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The Effectiveness of the Headway for The Jakarta MRT during the Covid-19 Pandemic

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Abstract: Population growth and mobility continues to increase, encouraging the DKI Jakarta provincial government to develop a public transportation called Jakarta Train Integrated Raya Mode (MRT). Covid-19 pandemic at the beginning of 2020 resulted in the decline of the economy throughout the world, including Indonesia. The policies made by the government in limiting community mobilization have an impact on decreasing cash flow in the transportation service sector, such as, MRT Jakarta. PT. MRT Jakarta (The MRT Management) then implemented changes to the train headway that was adjusted to the current pandemic conditions by considering policies from the government and income during the pandemic. This paper discusses the use of electric power in the MRT headway from a technical and economical perspective in order to find the ideal advice in operating trains during the pandemic. This is an empirical research using prescriptive primary materials through interviews and valid data obtained from the research institution and an assessment of literature studies that are relevant to the problems that have been studied. The results showed the amount of electrical power used by the MRT trains from Lebak Bulus Station (LBS) to Bundaran Hotel Indonesia (BHI) station using 6 trains in one series, namely, 400.564 kWh with an average consumption of electrical energy before the pandemic reached 3,163,654 kWh per month. During the pandemic, the use of MRT energy reached 1,913,037 kWh per month. The results showed that the electric power when using 4 trains in a series is 178.568 kWh. The implementation of the train headway before the pandemic indicated an effective value since this was accompanied by high ticket sales. However, during the pandemic, the electricity consumption of the MRT train has not reached an effective value and the income from ticket sales has not been able to meet the cost of electricity bills. To maintain the effectiveness, changes in the minimum account value be readjusted by the MRT Management and PLN by adjusting the policies set by the government during the pandemic. The MRT train headway pattern was then realigned with service users and policies set by the government so the electrical energy costs could be effective. Finally, the use of 4 trains in a series of the MRT trains when traffic is low may reduce power consumption of 221.996 kWh. However, the use of 4 trains means may cause there are no replacement trains during the MRT operations.

Keywords: Effectiveness, MRT Jakarta, train electric power, Covid-19

INTRODUCTION

Rapid population growth and very high population mobility put Jakarta in the 10th most congested city out of 416 countries in 2019 due to a survey from the UK traffic congestion monitoring agency called Tom Index. With the congestion problem, the Provincial Government of the Special Capital City Region (Pemprov DKI) Jakarta seeks to use mass transportation, the construction of the Integrated Mode of Raya (MRT) [1]. The MRT Jakarta is projected to be able to transport 173,000 people per day in the first year of operation) and was able to reduce CO_2 emissions from burning vehicle fuel by 30,000 tons by 2020. With the existence of the MRT, it is really expected that people will use public transportation to overcome congestion in the capital. As previously mentioned, in the first year of operation, the MRT implemented a headway between trains at peak hours every 5 minutes and during normal hours every 10 minutes. Headway itself has an understanding as the time interval for transportation facilities to pass through a stop.

Unfortunately, Covid-19 has hit all over the countries in the World [2] since the end of 2019 and an impact of the pandemic has led to a reduction in the MRT train route, which is in accordance with the policies of the DKI Jakarta Provincial Government in controlling the mobility of its people. On the other hand, the pandemic caused a decline in the MRT management from ticket sales or farebox. Under normal conditions, the MRT train operates from 05.00 am to 12.00 pm, it changes from 05.00 am to 09.00 pm with flat train operations so there is no rush hour during this pandemic. With this pandemic condition, the MRT management is trying to implement effective policies in the operation of trains. One of them is to change the train headway and reducing operating hours. On the other hand, the management as a BUMD (Regional Owned Enterprises) in the transportation sector belonging to DKI Jakarta must fully support the government's efforts in suppressing the spread of the Covid-19 virus. Effectiveness relates to the degree of success of an operation in the public sector so that the policy can be effective if it has a major influence on the ability to provide public services according to the predetermined targets. This paper discusses the analysis of the effectiveness of MRT progress from a technical and economic perspective in order to find ideal suggestions for operating trains during the pandemic. The pandemic at the beginning of 2020 resulted in a decline in the level of mobility and the economy of the community. The MRT management implemented a limited MRT train operating system. The paper only deliberates the use of electric power by the MRT trains during peak and normal hours before and during the pandemic. It also converses the relationship of the economic value obtained from ticket sales with the costs incurred for the power used by the train when operating.

The results showed that the power required by a series of the MRT trains from LBS to BHI Station with a distance of 14.6 km when using 6 trains in one series is 400.564 kWh, while the power required when using 4 trains in a series is 178.568 kWh. The average electricity consumption of the MRT train before the pandemic, from September 2019 to March 2020, reached 3,163,654 kWh, while during the pandemic, which started from April 2020 to October 2020, it was 1,913,037 kWh. The implementation of the headway before the pandemic has been effective with energy consumption of only of the minimum account. Meanwhile, during the pandemic from April 2020 to May 2020, the electricity consumption of the MRT train was very low, but in June, July and August 2020 it was very high. The cost of electrical energy of the MRT is based on the minimum account value consisting of installed power and running hours. The electricity tariff charged is non-adjustment of Rp.1,051.74/kWh. During the pandemic from April 2020 to October 2020, the implementation of the MRT headway train underwent changes in line with the policies set by the government. Ticket sales during the declining pandemic have not been able to meet the cost of electricity bills, causing the MRT management suffered losses. This showed the application of the headway has not reached an effective and efficient value. The consumption of electrical energy in April and May 2020 is still very small. Meanwhile, in June, July and August 2020, electricity consumption was almost 100% of the minimum account value, so additional costs were required to pay for non-traction electricity (depots and stations). Ticket sales in September and October 2020 have not been able to meet the electricity bill charged to the management. Due to the previously mentioned problem, the suggestions submitted are the changes in the minimum account value be readjusted by the management and PLN by amending the policies set by the government during the pandemic. During the pandemic, the MRT train headway pattern may be readjusted with service users and policies set by the government so that electrical energy costs could be effective. The use of 4 trains in a series of MRT trains when traffic is low can reduce power consumption by 221,996 kWh. Unfortunately, the use of 4 trains may result in the absence of a backup system for the train propulsion system.

LITERATURE REVIEW AND THEORY

Jakarta's integrated raya mode (MRT)

The MRT trains has operated since March 24, 2019 with a 14.6 km line construction from LBS to the BHI and contain 7 elevated stations and 6 underground stations including one depot area of 8.5 hectares in Lebak Bulus [1]. In one train series, the MRT consists of 6 trains with a Communication Based Train Control (CBTC) signaling system and an automatic train operating system with Grade of Automation 2 (GoA 2). Have been previously mentioned, Covid-19 simultaneously spreads everywhere including Indonesia and covers almost all countries in the world since the end of December 2019 starting from Wuhan China [2]. Indonesia confirmed positive cases of 1,476,452 people on 18 of October 2021 with a death toll of 39,983 people and the case fatality rate is around 2.7%. in the middle of 2020, PSBB or Large-Scale Social Restrictions were implemented by the Government of Indonesia to limit the population in an area suspected of being infected with Covid-19 to prevent the possible spread of the virus. The local regulation basically based on standard operational procedure decided by the World Health Organization (WHO) taking into account operational technical, political, economic, social, cultural, defense and security considerations given by the government. The pandemic has surely influenced on the operation of all public transportation in the country, specifically for the MRT and KRL. As previously mentioned, KRL is one of the railway facilities that has its own propulsion called a traction motor and applies an electric power source. KRL gets its electricity supply from the traction substation through the overhead power grid (LAA). The power source used is 1,500 Vdc and is transmitted via a contact wire that is directly connected to the pantograph. This power source is then converted into AC voltage to supply the traction motor [4].

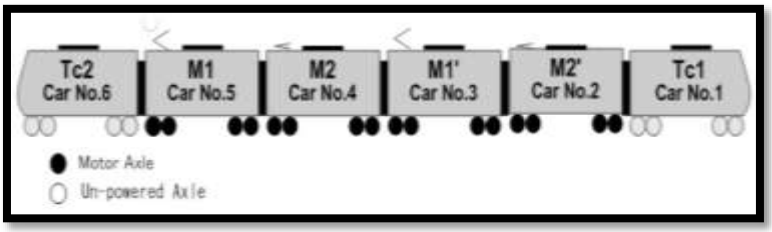

Figure 1. MRT train arrangement [5].

As seen in Figure 1, the MRT train series consist of two types of trains, namely, the motor car (MC) which is the part of the train with a drive and the trailer car (TC) which is the part of the train without the driver. Table 1 deploys the mass design of the MRT train according to the conditions of average weight (AW) and the mass of passengers.

Table 1. Mass of MRT train Jakarta [5].

Train	Tc1	M1	M2	M1’	M2’	Tc2	Total
Seats	48	54	51	54	51	48	306
AW0 (ton)	31.20	35.80	35.50	35.80	35.50	31.20	205

AW2 (ton)	38.82	44.08	43.78	44.08	43.78	38.82	253.56
AW3 (ton)	49.92	55.42	55.72	55.72	55.42	49.92	322.12

Notes :
AW0 = without passengers but with complete train equipment
AW2 = AW0 + passenger seat + standing passenger with average 3 persons/m^2
AW3 = AW0 + passenger seat + standing passenger with an average of 8 people/m^2
Passenger weight: 60 kg/person

Table 2. Spesification of MRT train Jakarta [5].

Specification	Information
Number of trains per set	6 trains per a trainset
Composition of train	Tc1-M1- M2-M1'- M2'- Tc2
Traction of motor rating	126 kW continous 140 kW one hour rating
Traction system	
a. Voltage	1.100 Vac
b. Type of pantograph	Single arm pantograpgh
Maximum of speed	
a. Over pass	100 km h^{-1}
b. Tunnel	80 km h^{-1}
Maskimum axel load	14 ton
Acceleration	0.92 m s^{-2}
Deccelaration	Service brake : 0.82 m s^{-2} Emergency brake : 1 m s^{-2}
Doors	4 doors in one side
Dimnesion of train	L : 20,000 mm (intermediate car) W : 2,950 mm H : 3,655 mm (rail head-roof)
Capacity in one trainset	Tc : 308 and M : 338
Material of carbody	Stainless steel
Additional features	Pneumatic brake dan regenerative brake Bolsteer – less bogie Electrical door system Emergency door at each of the trainset
Length	20.5 m
Width	2.95 m
Weight	
Trailer car Motor	27.7 ton 35.7 ton

An induction motor is an electrical device that converts electrical energy into mechanical energy as well as electricity into 3-phase electricity. Induction motors are also known as asynchronous motors or asynchronous motors. When the phase U voltage enters the stator winding making the S (south) pole, the magnetic lines of force flow through the stator, while the other two poles are N (north) for the V phase and the W phase and the compass will attract each other with the S pole. The S pole then moves to the V phase, the compass rotates 120^0, and the S pole moves to the W phase, so that in the stator winding a rotating magnetic field arises and the compass will rotate again to 240^0. The events take place alternately to form a rotating magnetic field so the compass rotates in one full rotation. This process runs continuously and in an induction motor, the compass is replaced by a cage rotor which rotates on its axis. Since there is a difference in rotation between the rotating field of the stator and the rotation of the rotor, it is then called an asynchronous induction motor or asynchronous motor [5]. Meanwhile, the risen speed of the rotating magnetic field on the stator can be calculated by the following formula [6]:

$$ns = (f \times 120)/p \quad (1),$$

$$Slip = [(ns - nr)/ns] \times 100\% \quad (2),$$

where ns and nr are the synchronous speed of the stator field and the rotor shaft (rpm), respectively. In addition, f and Slip are respectively the frequency (Hz) and the difference between the rotor and stator speeds. In calculating the input power of a 3-phase induction motor, it can be calculated by the following simple formula [6]:

$$P_{in} = \sqrt{3}\ x\ V\ x\ I\ x\ \cos\varphi \quad (3),$$

where, P_{in} and V are input power (watts) and voltage (volts) and I and Cos are current (A) and power factor. In the MRT, the traction motor used is a 3-phase squirrel cage induction motor. The motor is controlled by a Variable Voltage Variable Frequency (VVVF) inverter and drives the wheelsets to generate power and provide regenerative braking. Four units of traction motor current bank in each trainset are to supply the motor for wheel drive [7].

Regenerative braking of MRT

The MRT train has a regenerative braking system where during the braking process, the traction motor will turn into a generator by converting mechanical/kinetic energy into electrical energy [7]. The regenerative braking process on the MRT train arises when the train has a speed of 60.2 km/h until the train speed is 10 km/h. Apart from that speed, the MRT trains do not perform regenerative braking but pneumatic braking. The energy generated from the regenerative braking of the MRT has not been fully utilized and the energy is not stored in the battery but is transmitted back to the overhead contact wire (OCS).

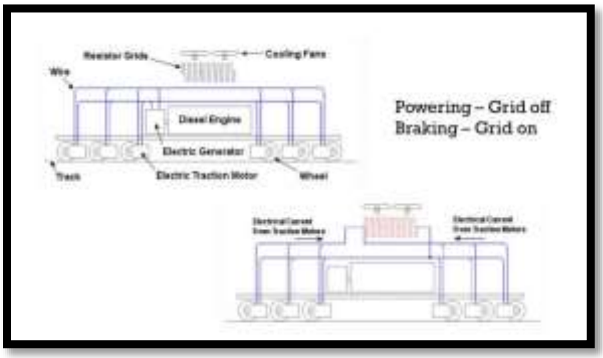

Figure 2. Regenerative braking on the MRT [7].

Here are some formulas that can be applied to estimate the power of regenerative braking for the MRT train. To compute all related speeds, distance, power and work of the previous matter, the following formulas can be utilized [7]:

$$v = \frac{s}{t} \quad (4)$$

$$v_t = v_o + at \quad (5)$$

$$s = v_o\, t + ½\, a\, t^2 \quad (6)$$

$$P = V \times I \quad (7)$$
$$W = P \times t \quad (8),$$

where, v, s and t are respectively speed (m/s), distance (m) and time (s). Meanwhile, v_t, v_o and a are final, initial and acceleration (m/s^2), correspondingly. At last, P, V, I and W are respectively power (watt), voltage (volt), current (A) and work (J). To estimate power of the MRT during regenerative braking, the following formulas have been applied [7].

$$\mu_{regenerative} = \frac{Wout}{Win} \quad (9)$$
$$P_{regenerative} = \frac{\mu\, regeneratif \; x \; m \; x \; v^2}{2\Delta t} \quad (10),$$

where, $\mu_{regenerative}$ = 0.93, W_{out}, power out (watts), W_{in}, power in (watts) and $P_{regenerative}$, regenerative braking power (watts).

Headway and Gapeka

Headway is defined as the interval or time lapse between the moment when the front of the train passes one point/a station to the time the front of the next train passes through the same point in minutes [4]. The signaling system used by the MRT train is a moving block signaling system and moving block is the concept of a moving block zone which is defined as the area from the tail of the next train to the previous train with a margin taken for safety. In the MB-STP moving block system, the previous train is always considered a wall [8]. In operation, to ensure the safety of train travel, there are several things that must be considered in determining the headway of the train, namely [9], a) the ability of the railway line that can be passed according to the railway facilities, b) the distance between two stations or blocks and c) operating facilities. In addition, the determination of the headway of the train must also pay attention to the demand to service, transport capacity and tariffs. This is related to operational costs that must be incurred. Under normal conditions, the MRT headway is 5 minutes apart during peak hours, namely, 07.00 am to 09.00 am and 05.00 pm to 07.00 pm and 10 minutes apart during peak hours. During this pandemic, the MRT train operates without a headway during rush hours.

The train travel chart, commonly called Gapeka, is a guideline for regulating the implementation of train travel which is depicted in the form of a line showing the station, time, distance, speed, and position of the train journey starting from departing, crossing, successive, and stopping which are graphically depicted for controlling train travel [10, 11]. During this pandemic, the MRT management applied a different operating pattern than usual. Changes in the MRT train operating pattern can be seen in Table 3.

Table 3. Pattern of the MRT operation [11].

Pattern of operation	Gapeka	Operation time	Number of trips	*Headway*	Number of train set	Date operation
Normal	Gapeka Weekend	05.00–00.00	219	Flat 10 min.	7	1 – 15 Mar. 2020 dan 17 – 22 Mar. 2020
	Gapeka Weekday		285	Peak hour 5 min. Off peak 10 min.	14	
Policy of PSBB during the pandemic	Gapeka Special 01	06.00 – 20.00	107	06.00 – 15.00 Headway 20 min. 15.00 - 20.00 Headway 10 min.	7	16 March 2020

	Gapeka Special 02	06.00 – 20.00	235	Peak hour 5 min. Off peak 10 min.	14	23 – 24 March 2020
	Gapeka Special 03	06.00 – 20.00	169	Flat 10 min.	7	25 March 2020
	Gapeka Special 04	06.00 – 20.00	157	Flat 10 min.	7	26 – 29 March 2020
	Gapeka Special 05	06.00 – 20.00	83	Flat 20 min.	4	30 March – 9 April 2020
	Gapeka Special 06	06.00 – 18.00	73	Flat 20 min.	4	10 – 19 April 2020
	Gapeka Special 07	06.00 – 18.00	49	Flat 30 min.	3	20 April – 4 June 2020
	Gapeka Special 08	05.00 – 21.00	189	Flat 10 min.	7	5 June 2020
	Gapeka Special 09 (weekend)	06.00 – 20.00	83	Flat 20 min.	4	6 June – 23 Aug. 2020
	Gapeka Special 10 (weekday)	05.00 – 21.00	249	Peak hour 5 min. Off peak 10 min.	14	6 June – 30 July 2020 12 October – 30 October 2020
	Gapeka Special 11 (weekday)	05.00 – 22.00	261	Peak hour 5 min. Off peak 10 min.	14	3 August - 16 September 2020
	Gapeka Special 12	05.00 – 20.00	175	Flat 10 min.	7	17 September – 20 September 2020
	Gapeka Special 13	05.00 – 19.00	163	Flat 10 min.	7	21 September – 11 October 2020

Minimum account

The minimum account is the minimum electricity consumption every month which is determined by the minimum running hours and installed power. For regular customers, the minimum on time is 40 hours.

Table 4. Subscription class for industrial sector [12].

Items	Premium				Reguler
	Premium	Gold	Silver	Bronze	
Services	2 sources 2 sub-station 2 sub-system	2 sources 2 sub-station 2 sub-system	2 feeder 2 transform. 2 sub-station	2 feeder 1 transformer	1 feeder
Minimum account	200	235	110	50	40
Load curtailment	No	Last order	No	Last order	Yes
Parallel generating customer	100%	100%	No	No	No
Reduction of bills due to load curtailment	Yes	No	Yes	No	Yes
Reduction of bills due to blackouts	Yes	Yes	Yes	Yes	Yes

Addition of tariff Rp/kWh	130	105	55	30	0
*Ultra premium services equal to premium services plus UPS (Uninterrupted power Supply)					

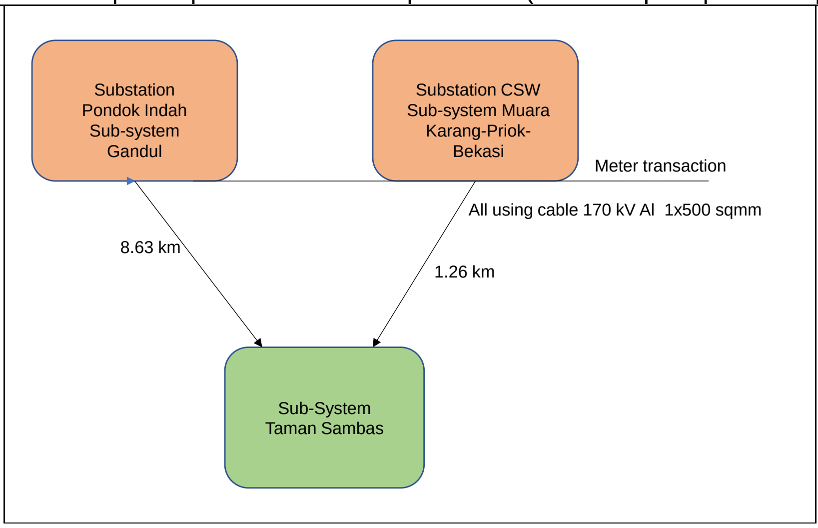

Figure 3. Power system of the MRT train [12].

Based on the Power Purchase Agreement (SPJBTL) between the PLN and the MRT management, the amount of installed power used by the MRT train is 60,000,000 VA. For the electricity tariff, the PLN charged to the MRT Management for Rp. 1,051.74/ kWh. Fortunately, the electricity tariff for the time of peak load and outside of peak load time is the same. Minimum light hours are very important in MRT travel and vary between 40 hours in May 2020, 70 hours from September 2020 to now and 110 hours on 21 December 2016 [13]. To compute the minimum account value, it can be implemented using the following formula [12]:

Min. account (kWH) = Installed power (VA) x Min. power-on hours (hours) (11).

In the MRT service users in the first year of operation, the Management was able to record significant new service users. The enthusiasm of the public in using the MRT train was from April 2019 to December 2019 and they are more than 23 million [1] and around 8.9 million from October 2020 to December 2020 [14].

RESEARCH METHODOLOGY

Research stages

The stages of the process that was carried out in this research are described in the flow chart can be seen in Figure 4 below. The stages of research in this thesis start from identifying problems regarding the operation of the MRT and all matters related to it, including the infrastructure and facilities and that of the MRT related to its operation. Then proceed with data collection, including data and information related to the use of MRT operating power, such as, how many trips occurred when the MRT train is operating, as well as primary and secondary information data. All the data were processed and analyzed in the results and discussion section so that a conclusion is finally obtained. The data achieved in the preparation of this study were carried out from documents owned by the MRT Management, literature journals and final assignments and interviews with power system maintenance engineers. The data which have been processed was used as a basis for knowing the amount of electrical power and costs required during the operation of the MRT train. The results of these calculations have been submitted to the MRT management for further related policies. In the process of researching this scientific paper, it is necessary to use the tools to analyze the calculation of the effectiveness of the MRT train headway to reduce the cost of electrical energy during the pandemic. The following tools were utilized in this study, namely, laptops/computers, stationery, Microsoft Word and Excel, Google chrome Web browsers, cellphones and calculators.

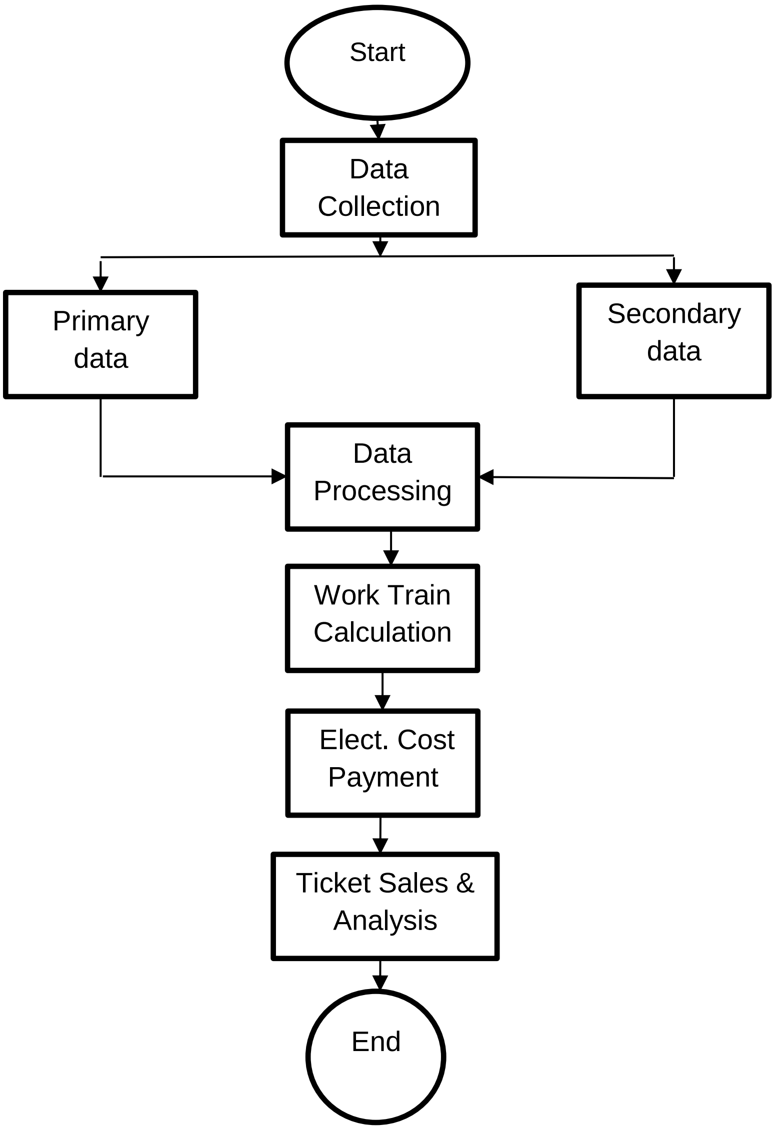

Figure 4. Flow chart of research activities

RESULTS AND DISCUSSION

MRT electric power calculation and regenerative braking

The MRT train has a regenerative braking system where during the braking process, the traction motor will turn into a generator by converting mechanical/kinetic energy into electrical energy. The resulting energy from this regenerative braking will be returned to the OCS. The regenerative braking system of the MRT train works when the train speed is 60.2 km/h to 10 km/h with a train deceleration value of 0.8 m/s^2. To calculate the length of time for regenerative braking, the time (t) obtained is 17.375 secs. and the length of the regenerative braking distance estimated is 169.407 m. Furthermore, to estimate the amount of energy produced during regenerative braking with the mass of the train when it is fully loaded with passengers, equation (10) can be used and $\mu_{regenerative}$ 0.93, the mass of the train used in this calculation is when the train condition is AW3, then W_{in} is 43,655,313 joules and $W_{ou}t$ is 40,599,441 joules. The amount of power generated each time, the MRT train performs regenerative braking can be gauged by equation (10) and the power $P_{regenerative}$ is 2,404.245 kW. Finally, $W_{regenerative}$ obtained is 11,593 kWh. Finally, the total regenerative of braking power produced by the MRT train from LBS to BHI Roundabout Station passing through 13 stations and making 12 stops is 139.116 kWh.

Total power computation of the MRT Jakarta

Calculations and measurements carried out by the MRT Management and Sumitomo Corporation obtained current and voltage consumption data on motor traction when the MRT trains operate commercially, namely, 70 amperes and 920 Vac. To gauge the amount of power required by the traction of the MRT train motor, equation (7) was used to obtain P_{in} = 93.697 kW. It is known that the travel time from LBS to BHI Station is 28 minutes 50 seconds with a travel time of 21 minutes 40 seconds and a train stop time of 7 minutes 10 seconds. Meanwhile, during normal hours, the travel time is 28 minutes 30 seconds with a travel time of 21 minutes 40 seconds and a stop time of 6 minutes 50 seconds. The magnitude of the traction power of the MRT train motor can then be gauged by equations (7) and (8) previously mentioned with the value of t being the travel time of the train without stopping time, which is 21 minutes 40 seconds at W = 33.730 kWh. In one trainset series of the MRT, there are 16 traction motors so that the total traction power is P_{in} of 539.680 kWh, so the total power required by a series of the MRT trains from LBS to BHI Station with a distance of 14.6 km is P_{total} of 400.564 kWh.

Income and expenses of the MRT before the pandemic

The power consumption of the MRT train is analyzed from the reduction in train power when powering minus the power generated during regenerative braking. From the calculations in result section, the total value of train consumption in 1 trip is 400.564 kWh. Before the pandemic, the MRT train operated from 05.00 am to 12.00 pm with a total of 285 trips on weekdays and while on holidays, the number of trips was only 219. Table 5 below describes the number of trips in September 2019.

Table 5. Total trips of the MRT in September 2019.

Dates of operation	Pattern of Gapeka	Trip	Number of trips
1	Gapeka Weekend	219	219
2 to 6	Gapeka Weekday	285	1,425
7 and 8	Gapeka Weekend	219	438
9 to 13	Gapeka Weekday	285	1,425
14 and 15	Gapeka Weekend	219	438
16 to 20	Gapeka Weekday	285	1,425
21 and 22	Gapeka Weekend	219	438
23 to 27	Gapeka Weekday	285	1,425
28 and 29	Gapeka Weekend	219	438
30	Gapeka Weekday	285	285
Total trips of the MRT train			7,956

To calculate the total power consumption of the train during September 2019, it can be implemented by considering the train power consumption in September 2019 is 400.564 kWh x number of trips and obtained 3,186,887 kWh. Meanwhile, the minimum account of PT. MRT Jakarta in September 2019 can be estimated by equation (11) with the running of 110 hours and obtained 6,600,000 kWh. Based on the electricity rate agreed between The MRT Management and the PLN, the cost of electrical energy charged per kWh is IDR

1,051.74, so the minimum account fee is IDR 6,941,484,000.00. From the calculation, it can be seen that the total consumption of the MRT trains during September 2019 was smaller than the minimum account value for that month with a ratio of 1 to 2. Finally, it can be accomplished that the operating pattern in September 2019 was efficient.

Table 6. Revenue of PT. MRT before the pandemic.

Time (month)	Ticket sales (Rp)
September 2019	22,813,775,400
Oktober 2019	22,699,712,600
November 2019	22,273,579,200
Desember 2019	26,042,492,372
Januari 2020	21,919,000,000
Februari 2020	20,923,000,000
Maret 2020	11,216,000,000
Total	147,887,559,572

From the data in the table above, it can be seen that the income of the MRT Management which was sourced from ticket sales in September 2019 worth IDR 22,813,775,400.00 and the value is greater than the costs that must be incurred to pay for electrical energy costs. This showed that the application of the train headway has been effective.

Income and expenses of the MRT Management during the Pandemic

The outbreak of the virus in early 2020 prompted the Indonesian government to implement new policies to deal with this pandemic situation. One of the policies taken is to limit the operational hours of the transportation sector to suppress people's mobility. On the other hand, this policy has an impact on the expenditure and income of transportation companies which are unstable. Therefore, the MRT Management applied a different operating pattern than usual while still adjusting to government policies. A significant change in the operation pattern of the MRT train occurred starting from April 2020, namely, by reducing operating hours and the number of trainsets. The number of train trips during April 2020 is described in table 7 below.

Table 7. Total of MRT train trips in April 2020.

Dates of operation	Pattern of Gapeka	Trip	Number of trips
1 to 9	Gapeka special 05	83	747
10 to 19	Gapeka special 06	73	730
20 to 30	Gapeka special 07	49	539
Total trips of MRT trains			2,016

Tabel 8. Number of the MRT trips from September 2019 to October 2020.

Month	Total trips	Month	Total trips
September 2019	7,956	April 2020	2,016
October 2019	8,307	May 2020	1,519
November 2019	7,956	June 2020	5,448
December 2019	8,175	July 2020	6,225
January 2020	8,241	August 2020	6,079
February 2020	7,671	September 2020	6,042
March 2020	6,980	October 2020	6,105

From the calculation of the total power consumption of the train in the result section, it can be seen that the total electrical energy needed by the MRT train for April 2020 is 807,537 kWh. Based on the minimum account of the MRT management, which is 90 (hours), and with a minimum account of 5,400,000 kWh and the non-adjusment electricity tariff of IDR 1,051.74/kWh, the minimum account fee is IDR 5,679,396,000.00.

Tabel 9. Revenue of the MRT Management during the pandemic.

Month	Ticket sales (x Million Rp.)
April 2020	1,003
May 2020	466
June 2020	2,910
July 2020	4,646
August 2020	4,454
September 2020	3,201
October 2020	2,845
Total	19,525

Based on the data from table 9, the amount of costs incurred to pay for electrical energy is not directly proportional to the income of the MRT Management in April 2020. Revenue of the Management is IDR 1,003,000,000.00, while the minimum account fee that must be paid is IDR 5,679,396,000.00. On the other hand, the ratio of train power consumption during April 2020 was only 1 in 7 with available electrical energy. Therefore, the implementation of the MRT train operating pattern in April 2020 has not yet reached an effective and efficient value. In table 10, it is described the expenses and income of the MRT Management before and during the pandemic. The value of train power consumption is based on data in previous table and the total train trips during September 2019 to October 2020. Changes in operating patterns that vary in line with the policies set have resulted in the rise and fall of expenses and income of the MRT management.

Tabel 10. Income and expenditure of the MRT Management before and during the pandemic.

Minimum Account					Total consumption of train power (kWh)	Train power/ Min. account	Ticket sales (Rp x 1,000,000)
Time	Power available (kVA)	Operation (hour)	Min. account (kWh)	Total cost (Rp x 1,000,000)			
Sept. 2019	60,000	110	6,600,000	6,941.484	3,186,887	1/2	22,813.776
Oct. 2019	60,000	110	6,600,000	6,941.484	3,327,485	1/2	22,699.713
Nov. 2019	60,000	110	6,600,000	6,941.484	3,186,887	1/2	22,273.579
Dec. 2019	60,000	110	6,600,000	6,941.484	3,274,611	1/2	26,042.492
Jan. 2020	60,000	110	6,600,000	6,941.484	3,301,048	1/2	21,919.000
Feb. 2020	60,000	110	6,600,000	6,941.484	3,072,726	1/2	20,923.000
Mar. 2020	60,000	90	5,400,000	5,679.396	2,795,937	1/2	11,216.000
April 2020	60,000	90	5,400,000	5,679.396	807,537	1/7	1,003.000
May2020	60,000	40	2,400,000	2,524.176	607,255	1/4	466.000
June 2020	60,000	40	2,400,000	2,524.176	2,182,273	1	2,910.000
July 2020	60,000	40	2,400,000	2,524.176	2,493,511	1	4,646.000
Aug. 2020	60,000	40	2,400,000	2,524.176	2,435,029	1	4,454.000
Sept. 2020	60,000	70	4,200,000	4,417.308	2,420,208	4/7	3,201.000
Oct. 2020	60,000	70	4,200,000	4,417.308	2,445,443	4/7	2,845.000

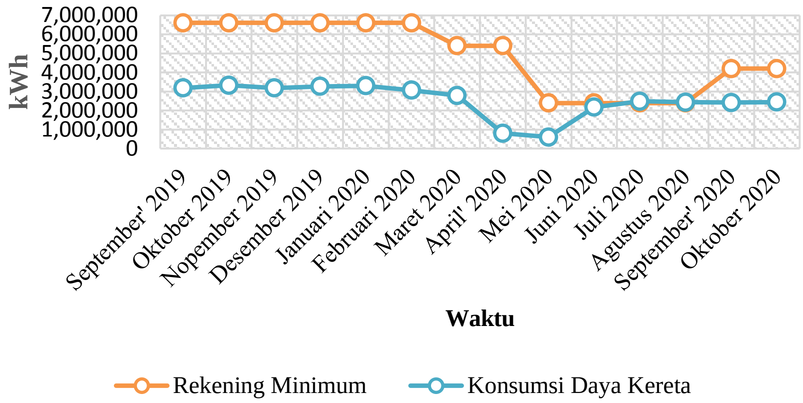

Figure 5. Minimum account and power consumption of the MRT.

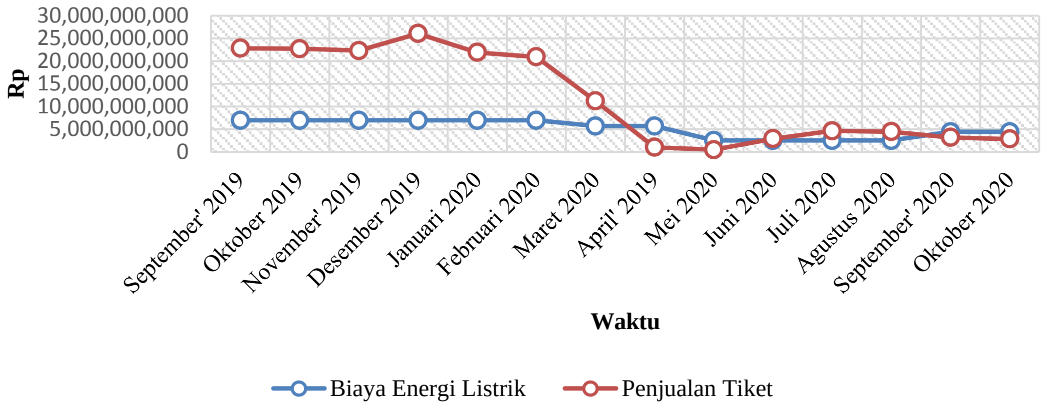

Figure 6. Income and expenditure of the MRT Management from Sept. 2019 to Oct. 2020.

As seen in figure 6, the pattern of train operation before the implementation of the PSBB was effective and efficient. Where the ratio of electrical energy used for train consumption is only of the total minimum account. The figure also showed that the power from the minimum account is still able to meet the consumption of non-traction electrical energy (depots and stations) so no additional costs were needed due to the use of excess electrical energy. In addition, the nominal income of the MRT Management from ticket sales is worth more than the cost to pay the electricity bill. During the pandemic, the Management experienced a decrease in the amount of revenue from ticket sales. The operating pattern applied has not been able to work effectively. This can be seen from the amount of costs incurred not comparable to the income earned by the Management. In April and May 2020, the use of electrical energy has not been maximized, this can be seen in Figure 6 where the consumption of electrical energy used is still very small. Ticket sales data in the Figure showed that in June, July and August 2020, the value of revenue from ticket sales is greater than the cost of electrical energy. However, the energy consumption of the train traction used reaches 100% of the minimum account capacity, and hence this makes the Management has to pay more energy for non-traction power (depots and stations). The pattern of operations in June, July and August 2020 has not shown an effective and efficient value. The use of electrical energy in September and October 2020 has shown an effective value, but the value of ticket sales has not been able to meet the cost of electrical energy.

Power estimation when reducing the number of trains in one MRT train series

The MRT train in one series consists of 6 trains with 16 working traction motors. To calculate the amount of energy produced when using 4 trains and 8 traction motors in one series, that is by looking for the results of the reduction of the total power minus the regenerative power. To compute the length of regenerative braking time, equations (4), (5) and (6) were used and t = 17.375 seconds is obtained. The length of the regenerative braking distance was gauged using the previous equation and obtained s = 169.407 m. To estimate the amount of energy produced during regenerative braking with AW3 train conditions, the equations (7) and (8) were utilized. From the previous table, the total mass when using 4 trains with AW3 conditions is 210.98 tons and W_{in} and W_{ou}t were obtained by 28,593,064 joules and 26,591,549 joules, respectively. The amount of power generated when the train performs regenerative braking was estimated applying the equation (2.10) of $P_{regenerative}$ 1,574 kW and $W_{regenerative}$ 7.61 kWh. The total regenerative braking power produced by the Jakarta MRT train from LBS to BHI Roundabout Station by passing 13 stations and making 12 stops is 91.27 kWh. To determine the amount of power required by the traction motor of the MRT train, equation (7) was used with a current of 70 A and 920 volts and the obtained P_{in} = 93.697 kW. Considering the travel time from LBS to BHI Station without calculating the train stop time is 21 minutes 40 seconds. The magnitude of the traction power of the Jakarta MRT train motor which was calculated by the previous equation is 33.73 kWh. When using 4 trains in a series, there are 8 traction motors so the total traction power is P_{in} = 269.84 kWh. Finally, the total power required by a series of MRT Jakarta trains from LBS to BHI Station with a distance of 14.6 km is 178.57 kWh.

CONCLUSIONS AND SUGGESTIONS

Based on the all calculation the MRT power before and during the pandemic, it can be concluded that the power required by a series of the MRT trains from LBS to BHI Station with a distance of 14.6 km when using 6 trains in one series is 400,564 kWh, while the power required when using 4 trains in a series is 178,568 kWh. The average electricity consumption of the MRT train before the pandemic, from September 2019 to March 2020, reached 3,163,654 kWh, while during the pandemic, which started from April 2020 to October 2020, it was 1,913,037 kWh. The implementation of the headway before the pandemic has been effective with energy consumption of only of the minimum account. Meanwhile, during the pandemic in April 2020 to May 2020, the electricity consumption of the MRT train was very low, but in June, July and August 2020 it was very high. The cost of electrical energy for the MRT Management is based on the minimum account value consisting of installed power and running hours. By considering the electricity tariff is Rp.1,051.74/kWh, during the from April 2020 to October 2020, the implementation of the MRT headway train underwent changes in line with the policies set by the government. Ticket sales during the declining pandemic have not been able to meet the cost of electricity bills, causing the MRT Management suffered losses. This showed that the application of the headway has not reached an effective and efficient value. The consumption of electrical energy in April and May 2020 is still very small. Meanwhile, in June, July and August 2020, electricity consumption was almost 100% of the minimum account value, so additional costs were required to pay for non-traction electricity. Ticket sales in September and October 2020 have not been able to meet the electricity bill charged to the MRT Management. Finally, the use of 4 trains in one series of MRT trains when traffic is low may reduce power consumption by 221,996 kWh. However, the use of 4 trains resulted in the absence of a backup system for the train propulsion system.

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