective problem-solving abilities [2].

User interface and user experience are closely linked to the usability of the website itself. User experience, or customer experience, refers to the overall process of user interaction with a product or service and their responses to it [3].

The author wishes to conduct research by focusing on analyzing problems and evaluating improvements in the user interface and user experience of the Taring Application. The Taring Application is used for online civil registration services for both Indonesian and foreign citizens, and it is published by the Denpasar Civil Registration and Civil Service Office.

The identified problems include uncomfortable color choices. The login and registration interfaces need improvement in terms of button placement and font size. The use of irrelevant images, lack of information, and lack of dynamism due to no changes when selecting sidebar

features can confuse users. These problems are supported by reviews on Google Reviews, with a total score of 3.0 out of 5.0 based on 383 reviews. Users complain about the lack of complete information in the Taring Application, which forces them to repeatedly visit the Denpasar Civil Registration and Civil Service Office to handle their population-related matters.

The importance of usability testing in applications is explained in a similar study that discussed an online student learning application called MejaKita. Design improvements were made using the Goal-Directed Design method, and usability testing was conducted by measuring three variables: effectiveness, efficiency, and user satisfaction using the System Usability Scale method [4].

A similar study focused on usability testing of the Forum Politeknik Statistika STIS website using the Cognitive Walkthrough method. The research results showed a decrease in the error rate from 11 errors to 3 errors and an improvement in the completion rate from 0% to 66.6% among respondents after the website's display was modified and improved. This research contributes to this study by examining and utilizing the Cognitive Walkthrough method [5].

A case study of the Schoters Education Consultant Application using the Goal-Directed Design (GDD) method for its design. The research utilized the Cognitive Walkthrough and System Usability Scale (SUS) methods for analysis and evaluation, resulting in an overall usability improvement of 20% based on the Cognitive Walkthrough and System Usability Scale questionnaire. The referenced research is included in this study because it employs the same method with different cases [6].

A similar study was conducted focusing on evaluating the user interface and user experience of the Dua Mata application, which had an outdated design. The research used the Quality in Use Integrated Measurement (QUIM) method to identify usability problems in the old design. QUIM involves 25 questions with 10 standard factors to calculate the scale of problems experienced by application users. The findings demonstrated that the use of the Goal-Directed Design method improved the previous QUIM scores and reduced the completion time for each task scenario. The referenced research is included in this study because the Goal-Directed Design method has been proven to enhance the usability of an application [7].

To assess the effectiveness of the Cognitive Walkthrough method, a study compared the results of usability evaluations using three different methods: Usability Testing, Cognitive Walkthrough, and Heuristic Evaluation. The objective was to identify usability issues and compare the problems identified by each method [8].

The study conducted the evaluation and design of the Jawa Timur Park Group website using the Goal-Directed Design and System Usability Scale methods. After implementing improvements in the website design of Jawa Timur Park Group using the Goal-Directed Design method, there was an increase in the average results of the System Usability Scale. The referenced research is included in this study as a reference for the procedures and workflow of the Goal-Directed Design method and the System Usability Scale [9].

The authors' research differences from previous research in the different case studies being examined. The author wishes to generate user testing data obtained through the Cognitive Walkthrough method and recommendations for improvement in application design using the Goal-Directed Design method. The recommendations provided may involve interface enhancements or functional improvements, enabling the application design to be further optimized and focused on meeting the needs and objectives of the users.

Methodology

The design of the user interface for the Taring website is conducted using the Goal-Directed Design method, which is designed to focus on different user goals and involves users from the beginning to the end of the design process. The method involves six phases of research: Research, Modeling, Requirement, Framework, Refinement, and Support [10].

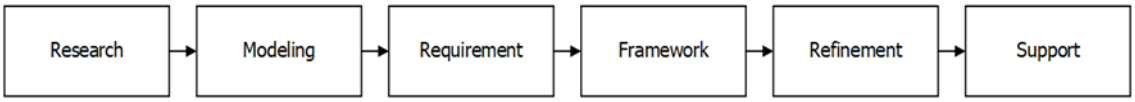

Figure 1. Research flow of goal-directed design method

Figure 1 shows an overview of the process flow of the design method. The entire flow is carried out in stages starting from the investigation process of the case study at the research stage to the testing and evaluation stages of the design results. The description of each stage of the flow is explained below.

1. Research

Employs ethnographic techniques (observation, interviews, questionnaires, or other data collection methods) to generate qualitative data about potential users or actual users of a product [11]. Usability testing is conducted using the System Usability Scale (SUS) method with 10 questions that must be answered by respondents after performing the task scenario.
The questionnaire with the System Usability Scale method uses the Likert scale as the calculation scale. The assessment is based on three categories based on the final SUS score with a range of values as in Table 1 below.

Table 1 SUS score range category

No	Score Range	Grade Scale	Acceptability Range
1	Score >= 81	A	Acceptable
2	Score > 68 and Score < 81	B	
3	Score = 68	C	Marginal
4	Score >= 51 and Score < 68	D	Not Acceptable
5	Score < 51	E	

The final SUS score is in the range of 0-100 as shown in Table 1. Based on the final SUS score, it can be identified how high the level of usability and acceptable design of the application system developed [11].

2. Modelling

The data obtained from the Research phase are used to model the users. Personas represent the observed and identified behaviors, attitudes, goals, and motivations of the users and are intended to understand what the users need.

3. Requirement

Scenario-based design methods are used to describe the detailed flow of tasks based on the personas' goals obtained in the previous phase. The goal of the Requirement phase is to balance the users' needs, business requirements, and technical aspects of the required design [12].

4. Framework

It involves designing the interaction between frameworks using visual tools. In this phase, the elements of existing functions, such as website wireframes and scenarios depicting how users interact with the system, are defined [13].

5. Refinement

Focuses on the detailed design development of each component or element of the user interface, such as determining the visual style, icons, colors, and other visual elements that align with the users' goals and experiences.

6. Support

Involves evaluating and testing the interface design. The Support research will use the Cognitive Walkthrough method to evaluate the created design.

Cognitive Walkthrough is a usability testing method that evaluates one or more aspects through several task scenarios and a set of questions to uncover issues from a user perspective. The Cognitive Walkthrough method evaluates each step taken by respondents to complete task scenarios in an application. Evaluating each step is necessary to conduct scenarios and identify usability problems that hinder user exploration.

Usability is derived from the term "usable," which generally means being capable of being used effectively. Something can be considered highly usable if failures in its use can be eliminated or minimized while providing benefits and satisfaction to the users [14]. Usability testing, employing techniques, focuses on assessing the level of usefulness provided by a system [15].

Usability testing using the Cognitive Walkthrough method consists of two stages: preparation and execution. The preparation stage involves reviewing the literature, studying the system being tested, selecting respondents, and developing task scenarios that need to be completed by the respondents. The execution phase involves the sequence of walkthrough actions and problem recording. The usability testing aligned with Goal-Directed Design, which is inherently focused on behavioral design, thus making it the chosen testing method for this research [16].

Usability testing is conducted concurrently with task scenario testing. The testing is performed using the System Usability Scale method, which involves 10 questions that respondents must answer after completing the task scenario. The System Usability Scale is an evaluative method for usability that can yield satisfactory results based on considerations of small sample size, time, and cost [17]. The System Usability Scale also possesses clear instruments on calculation methods for evaluating an application. Consequently, the resulting evaluation scores possess accuracy and accountability [18]. The results from the System Usability Scale are tested to ensure the research results are valid and reliable. Validity testing measures the extent to which a research instrument can produce actual variables. Reliability refers to the degree to which a measurement instrument can be trusted or relied upon. Reliability is defined as the level of confidence in the results of measurement [19].

Results and Discussions

In this study, the author used the Goal-Directed Design method which involves Research, Modeling, Requirement, Framework, Refinement, and Support.

1. Research

The scope for determining the users of the Taring application is limited to the residents of Denpasar, Bali, as the Taring application specifically caters to population and civil registration within that area. The users are divided into two categories: those who have previously used the Taring application and those who have never used it. During this research phase, an analysis is conducted through the distribution of a user needs questionnaire to comprehend the objectives and requirements of the users.

2. Modeling

In the Research phase, the analysis results are translated into concise, compact, and clear visual representations. These visual representations take the form of user personas, which serve as a guide for designing the user interface in the Requirement phase. User personas encompass the goals, motivations, needs, and constraints of both existing users and potential users.

For ease of reading and comprehension, findings are presented first followed by discussion. The Findings sub-title and Discussion sub-title are presented separately. This section should occupy the most part, a minimum of 60%, of the whole body of the article.

Figure 2. User persona

The user Persona in Figure 2 is an element that encompasses respondent characteristics to aid in design development. User Persona is created to summarize and synthesize questionnaire results to understand the target audience and their needs.

3. Requirement

The Requirement phase involves describing the detailed flow of tasks based on the personas' goals obtained in the previous phase. In this phase, task scenarios are tested using the Cognitive Walkthrough and System Usability Scale methods. Testing a new or ongoing system is necessary to ensure that the system functions according to the expected functionality and that any errors or deficiencies can be detected and rectified promptly [20].

a. Effectiveness

The effectiveness result indicates how many respondents were able to complete the task scenarios performed in the tested application.

Table 2. Users' results of effectiveness

Respondent Code	Successful Tasks	Total Task Scenarios	Percentage	Average Percentage
KR1	57	58	98.27	97.41%
KR2	57	58	98.27	
KR3	56	58	96.55	
KR4	56	58	96.55	
KR5	56	58	96.55	
KR6	56	58	96.55	
KR7	57	58	98.27	
KR8	57	58	98.27	
KR9	57	58	98.27	
KR10	56	58	96.55	

Table 2 shows the level of effectiveness at 97.41% of task scenarios completed when using the Taring application. Out of 58 scenario tasks that were put forward, an average of 56 to 57 scenarios were completed.

Table 3. Potential Users' Results of Effectiveness

Respondent Code	Successful Tasks	Total Task Scenarios	Percentage	Average Percentage
KR11	56	58	96.55	95%
KR12	54	58	93.1	
KR13	55	58	94.82	
KR14	54	58	93.1	
KR15	57	58	98.27	
KR16	54	58	93.1	
KR17	54	58	93.1	
KR18	54	58	93.1	
KR19	57	58	98.27	
KR20	56	58	96.55	

Table 3 also indicates a high result for the average percentage from all task scenarios. with the lowest number of successful tasks being 54, and 57 for the highest number of successful tasks.

b. Efficiency

The efficiency result represents how quickly respondents were able to complete the task scenarios performed in the tested application.

Table 4. Users' Results of Efficiency

Average Time	129.4 seconds
Successful Task Durations	7257 seconds
Total Task Duration	7507 seconds
Overall Relative Efficiency	96.7%

On the efficiency factor, the results of the task for the test scenario also show exceptional results as shown in Table 4. The overall relative efficiency of 96.7%, which obtained from the results of calculating the percentage between the number of successful task durations and the total durations of the task.

Table 5. Potential Users' Results of Efficiency

Average Time	158.6 seconds
Successful Task Durations	7596 seconds
Total Task Duration	9201 seconds
Overall Relative Efficiency	82.5%

Table 5 shows the results of overall relative efficiency, also derived from calculating the percentage of comparison between successful task duration and total task duration. The percentage of overall efficiency gives a smaller value than before, which indicates that the results of the task scenario on potential users give a lower value in the efficiency aspect than the scenario tasks performed on users.

c. Usability Level

The usability level refers to the usability result obtained using the System Usability Scale method from respondents who have performed the task scenario tests.

Table 6. Results of Usability Level

Total Number of Respondent Scores	1016
Usability Level	50.8
Grades	E (Not Acceptable)

The questionnaire is used in testing the usability level. Table 6 shows the results of application usability results which indicate unfavorable results obtained from testing users with a score of 493 or 49.3 and prospective users giving a score of 523 or 52.3. Where the overall average score is 50.8 which is categorized as not acceptable.

4. Framework

The Framework phase is the stage of designing low-fidelity mockups in the form of wireframes. Wireframes are created based on user needs and serve as a guide or foundation for creating mockup designs, which are then further refined during the prototyping phase.

5. Refinement

The Refinement phase is focused on developing detailed designs for each component or element of the user interface, such as determining the visual style, icons, and colors. The design is created based on the low-fidelity mockup created in the previous phase and transformed into a high-fidelity mockup.

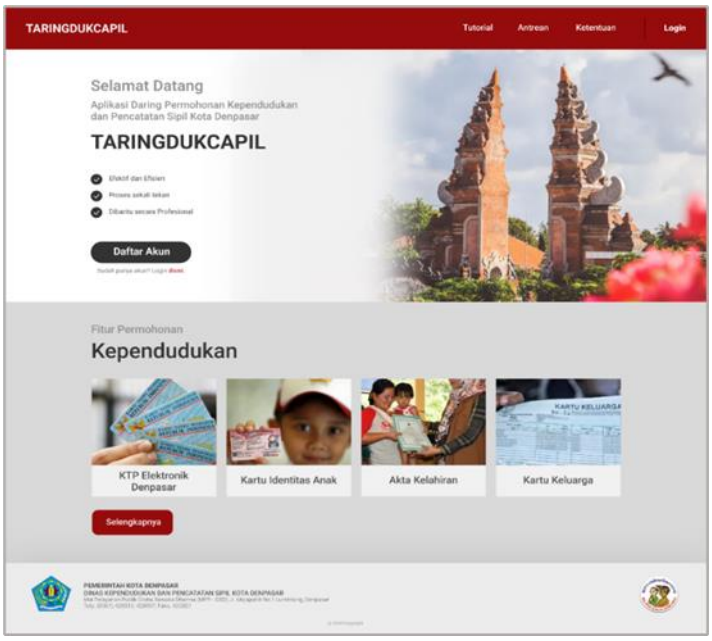

Figure 3. Mockup of homepage

Figure 3 is the mockup design for the Homepage. The design applies a different visual concept from the previous design but still maintains the essence of the website. The homepage is designed with an attractive appearance with a clean and simple interface.

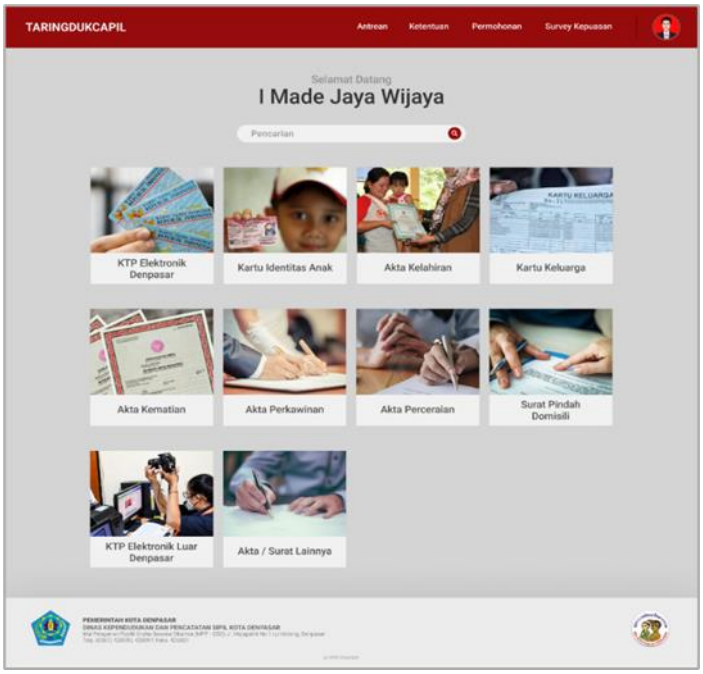

Figure 4. Mockup of feature page

The mockup of the Feature Page is shown in Figure 4. The service feature view is displayed by applying containers to represent each feature. The feature is also accompanied by a description of the image to make it easier for users to understand the usefulness of the service.

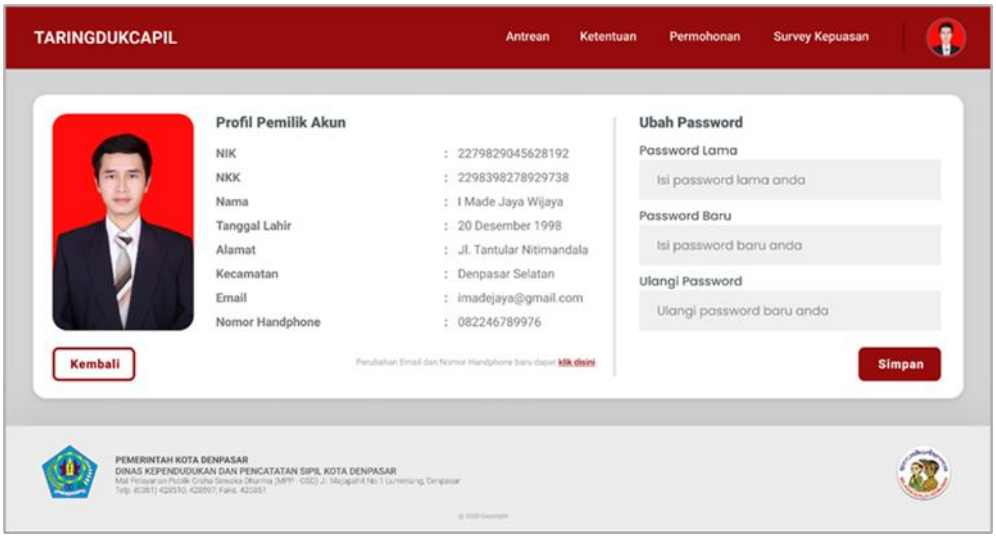

Figure 5. Mockup of the account profile page

Figure 5 is the mockup design for the Account Profile Page. The account profile page section displays user identity data. In addition, users can also change the password for the account directly on this page.

6. Support

The Support phase is the stage of testing the design and evaluating the improvements obtained after the initial testing. The Support testing phase involves using the Cognitive Walkthrough method and the System Usability Scale questionnaire.

a. Effectiveness

The effectiveness result indicates how many respondents were able to complete the task scenarios performed in the tested application.

Table 7. Users' final results of effectiveness

Respondent Code	Successful Tasks	Total Task Scenarios	Percentage	Average Percentage
KR1	58	58	100	100%
KR2	58	58	100	
KR3	58	58	100	
KR4	58	58	100	
KR5	58	58	100	
KR6	58	58	100	
KR7	58	58	100	
KR8	58	58	100	
KR9	58	58	100	
KR10	58	58	100	

Table 7 shows the result of effectiveness based on user assessment. The results on the effectiveness aspect performed on each of the 58 tasks, and gave an average percentage of 100% as a result.

Similar results are also shown in the potential user's final result of effectiveness. These results can be seen in Table 8. Overall, the results on the effectiveness aspect gave successful results with an average percentage of 100%.

Table 8. Potential users' final results of effectiveness

Respondent Code	Successful Tasks	Total Task Scenarios	Percentage	Average Percentage
KR11	58	58	100	100%
KR12	58	58	100	
KR13	58	58	100	
KR14	58	58	100	
KR15	58	58	100	
KR16	58	58	100	
KR17	58	58	100	
KR18	58	58	100	
KR19	58	58	100	
KR20	58	58	100	

b. Efficiency

The efficiency result represents how quickly respondents were able to complete the task scenarios performed in the tested application.

Table 9. Users' final results of efficiency

Average Time	78.8 seconds
Successful Task Durations	4575 seconds
Total Task Duration	4575 seconds
Overall Relative Efficiency	100%

Table 10. Potential users' final results of efficiency

Average Time	105.4 seconds
Successful Task Durations	6114 seconds
Total Task Duration	6114 seconds
Overall Relative Efficiency	100%

The evaluation was performed to see the comparison between users and potential users in terms of efficiency in using the application. The average results generated by users as shown in Table 9 provide better results with less time than potential users shown in Table 10. However, both provide good results.

c. Usability Level

The usability level refers to the usability result obtained using the System Usability Scale method from respondents who have performed the task scenario tests.

Table 11. Results of usability level

Total Number of Respondent Scores	1778
Usability Level	88.9
Grades	A (Acceptable)

Table 11 is a processed data table from the results of testing using the SUS questionnaire against the application design prototype. The results show an increase when compared to the results of testing on the old application design. The score on usability level testing on the Taring application prototype shows good results, namely at 88.9 which is based on the SUS score category in Table 1, classified as category A (acceptable).

7. Comparison of Results

The analysis results of the Taring application will be compared with the testing results obtained from the prototype of the Taring application using the same respondents. The purpose of this comparison is to determine any changes in the outcomes obtained from the analysis and testing through the tested task scenarios.

a. Users

The effectiveness has increased from 97.41% to 100%, while Efficiency has increased from 96.7% with an average completion time of 129.4 seconds to 100% with an average completion time of 78.8 seconds.

Table 12. Users' comparison of result

Comparison	Effectiveness	Efficiency
Before	97.41%	96.7% (129.4 seconds)
After	100%	100% (78.8 seconds)

Table 12 shows that the aspect of user-perceived effectiveness has increased after implementing the new design. This proves that the new design can bring increased effectiveness for users in utilizing the website.

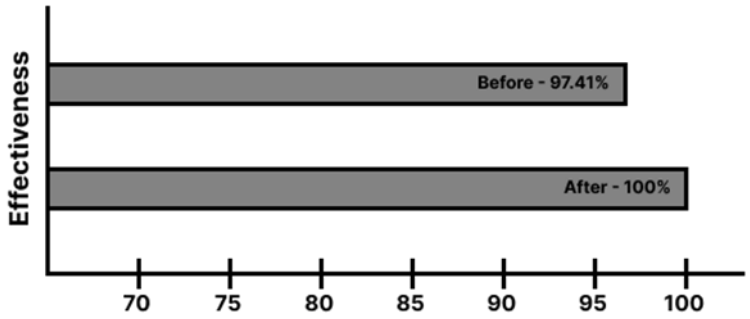

Figure 6. Graph of user effectiveness comparison

The comparison of the results before and after the implementation of the new design on the effectiveness aspect can be seen in Figure 6. The graph shows an increase in the effectiveness of using the website.

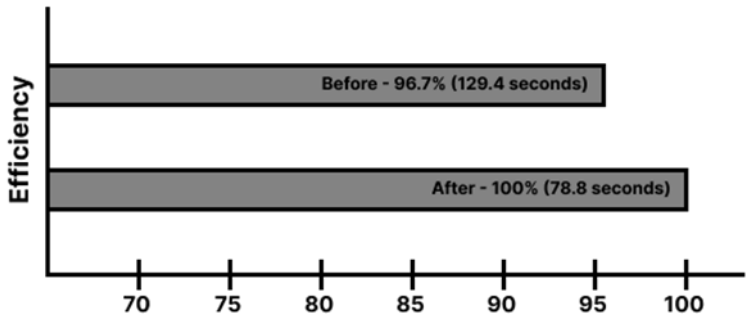

Figure 7. Graph of user efficiency comparison

Figure 7 shows a comparison of the results before and after the implementation of the new design in terms of efficiency. According to users, efficiency increases with the new design

b. Potential Users

The effectiveness has increased from 95% to 100%, and the efficiency has increased from 82.5% with an average completion time of 158.6 seconds to 100% with an average completion time of 105.4 seconds.

Furthermore, Table 13 shows the results of the efficiency and effectiveness aspects for potential users. The table shows an increase, especially in the efficiency aspect which increased from 85.5% to 100%.

Table 13. Potential Users' Comparison of Result

Comparison	Effectiveness	Efficiency
Before	95%	82.5% (158.6 seconds)
After	100%	100% (105.4 seconds)

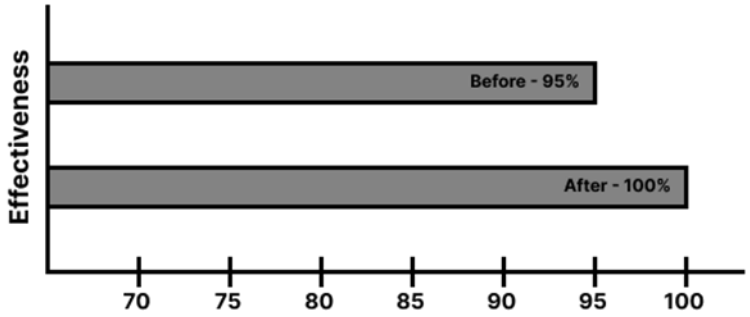

Figure 8. Graph of potential user effectiveness comparison

The graph of the effectiveness aspect for potential users is shown in Figure 8. The graph shows the difference between the results of the effectiveness assessment before and after the application of the design.

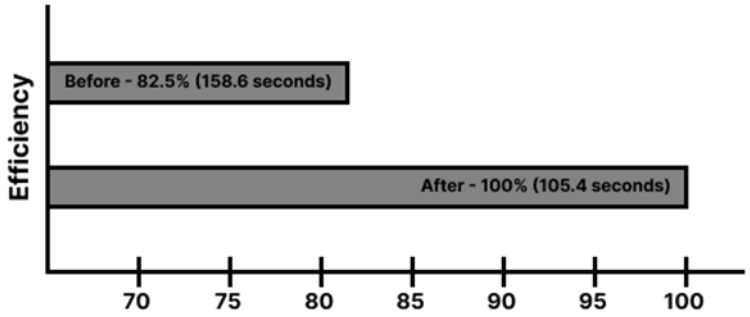

Figure 9. Graph of potential user efficiency comparison

Figure 9 shows a graph of the effectiveness aspect for potential users. The graph shows a significant increase in the effectiveness aspect of the new design.

c. Usability

In the overall System Usability Scale (SUS) score, there was an increase from 50.8 with a grade of E (not acceptable) in the analysis phase to 88.9 with a grade of A (acceptable) in the evaluation phase.

Table 14. Comparison of Usability

Comparison	Overall
Before	50.8 (E)
After	88.9 (A)

Table 14 shows the final results of the assessment of website usability. Based on the interpretation of the SUS score shown in Table 1, it shows that the usability of the website with the previous design gets a value of E (Not Acceptable). While usability after the application of the new design shows the value of A (Acceptable).

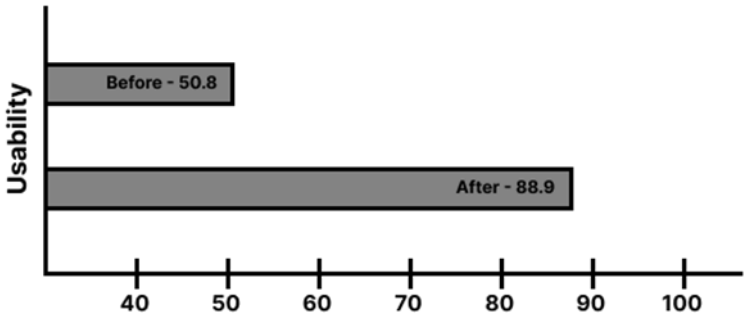

Figure 10. Graph of usability score comparison

Figure 10 shows a comparison graph of the usability assessment score results. The comparison graph of the assessment score results on the usability aspect shows a significant increase where the initial score shows a result of 50.8 and the score after the implementation of the new design gives a value of 88.9.

8. Improvement Recommendation

The design improvement solution is a summary of problems and input from respondents during the requirements and support stages. Research conducted previously by applying Goal-Directed Design provides solutions based on the problems found in the application [4]. This is also done in the evaluation process on this website, based on existing problems and input, an improvement solution is made, as follows.

Table 15. Improvement recommendations

No	Design Improvement Recommendation	Task Scenario	Stages
1	Add the list button on the main page	Task 1	Requirements
2	Combine and add the button feature 'Send OTP Code' on the registration page		
3	An additional feature of moving the forms for Foreigners to Indonesian Citizens is one button on the login page.	Task 2	
4	Add the validation page for users when submitting an application	Task 3-11	
5	Improvements in writing style and layout location of application requirements to be more comfortable to read		
6	Change the images in the application features using more relevant and consistent images.		
7	Improvement for the forms starts from the province first and fixes writing errors.	Task 12	
8	Change the 'Save' button to the 'Continue Application' button with the same function.		
9	Removing the 'Check Application' button on the application checking page and adding a 'Return' or 'Back' button.		
10	Improve the writing for the address after filling out the form to be more effective.		
11	Fix the queue write of the maximum quota/quota	Task 13	

	daily (500/0) to be daily quota/quota maximum (0/500). Added day details and removed holidays.		
12	Improve the appearance of the conditions page for a more comfortable view.		
13	Improve the queue details button to become easily visible.		
14	Move the 'Back' button to the top position so users can easily find the button to return.		
15	Add the 'change personal account data' feature on the profile page.	Task 14	
16	Add validation process when the user logs out.		
17	Improve the design of the footer so it will be more comfortable for users to see		
18	Add a view password feature when filling out the password form to make it easier for users to check the input password	Tasks 1,2, and 14	Support
19	Add revalidation when clicking the 'Back' button so that filling in the form is not wasted. Form is not wasted.	Task 12	
20	Addition of a page validation page after filling the form and an 'Edit Data' button button to make changes if there is an error form filling.		

The improvement recommendation shown in Table 15 is a summary of suggestions for implementing solutions to improve website design. There are several stages, namely requirements and support, where each stage has several design suggestions based on the scenario tasks carried out.

Conclusion

There is a total of 20 improvement recommendations were derived from the Goal-Directed Design and Cognitive Walkthrough methods. Out of the 20 improvement recommendations, 17 pertain to the requirement phase, while 3 pertain to the support phase. Effectiveness and Efficiency have increased, indicating that respondents were able to complete the given task scenarios without any obstacles.

The overall System Usability Scale score shows an increase from 50.8 with a grade of E (not acceptable) to 88.9 with a grade of A (acceptable). The comparison results indicate that the designed prototype has better usability than the Taring application because the prototype is designed based on the needs and solutions derived from the constraints experienced by the respondents.

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The impact of ChatGPT on the critical thinking ability of UIN Sunan Kalijaga students

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Abstract: This study aims to identify and analyze the impact of using ChatGPT, an artificial intelligence (AI) language, on students' critical thinking. The use of ChatGPT is becoming common at this time to get information and instant needs of students. However, the impact on critical thinking skills in students still needs to be studied. This research method uses quantitative methods. Giving questionnaires to a group of students who use ChatGPT is carried out online, data from this study is used to identify the impact of using ChatGPT on students' critical thinking levels. Using quantitative methods and online questionnaires, the study was able to collect relevant and detailed data on the impact of using ChatGPT. This makes it easier for researchers to identify data, as well as provide a deeper understanding of ChatGPT's influence on students' critical thinking. The results in the research we have done obtained 3.593 on the Likert scale. This shows that ChatGPT has a moderate effect on critical thinking skills. Dependence on the use of ChatGPT can reduce the level of critical thinking skills. Therefore, it is important to remember that although this study obtained positive results, the use of ChatGPT should be balanced with the development of independent critical thinking skills and critical evaluation of the information provided by the AI model.

Keywords: artificial intelligence, ChatGPT, critical thinking, college student, OpenAI

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Introduction

People in the 5.0 era must be literate in information and communication technology. When various industrial fields and needs began to turn digital and began to take advantage of AI, Big Data, robotics, automation, machine learning, and the Internet of Things, that was when Industry 5.0 technology began to emerge [1]. Technology is a tool that can help, facilitate, and improve learning activities. Artificial intelligence technology, sometimes known as AI, is one such technology that is possible and should be used. AI is an imitation of human intelligence that is based on machines and programmed to think like humans [2].

AI technology is designed because it provides benefits for its users in terms of efficiency. AI can do jobs that are faster and more accurate than humans, including data processing, risk analysis, and decision-making ability [3]. ChatGPT is one of the AI technologies that is trained to interact in a conversational way [4]. ChatGPT which is a Natural Language Processing or NLP (Natural Language Processing) tool can understand and produce human-like conversation and writing [5]. Since its release by OpenAI on November 30, 2022 [6], ChatGPT has become popular after gaining worldwide popularity and attention for its extraordinary ability to generate coherent, systematic, and informative responses [7].

ChatGPT can provide extraordinary responses because it has a large data store and an efficient design to understand and explain user requests [8]. ChatGPT can also be used in health education for various purposes, such as enhancing individualized learning and emphasizing critical thinking and problem-based learning [9]. In addition, ChatGPT can be used to analyze students' understanding of direct evaluation of given assignments [10]. However, there are concerns about the potential of AI technology to spread bias and stereotypes [11]. However, users are expected

not to be complacent about using ChatGPT because it can cause negative dependencies. This dependence can lead to a decrease in critical thinking power and the level of creativity [12].

Therefore, Nadia Fairuza, a researcher at the Center of Indonesian Policy Studies (CIPS) stated that the use of ChatGPT must be accompanied by adequate mastery of critical thinking skills. In addition to overcoming this dependence, this aims to make the use of ChatGPT among students productive and appropriate [13]. In the theory of effectiveness, effective technology is a system that can provide added value or positive influence on user behavior [14]. In the rapid development of technology, it is necessary to have the ability to think critically in dealing with various problems in the personal and social life of society [15].

The ability to think critically means being able to reflect actively and sustainably. It is based on in-depth investigation using thinking and reflection procedures to develop valid, correct, and convincing findings [16]. Critical thinking always tries to diagnose or validate something that already exists so that it becomes a probability. In critical thinking, probability has the meaning to always evaluate information based on analytically strong evidence and facts. In addition, critical thinking skills are also convergent. This relates to skills in seeking information from various sources to broaden views on a topic. So that it can be said that the ability to think critically emphasizes the ability to combine many things into one thought by the rules allowed by the general public [17]. Facione divides six components in critical thinking skills, namely the ability to interpret, analyze, evaluate, infer, explain, and self-regulate [18].

College students are an active community that uses the internet. This is in accordance with data from the 2023 report on Indonesia's internet penetration rate conducted by the Indonesia Internet Service Provider Association. In this data, student profiles show that they are the largest internet users in Indonesia with a penetration rate of 98.88% [19]. So with this students are required to think critically about various information. The quality of a nation's human resources, especially students who rely on education, determines its progress. Education enables students to study well and reach their full potential [20]. To improve students' critical thinking skills, it is necessary to innovate in the world of education, especially in terms of learning [21]. The use of information and communication technology itself can improve student achievement and cognitive abilities [22].

The State Islamic Religious College (PTKIN) is critical to the improvement of education in Indonesia. This is because the majority of Indonesians are Muslims [23]. UIN Sunan Kalijaga Yogyakarta is a well-known Islamic university in Indonesia. UIN Sunan Kalijaga's scientific development foundation uses the term integration-interconnection, which refers to a foundation that blends religious knowledge with science and technology [24]. In times of development, UIN Sunan Kalijaga remains committed to sustaining the quality of its graduates. This is reflected in the prizes it has received, such as Cyber Campus and Libraries that use RFID technology, also known as Radio Frequency Identification [25].

With the rapid development of technology, we need to understand its impact on various aspects of life, one of which is education. Therefore this study aims to determine the effectiveness and influence of ChatGPT on the ability to think critically in the real world of the academic community, especially students. The urgency of this research is very important as a form of attention to rapidly developing technology and as an update to previous studies. Considering that the number of studies on ChatGPT is still limited, this research is expected to provide benefits for educational observers. In addition, this research provides benefits for technology observers to find out how extensive the impact of ChatGPT is on students' critical thinking skills in Indonesia, especially UIN Sunan Kalijaga. Students of UIN Sunan Kalijaga became the subject of research because of the facts that occurred in the field. Students are one of the users who often use ChatGPT.

Methodology

This study uses a type of quantitative research. According to Aliga and Gunderson, quantitative research is research that seeks to explain a situation by collecting data in the form of numbers that are analyzed using certain statistical-based methods [26]. Data were analyzed quantitatively using descriptive statistics [27]. Descriptive statistics themselves can be directed at disbursing the mean (average), percentage, or mode. The aim is to see the level of frequency of an answer response [28].

The population is a collection of generalizations consisting of subjects who have certain quantities and characteristics according to those determined by the researcher [29]. The population in this study were UIN Sunan Kalijaga students who had used ChatGPT. The total population in this study was 85 people. This number has fulfilled the characteristics of the population because in sampling using the simple random method. The sample is part of the whole and the characteristics possessed by the population in the study [27]. The sample itself must be able to reflect the condition of the population. This is important because, at the end of the study, the conclusions from the sample must also be able to represent the conclusions of the population [30]. The sample in this study were students of the faculties of Science and Technology, Tarbiyah and Teacher Training, Social Sciences and Humanities, Ushuluddin and Islamic Thought, and Islamic Economics and Business at UIN Sunan Kalijaga Yogyakarta.

The sampling method in this study was simply random. According to simple random, sampling in this way is a direct sampling technique from the population randomly. The data collection technique used in this study is a survey data collection technique. Surveys or self-administered surveys are primary data collection methods by distributing questions to individual respondents or respondents [31]. In collecting data, researchers used online questionnaires via Google Forms. Questionnaires are data collection techniques that are carried out by giving a set of questions or written statements to respondents to answer [27]. The goal is to obtain data that is relevant to the research objectives and obtain data with a high level of validity and reliability [32]. The quality of the research instruments was tested by conducting validity and reliability tests using SPSS 20 software. SPSS is a computer program that has high enough capabilities to assist researchers in processing and making statistical analysis data [33]. In addition to testing the validity and reliability, SPSS 20 is used to analyze the results of this research data. A validity test is carried out to show the extent to which a measuring device can measure what it wants to measure. Meanwhile, the reliability test is used to show the consistency of a measurement result if the measurement is repeated [23].

The research instrument is a device for collecting research data so that it can be trusted, the level is reliable, precise, and can be factually accounted for [26]. In this study, the instruments were prepared based on the theory of effectiveness put forward by Sahfitri (2012) and the components of critical thinking skills put forward by Facione. The instrument used in collecting data is a question in the form of a questionnaire consisting of 8 questions. The instrument is attached in the Table below.

Table 1. Measurement Instruments

Grain	Instrument	Indicator	Variable
1	Critical thinking skills before using ChatGPT	Effectiveness	X1.1
2	Critical thinking skills after using ChatGPT	Effectiveness	X1.2
3	Ability to understand and analyze complex information (interpretation) after using ChatGPT	Components of Critical Thinking Ability	X2.1
4	Ability to describe and dissect information to identify important elements in a problem or argument (analysis) after using ChatGPT	Components of Critical Thinking Ability	X2.2
5	Ability to evaluate arguments based on validity, reliability, and reliability (evaluation) criteria after using ChatGPT	Components of Critical Thinking Ability	X2.3
6	Ability to make rational and testable conclusions based on existing evidence (inference) after using ChatGPT	Components of Critical Thinking Ability	X2.4
7	Ability to present arguments clearly and defend opinions logically (explanation) after using ChatGPT	Components of Critical Thinking Ability	X2.5
8	Ability to manage time and resources wisely when evaluating and responding to arguments (self-regulating) after using ChatGPT	Components of Critical Thinking Ability	X2.6

The answers to each questionnaire instrument in this study used a Likert measurement scale. The Likert scale is a scale for measuring the attitudes, opinions, and perspectives of respondents about research variables [34]. The Likert scale is shown in Table.

Table 2. Likert Scale

Answer Criteria	Score
Very good (VG)	5
Good (G)	4
Acceptable (A)	3
Poor (P)	2
Very poor (VP)	1

Results and Discussions

Respondents were students of FEBI (Faculty of Economics and Islamic Business), FST (Faculty of Science and Technology), FSH (Faculty of Sharia and Law), FISHUM (Faculty of Social Sciences and Humanities), FUPI (Faculty of Ushuluddin and Islamic Thought), and FITK (Faculty of Islamic Studies, Tarbiyah and Teacher Training).

A. Validity Test

In this study, the calculation of item validity was analyzed using the SPSS 20 program. Table 3 contains the following results.

Table 3. Validity Test Results

No	Variable	*Person Correlation*	Value r table	Annotation
1	X1.1	0.253	0.213	Valid
2	X1.2	0,741	0.213	Valid
3	X2.1	0.668	0.213	Valid
4	X2.2	0.674	0.213	Valid
5	X2.3	0.681	0.213	Valid
6	X2.4	0.728	0.213	Valid
7	X2.5	0.789	0.213	Valid
8	X2.6	0.671	0.213	Valid

Based on the results of the validity test in the table above, the effectiveness and critical thinking skills components show a positive value in person correlation and significance at α > 0.05. The technique of using person correlation is a validity test analysis technique by correlating item scores and total scores [35]. This means that the respondents' answers to all items of the effectiveness variable and the critical thinking skills component are valid. So that the statements in the questionnaire can reveal something that will be measured by the effectiveness variable and the critical thinking ability component.

B. Reliability Test

In this study, the calculation of item reliability was analyzed using the SPSS 20 program. Table 4 contains the following results.

Table 4. Reliability Test Results

Variable	*Cronbach's Alpha*	Annotation
X1.1, X1.2, X2.1, X2.2, X2.3, X2.4, X2.5, X2.6	0.812	Reliable

Based on the table above, it can be seen that the Cronbach alpha produced in the research variable is 0.812. Cronbach's alpha is the most frequently used measure of reliability in

describing the consistency of a questionnaire item [36]. The scale of an item can be said to be quite reliable if Cronbach's Alpha value is equal to or more than 0.50 to 0.60 [31]. This means that all question items in each variable are reliable enough to explain each research variable. So it can be concluded that the measuring instrument can consistently provide the same results or answers, even though it is used many times.

C. Descriptive Analysis

The analysis used in this study is the mean or average value of the measurement scale on the two indicators to describe the results of the answers. This data was obtained by distributing questionnaires to UIN Sunan Kalijaga students via an online Google form questionnaire to support the effectiveness and influence of ChatGPT on students' critical thinking skills.

The following describes the answers to the respondent's questionnaire on the effectiveness variable. The results of the answers are in Table and Table.

Table 5. Average Effectiveness Variable Results

Variable	Question Items	Respondents Answer					Average (of 5)
		VP	P	A	G	VG	
Effectiveness	X1.1	0	5	37	36	7	3.52
Average (100%)		0%	5.9%	43.5%	42.4%	8.2%	

Table 6. Average Effectiveness Variable Results

Variable	Question Items	Respondents Answer					Average (of 5)
		VP	P	A	G	VG	
Effectiveness	X1.2	3	13	38	24	7	3.22
Average (100%)		3.5%	15.3%	44.7%	28.2%	8.2%	

From Table and table 6 above, it can be seen that the average level of student's critical thinking skills before using ChatGPT is 3.52 (acceptable) out of 5 measurement scales. Respondents who stated that they were very good were 8.2%, those who stated that they were good were 42.4%, those who claimed it was acceptable up to 43.5%, and those who said it was poor and very poor comprised 5.9% and 0%, respectively. The average level of student's critical thinking skills after using ChatGPT is 3.22% (enough) of 5 measurement scales. Respondents who said they were very good were 8.2%, those who said they were good were 28.2%, those who claimed it was acceptable up to 44.7%, and those who said it was poor and very poor comprised 15.3% and 3.5%, respectively. This shows that there is an average decrease in the percentage of critical thinking skills after using ChatGPT by 0.30%. So the dependence on using ChatGPT has an effect that harms the critical thinking skills of UIN Sunan Kalijaga students.

The following describes the answers to the respondent's questionnaire on the component variables of critical thinking skills (interpretation, analysis, evaluation, interference, explanation, and self-regulation). The results of the answers are in table 7, table 8, table 9, table 10, table 11 and table 12.

Table 7. Results of the Average Variable Components of Critical Thinking Ability

Variable	Question Items	Respondents Answer					Average (of 5)
		VP	P	A	G	VG	
Components of Critical Thinking Ability	X2.1	1	6	33	35	10	3.55
Average (100%)		1.2%	7.1%	38.8%	41.2%	11.8%	

Table 8. Results of the Average Variable Components of Critical Thinking Ability

Variable	Question Items	Respondents Answer					Average (of 5)
		VP	P	A	G	VG	
Components of Critical Thinking Ability	X2.2	0	5	13	43	24	4.01
Average (100%)		0%	5.9%	15.3%	50.6%	28.2%	

Table 9. Results of the Average Variable Components of Critical Thinking Ability

Variable	Question Items	Respondents Answer					Average (of 5)
		VP	P	A	G	VG	
Components of Critical Thinking Ability	X2.3	0	16	35	27	7	3.29
Average (100%)		0%	18.8%	41.2%	31.8%	8.2%	

Table 10. Results of the Average Variable Components of Critical Thinking Ability

Variable	Question Items	Respondents Answer					Average (of 5)
		VP	P	A	G	VG	
Components of Critical Thinking Ability	X2.4	0	11	27	37	10	3.54
Average (100%)		0%	12.9%	31.8%	43.5%	11.8%	

Table 11. Results of the Average Variable Components of Critical Thinking Ability

Variable	Question Items	Respondents Answer					Average (of 5)
		VP	P	A	G	VG	
Components of Critical Thinking Ability	X2.5	0	7	34	34	10	3.55
Average (100%)		0%	8.2%	40.0%	40.0%	11.8%	

Table 12. Results of the Average Variable Components of Critical Thinking Ability

Variable	Question Items	Respondents Answer					Average (of 5)
		VP	P	A	G	VG	
Components of Critical Thinking Ability	X2.6	1	4	35	31	14	3.62
Average (100%)		1.2%	4.7%	41.2%	36.5%	16.5%	

From table 7 to 12 above, then a search process for the total average (mean) of the six questions is carried out using the mean formula [37]. Equation (1).

(1)

$$mean = \frac{3.55 + 4.01 + 3.29 + 3.54 + 3.55 + 3.55 + 3.62}{6}$$

$$mean = 3.593$$

So based on the calculation above, the result is 3.593, or enough on the Likert scale. This means that ChatGPT is quite influential in improving critical thinking skills. The results of this study have similarities with research conducted by [38] which stated that ChatGPT provides many benefits for students, such as providing information, and useful resources and helping to improve language skills, including grammar, vocabulary, and writing style. Likewise, research conducted by [39], [40], and [41] both show that ChatGPT has a good effect, especially in its use in education.

Conclusion

Based on the results of our research, it can be concluded that dependence on using ChatGPT has an unfavorable effect on the critical thinking skills of UIN Sunan Kalijaga students. This is consistent with data showing a decrease in critical thinking skills, before using ChatGPT by 3.52% and after using ChatGPT by 3.22%. Even so, ChatGPT has a positive influence on students' critical thinking skills based on the components proposed by Facione. Evidenced by the results of this study which showed a sufficient effect of 3.593. Students need to continue to develop critical thinking skills independently and use ChatGPT as a tool that needs to be evaluated critically. In the Education system, it is important to take proper steps in integrating ChatGPT to ensure that its use does not harm the learning process of students. With the right approach, ChatGPT can be an influential source of information in developing students' critical thinking skills.

Due to limited time and resources, the researcher suggests that future researchers conduct research on ChatGPT with issues that are currently being discussed using a larger number of samples and a wider range. Researchers also suggest to activists in the fields of education and technology to strive for ChatGPT integration to support the teaching and learning process.

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Modelling spatio-temporal energy consumption from nighttime radiance satellite dataset

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Abstract: National electricity consumption increases in line with continuous population growth and other socio-economic factors. The national electric power capacity goal develops largely for industrial manufacture and new settlement. The electrification- ratio on the target; is based on the accessibility of electricity services. The spatial distribution of electricity services coverage over the Indonesian territory is insufficient, particularly over the remote area that is out of electric services. Modeling by spatial (location) and temporal (year) to estimate electricity or energy consumption is necessary to develop using a low-light nighttime satellite dataset, therefore spatial boundaries can be accomplished. The modeling procedure starts by preparing the data frame of the independent variable input (amount of radiance) and the dependent variable output (the consumption of electricity or energy). The modelling method uses the curve-fitting approach where the indicator results by evaluating the R-square and RMSE values. The output model function is used to convert radiances into electrical power consumption units with a certain degree of accuracy. The selection of the input-output variable was achieved after variable analysis with the highest R-square outcome. Results indicate that the model functions in a polynomial form and correlations between variables are not simple. The selection of various model functions did not change the degree of correlation. The accumulative of energy radiances as independent variable input provides the optimum correlation result. The energy consumption from street lighting, in general, offers appropriate information that can be seen from satellites. The model function can be applied to a narrower spatial scale by input variable constraints.

Keywords: curve fitting, energy consumption, modelling, NTL nighttime, radiances

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Introduction

Energy and electricity demand grows continuously in line with the world or national population growth, foreign tourist arrivals, and other socio-economic factors. According to the national statistical agency [1], [2], Indonesia has a national population growth of about 1.27%. The national electric power capacity of 35,000 MW mainly has emphasized the manufacturing industry supply and development of the new settlement. The national electrification ratio had claims of 95% in 2017 based on the accessibility of people to get electricity services, not from the distribution of spatial distribution of electricity service coverage to the territory of Indonesia. Therefore, remote areas that require electricity services are not covered by this electrification ratio. Bali's tourism industry has a growth rate of about 23.14% and electricity demand continues to increase by about 8.49% per year [1]. Bali tourism is concentrated in the southern part of Bali Island, at Denpasar City and Badung Regency. This condition brings the disparity of electricity distribution that results in constraints in developing new tourism areas, generally located in remote areas.

Remote sensing satellites (RS) satellites are widely used for wide-area and even global coverage issues. RS has the capability of temporal, multi-spectral, and multi-polarization, and many types of sensors can be carried. Specifically, SRS low-light nighttime imagery carries a Photo Multiplier Tube (PMT) a passive panchromatic sensor of low-light imaging that is operated on a 0.47-0.95 μm spectral channel which is useful for observing low light at night on the surface of the earth [3], [4]. Nighttime light can be used as an indicator of human activity that can be measured from satellites and is suitable for mapping various settlement problems [5]. Applied in

the socio-economic field [6]. Modelling of spatial distribution and human population growth [7], overall electricity and energy consumption [8], economic growth rate [9], gas emissions from anthropogenic [10], and estimation of various other parameters [11].

The spatio-temporal dynamics of electricity consumption on a global scale have been reported in [12] using The Defence Meteorological Program (DMSP) Operational Line-Scan System (OLS) data, calibrated radiances of nighttime light (NTL) and global electricity consumption from World- bank. The results show that using calibrated radiances modified invariant region (MIR method) gives better results in estimating electricity consumption [13]. However, the input model does not include other socio-economic factors. Investigators [14] analyzed the spatio-temporal dynamics of electric power consumption on an urban and sub-urban scale in China by including NTL DMSP OLS data, vegetation index, socio-economic factors such as population and GDP from NASA's socioeconomic data and application center, and electricity consumption in China. However, the supporting dataset is not as input for modelling to estimate electricity consumption, but just for calibrating the NTL pixel. Researchers [15] use NTL DMSP OLS data in Indonesia by assessing the electrification progress of the NTL brightness level and showing the imbalance between the percentage of electrification in Java-Bali and other regions. However, it does not perform calibration processing and consumption of electric power modelling [16], [17].

Previously the method of predicting the growth rate of electricity consumption was only based on customer growth, GDP, and other socio-economic factors, and the electrification ratio was only based on the accessibility of the public to get electricity services. This paper will model spatially (based on location) and temporally (based on time/year trends) national electricity consumption in general, low-light SRS data at night. The results of the model will be able to be used to estimate trends in electricity consumption in a specific region (spatial). Besides, it specifically examines the electrification of ratios in Bali Province related to the development of new tourist destinations that require electricity networks. With this study, developing electricity infrastructure can be straightforward. Because model results can be used to estimate energy demand rapidly from satellite data.

Methodology

The outline of the modelling procedure is shown in Figure 1. The modelling step consists of twelve procedural blocks. The RS NTL dataset uses two operational satellites with NASA's NTL mission, i.e., DMSP OLS year 1992 until 2013 (22 years) and the Visible Infrared Imaging Radiometer Suite (VIIRS) year 2012 present [18]. The dataset is available in the global mosaic form (6 tile-scenes). The mosaic procedure results are subset into Indonesian territory (6oN-11oS, 95oE- 141oE) [4]. The modelling uses an annual scale of a dataset, the aggregation procedure is required for datasets that are not on an annual scale. The DMSP OLS dataset radiances require calibration procedural to eliminate saturation and inter-annual discrepancy from inter-change satellite missions [13]. The calibration procedure uses the modified invariant region (MIR) method [12]. The MIR method requires an NTL radiances composite dataset calibrated with regions known to have NTL level stability. Investigators in [12] use Japan as a calibration region. This paper uses their published calibration constants for the calibration procedure.

Figure 1 shows block process number 3 is MIR NTL calibration. MIR is a power regression function as seen in Equation (1), where NTLcorr is corrected NTL with a=5.400 and b=0.462 are parameters that had been obtained in [12].

$$NTL_{corr} = \left(\frac{NTL}{a}\right)^{\frac{1}{b}} \quad (1)$$

Block process number 4 is an aggregation of corrected NTL bases on each regional province of Indonesia per year. Every pixel on the NTL dataset had been tagged with their province-regency ID and year. Therefore, aggregation of corrected NTL solves as Equation (2).

$$NTL_{ID,YEAR} = \sum_{ID,YEAR} NTL_{corr} \quad (2)$$

The next procedure uses spatial analysis of the Indonesian province spatial data for spatial statistics or zonal statistics of each province in Indonesia from the calibrated radiances dataset [19]. The zonal statistical results measure 34 (rows) of provinces, in 29 years, and 6 statistical quantities of calibrated radiances (columns). This dataset becomes the independent variable (x) in the modelling i.e., the value of minimum (xmin), maximum (xmax), range (xrange), xmean (mean), standard-deviation (xstd) and accumulative (xsum) of radiances NTL.

The zonal statistics are shown as block process number 6 in Figure 1. For short, zonal statistics are described as follows, $NTL_{minimum}$ is minimum value of NTL, $NTL_{maximum}$ is the maximum of NTL, NTL_{range} is NTL maximum minus NTL minimum, NTL_{sum} is the summation of NTL concerning their province ID and year. While NTL_{mean} is the averaging of NTL and NTLstd is the standard deviation of NTL shown in Equation (3) and Equation (4).

$$the\ NTL_{mean} = \frac{\sum_1^n NTL_{corr}}{n} \tag{3}$$

$$NTL_{std} = \sqrt{\frac{1}{n}\sum_1^n (NTL_{corr} - NTL_{mean})^2} \tag{4}$$

The dependent variable (y) results in processing electricity and energy statistical data which became available from the year 2006 [1], [2]. Meanwhile, the NTL DMSP OLS data available from the year 1992 [4], [13]. Consequently, the modelling uses only the dataset from 2006, in 13 years. This dataset consists of 34 (rows) of provinces, in 13 years, and 7 types of customers (GWh) or 6 types of energy (kilolitres) (columns) i.e., power electricity of all costumers' sector (ypel), household (yrt), industrial (yin), commercial (yko), government (ygd), social (yso) and street-lighting (yjl). Modelling uses only 80 percent of these datasets for training models and the rest for testing models. The development of the model uses a fitting curve training process [20]. Several experiments were performed to obtain the suitable functions and parameters of the model. The model function will be in the form of a polynomial, power, or sum of sine [21].

The purpose of experiments gain the highest correlation coefficient between the independent variable (x) and the dependent variable (y). There are 6 statistical quantities of calibrated radiances as an independent variable (x) and 7 types of customers or 6 types of energy as a dependent variable (y). The model candidate was then tested to validate the model using the test dataset. The root means square error (RMSE) is used as an indicator of validation. The validated model as a national scale model was then applied to a smaller spatial scale i.e., Bali province. This implementation procedure analyses any deficiency of the model.

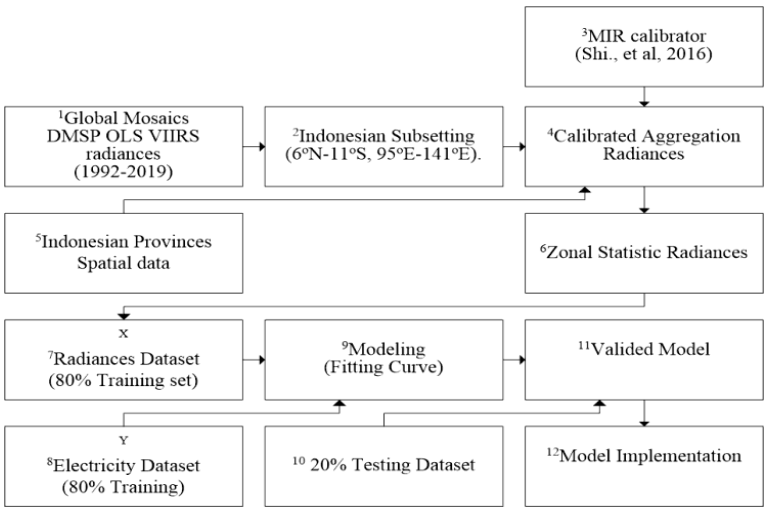

Figure1. The modelling procedural

Results and Discussions

Profiling of dataset

The profiling of the dataset is useful to identify the characteristics of each index. Figure 2 shows the accumulated energy radiances of NTL at a pixel (sum). The sum of NTL increases gradually until the year 2013. However, the sum of NTL seen has two distinct profiles. This is due to the dataset of NTL consisting of two types of NASA's NTL satellite mission. Starting from the year of 2012 the satellite NTL mission changes from the DMSP OLS to the VIIRS program mission. Unfortunately, there is no valid inter-satellite calibration for both missions [22]. The accumulated energy radiances of NTL dominate from Java Island where the West Java Province is known as the main industrial concentration. Figure 3 shows the electric power consumption in the unit of GWh. The trend of electric power consumption increases gradually corresponds with accumulated energy radiances of NTL. Figure 4 shows the energy (coal) consumption in unit Ton. The energy consumption also corresponds with both of the indices above. If looks at the mean of the NTL dataset for several provinces is described as follows. DKI has the highest mean NTL value (2.0 – 2.5e+02 $nWcm^{-2}\mu m^{-1}sr^{-1}$) and other provinces have an average of mean NTL below 0.5e+02 $nWcm^{-2}\mu m^{-1}sr^{-1}$.

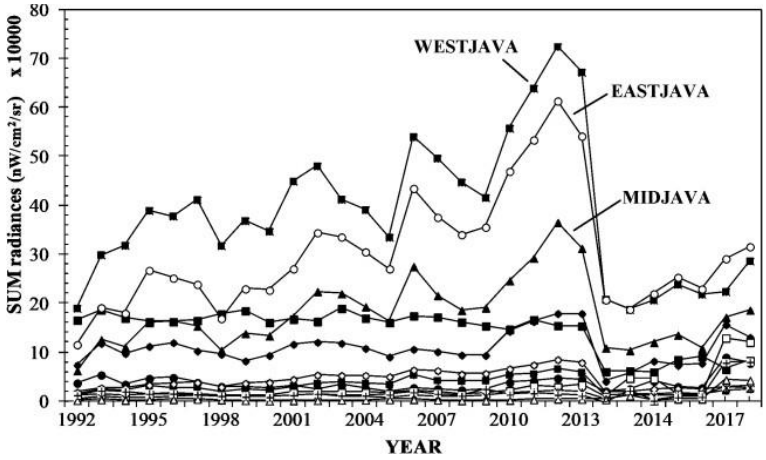

Figure 2. Profile of accumulative radiances dataset (sum)

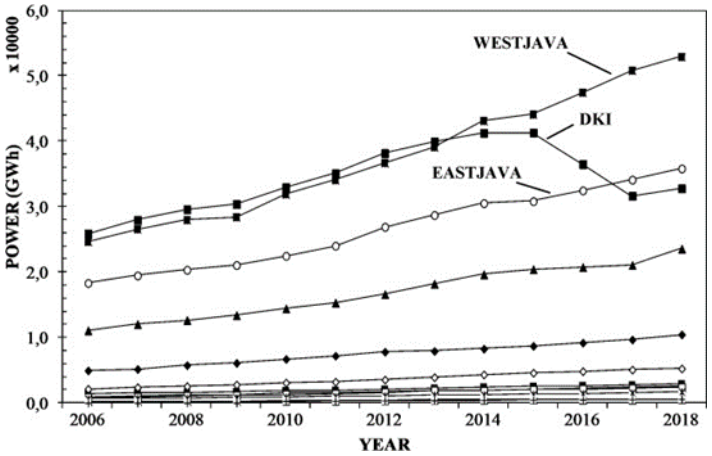

Figure 3. Profile of electric power consumption dataset (GWh)

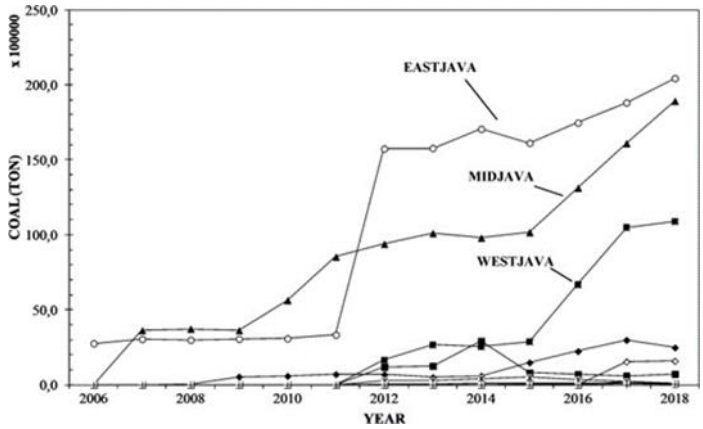

Figure 4. Profile of energy (coal) consumption dataset (Ton)

Curve-fitting experiments

The first, curve-fitting experiment sets the independent variable x as xmean radiances of NTL and the dependent variable y as the consumption of electrical power for all types of customers. After several curve-fittings experiments obtained the result as in Table 1. Overall, the R-Square is around 0.25 (low) and the selection of curve-fitting function does not provide a significant change in correlation results. The next, curve-fitting experiment sets the independent variable x is xsum radiances of NTL and the dependent variable y is ypel (the consumption of electrical power based on all customers). The results are as shown in Table 2. The R-Square is around 0.50 (adequate) and again the selection of curve-fitting function does not provide a significant change in correlation results.

Table 1. Summary of modelling experiment results for variable ypel against xmean

Curve Fitting	SSE	R Square	DFE	Adj R Square	RMSE	Coeff
Polynomial deg.1	2.63e+10	0.23	432	0.23	7.80e+03	2
Polynomial deg.2	2.62e+10	0.23	431	0.23	7.80e+03	3
Power nterms 1	2.49e+10	0.27	432	0.27	7.59e+03	2
Power nterms 2	2.47e+10	0.28	431	0.27	7.58e+03	3
Sum of Sine nterms 1	2.63e+10	0.23	431	0.23	7.81e+03	3

Table 2. Summary of modelling experiment results for variable ypel against xsum

Curve Fitting	SSE	R Square	DFE	Adj R Square	RMSE	Coeff
Polynomial deg.1	2.08e+10	0.48	440	0.48	6.87e+03	2
Polynomial deg.2	1.99e+10	0.51	439	0.50	6.73e+03	3
Power nterms 1	2.03e+10	0.50	440	0.49	6.80e+03	2
Power nterms 2	2.02e+10	0.50	439	0.50	6.78e+03	3
Sum of Sine nterms 1	1.99e+10	0.51	439	0.50	6.73e+03	3

Variables analysis

The two experimental results above (Table 1 and Table 2) show the relationship (correlation) between the NTL radiances with electricity consumption is not simple. The xsum radiances of NTL as an independent variable provide a better correlation approach. Furthermore, variable analysis is performed to determine the modelling parameter. The first analyzed performance with the dependent variable ypel (electric power consumption for all consumers GWh) is fixed and the independent variables x are varying for all statistical indexes of the radiance NTL dataset (nWcm-2µm-1sr-1). The model function uses polynomial degree 2 which provides the highest correlation (according to the highest R square value in Table 2). Results show in Table 3, xsum provides the highest R square.

Table 3. R-square results of the variable analysis with fixed ypel

ypel	xmin	xmax	xrange	xmean	xstd	xsum
R Square	0.03	0.07	0.07	0.34	0.16	0.51

The next analyzed fixed of independent variable xsum (according to the highest R square value in Table 3 above) with various of dependent variable y (GWh) for all types of electricity consumers and model function stick to polynomial degree 2 giving the R square results as Table 4 follows. The highest R square gained from yjl (the highway lighting consumer type).

Table 4. R-square results of the variable analysis with fixed xsum

xsum	ypel	yrt	yin	yko	ygd	yso	yjl
R Square	0.51	0.52	0.54	0.20	0.16	0.38	0.55

Modelling development

Model development determines the model function and its parameters. From variable analysis results, the model will develop using a polynomial degree-2 function with xsum as an independent variable and yjl as a dependent variable. The model has a national-scale scope and the curve-fitting plot result is shown as follows in Figure 5. In the figure, black points are scattering of xsum against yjl and the line is the fit curve of the model. The curve-fitting result gives the equation of the power consumption model (EPGWh) in Equation (5).

$$EP_{GWh} = p1 * NTL^2 + p2 * NTL + p3 \quad (5)$$

Where constants as follows: $p1 = -21.28;\ p2 = 154.8;\ p3 = 113.2$

Equation (1) requires normalizing of input NTL with the mean value of 7.42e+04 and the standard deviation value of 1.093e+05. Before entering Equation (1) above, NTL must be normalized by Equation (6) below.

$$nNTL = (NTL - 7.4e + 04)/1.093e + 05 \quad (6)$$

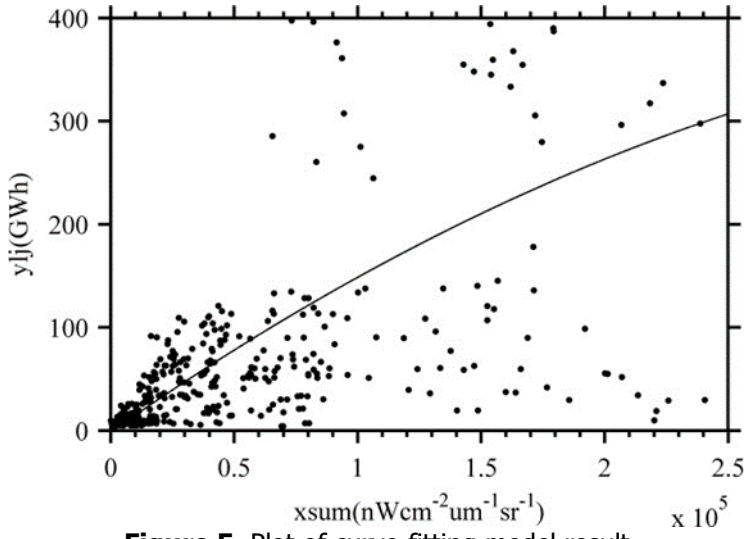

Figure 5. Plot of curve-fitting model result

Model validation

Furthermore, the model function results were validated using RMSE computation. RMSE is computed from differences (error) of EPGWh results with statistical data (BPS) of electricity consumption per province as in Equation (7).

$$RMSE = sqrt(mean(EP_{GWh} - BPS)^2) \quad (7)$$

As a result for the national-scale case, the RMSE has about 89.63 GWh. This value is lower than the mean value of the input dataset to the model. For more clearly comparison of the validation process, again it is shown in Figure 6. In the figure, the lines are the electrical power consumption of the original dataset and the black point is the scatter of output model results. As seen in Figure 6, the original dataset of electrical power consumption (straight line) quite coincides with the model output results (dots). The modelling achieved RMSE 11.56%, this result comparable with the investigator [7], who revealed RMSE 15% in a related study.

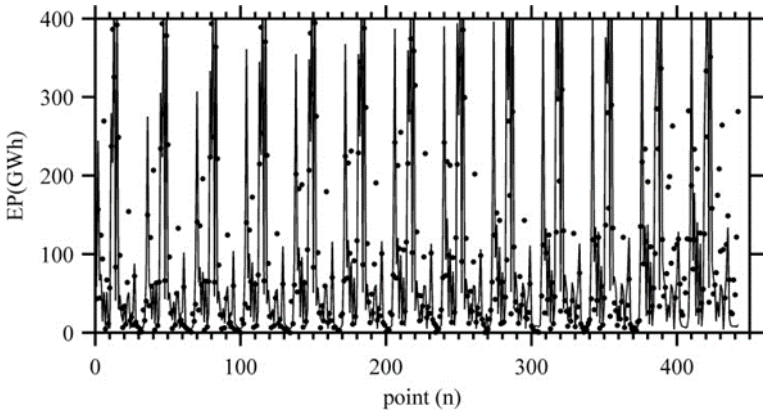

Figure 6. The plot of the model validation result

Model implementation and constraints

The modelling of energy or electrical power consumption from radiances of satellite datasets has huge potential in the application. In this paper, the model that was developed will be implemented into a narrower spatial-scale dataset and discuss the model constraint. As the most tourism industry, Bali province is greatly growing in electrical energy demand. Therefore, a yearly significant change in NTL can be easy to observe from the satellite. The model will be tested to obtain the electrical power consumption of all regencies of Bali province from radiances of satellites as an input of dataset periods from year 1992 to 2019. Results are shown in Figure 7. In the

figure, the line on the graph indicates the electrical power consumption for each region of Bali province. As expected, the main cities regencies of Bali province i.e., Denpasar, Badung, and Gianyar show the highest energy consumption. Other regencies that have lower accumulative radiances about 1000 $nWcm^{-2}um^{-1}sr^{-1}$ cannot estimate output results by the model. This is due to the model developed using the national scale of the dataset that has a high mean accumulative of radiance as an independent variable.

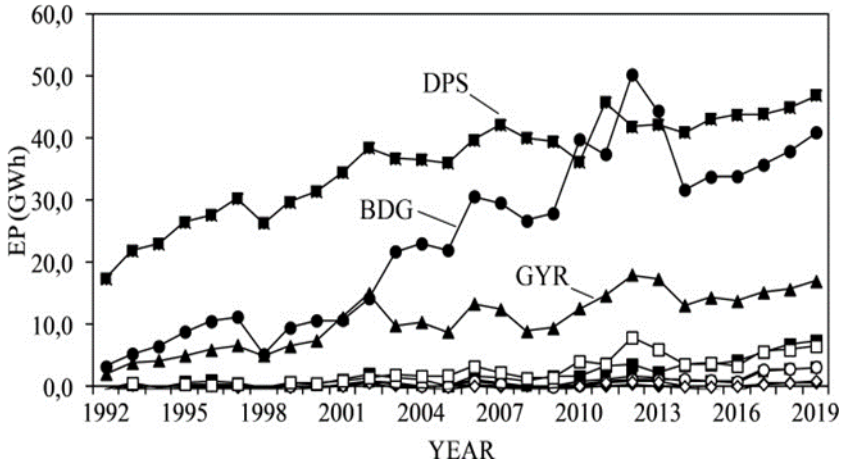

Figure 7. Model implementation

Forecasting

The electrical power load forecasting purposes to plan the optimal power generation. In forecasting, the study requires the observation or measurement data, state data or estimate from the model (this manuscript result), and optimally from both those data (the Kalman's based filter) [23]. The forecasting method can be used in the Auto-Regressive Integrated Moving Average (ARIMA) model [24].

Conclusion

Estimation of energy consumption from nighttime radiances of satellite dataset aims to rapidly obtain results within a wider area even globally. Modelling can be used to convert the nighttime radiances of satellites into energy consumption units with a certain degree of accuracy. The modelling procedure starts by preparing the dataset of the independent variable input (amount of radiance) and the dependent variable output (the consumption of electricity or energy). The relationship equation between variables is approached from a curve-fitting experiment. The variable analysis was used to select an approved variable with a large R-square outcome and validated with RMSE. Naturally, the model is in a polynomial form, and correlations between variables are not simple. The selection of various model functions did not change the degree of correlation. The accumulative of energy radiances as independent variable input provides the optimum of correlation result. The energy consumption from street lighting, in general, offers appropriate information that can be seen from satellites. The model function can be applied to a narrower spatial scale by considering input variable constraints. This study presents a novel method to estimate energy consumption rapidly with great accuracy. The model archives an RMS error of about 11.56%. The estimated energy consumption of Bali province from this model implementation makes the development of electricity infrastructure straightforward in the future.

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