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ANALYSIS OF OPERATIONAL PATTERN AND TRAIN TRAVEL CHART PLANS ON EXTENSION ROUTE OF MRT JAKARTA LEBAK BULUS - KOTA LINE

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Abstract: MRT Jakarta has successfully operated rail-based transportation services with Lebak Bulus – Bundaran HI line. Nevertheless, the construction of the South-North corridor MRT Jakarta line still continues. The construction of the line has entered phase 2A (Bundaran HI – Kota) which is planned to be operated in 2027. For the operation, a travel pattern operation is needed so that the service can carry the number of passenger requests that are expected to occur. In addition, a Train Travel Chart is also needed so the train journey is accordance with the planned operating pattern. This study discusses the determination of operating pattern plans and design of the Train Travel Chart that will be applied based on adjustments to existing operating patterns using survey methods and data observations. The data that used in form of primary data that is obtained by observing the conditions of existing operating patterns, meanwhile secondary data is obtained directly from PT MRT Jakarta. According to the results of the analysis, it can be concluded that basedon the estimated number of passengers as many as 589,800 people in the operation of the MRT Jakarta Lebak Bulus – Kota line, 20 trainsets are needed with a headwayapplied for 5 minutes during peak hours and 10 minutes during off-peak hours, with a congestion rate by 169% and travel time of 42 minutes 5 seconds. In addition, thereis a Train Travel Cart that is designed to be applied by the operating pattern of the MRT Jakarta trip on weekdays.

Keywords: *MRT Jakarta, operating pattern, Train Travel Chart, headway, congestion rate*

1. Introduction

MRT Jakarta is one of railway transportation that operated in Jakarta area since March 2019th. These operational services are phase 1 of whole part MRT Jakarta South-North corridor infrastructure network. The phase 1 has ±16 km of length from Lebak Bulus to Bundaran HI with a total of 13 stations which can be reached in 30 minutes by 5-minute headway on peak hour.

At this time PT MRT Jakarta continuing the construction of phase 2 that is divided into 2 segments. Those segments are consist of phase 2A from Bundaran HI Station to Kota Station which length 5,8 km with a total of 7 stations and phase 2B which is still under feasibility study process, that is from Kota Station to Ancol Barat Station which length 5,2 km with a total of 3 stations and 1 depot.

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The construction process of phase 2A which is Bundaran HI – Kota route is planned will be finished and operated in 2027th. With the increase in the length of the MRT Jakarta service line (phase 2A) to Kota, of course will change the operational pattern that had previously been applied in phase 1 of the Lebak Bulus – Bundaran HI route. Therefore, it will need an analysis to plan the operational pattern and a design of train travel chart as a further step in the operation of the MRT Jakarta crossing Lebak Bulus – Kota.

Literature Review

The Planning of MRT Jakarta Operational Pattern

In order to plan an operational pattern of MRT Jakarta train travel are require some data, including:

a. Demand forecast, an estimated number of passengers to be transported, especially at peak hours based on PHPDT (Peak Hour Per Direction Traffic) numbers.
b. Trainset capacity, is the number of passengers that is can be carried by MRT Jakarta trainset.
c. Travel time, the time that is spent for traveling from the origin station to the destination station including the dwell time.
d. Dwell time, the time that is needed for boarding up dan dropping off the passengers at the station.
e. Turnback time, the time that is needed for the train driver to move to another cabin and reverse the train direction.
f. Headway, which is the minimum interval of time or distance between a train to another train at the front or behind it.

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Line Capacity

Line capacity is the ability of a railway line to serve for railway operational trips in a specified period of time of one direction. Based on basic theory, line capacity depends on implemented headway train travel. So the formula that is used in calculating the line capacity of a railway urban line is:

$$T = \frac{3600}{H_c}$$

Detail:

T = Line capacity (railway trip/hour/direction)
3600 = Period of 1 hour (second)
H_c = Minimum headway (second)

MRT Jakarta Railway Signaling System

Railway signaling is the component system that is used for controlling the movement of railway traffic including to keep the safe distance between two trains. MRT Jakarta railway network uses Communication-Based Train Control (CBTC) signaling system that is based on a moving block system with a modern interlocking technology that has a Grade of Automation 2 (GoA2) level that is using a wireless connection between the trains and the signaling component which is installed along the rail track and also with the railway Operation Control Center (OCC).(Ricardianto, Agushinta, and Suryobuwono 2020)

The signaling system is connected to the train operation system, that is ATO (Automatic Train Operation) and ATP (Automatic Train Protection) system, so the train movement including the speed and the braking system are automatically controlled and operated by the system.

Train Travel Chart (GAPEKA)

Train Travel Chart or what in Indonesian is called by Grafik Perjalanan Kereta Api (GAPEKA) is the graphic diagram that is showing the position and time of railway journeys. This graphic is used as a guide for modulating the train journey so it will be corresponding with the predetermined train travel schedule.

On the MRT Jakarta operational services, there are 3 types of Train Travel Chart that is used, including GAPEKA Weekday which is applied on

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working days, GAPEKA Weekend which is applied on weekends, and WAM (Warta Maklumat) or MALKA (Maklumat KA) that is the temporary GAPEKA which only used on certain conditions and time.

2. Method

The research is using quantitative descriptive method for doing the analysis. While the data for research is collected in two forms, that is primary data which is obtained by doing live observation of the condition from existing MRT Jakarta operation patterns, also secondary data which is obtained directly from PT MRT Jakarta or some government regulations.

3. Discussion and Result

3.1 Analysis of Existing Operation Pattern of MRT Jakarta (Lebak Bulus – Bundaran HI Line)

3.1.1 Distance and Travel Time

The table below are showing the travel distance and the travel time of the existing MRT Jakarta line (Lebak Bulus – Bundaran HI).

Table 1. Distance, Travel Time, and Speed of Existing MRT Jakarta Phase 1

Dwell Time	Travel Time	Station Name	Distance (m)	Max. Operation Speed (km/h)	Max Line Speed (km/h)
-	02:20	Lebak Bulus	2.018	90	100
00:50	02:30	Fatmawati	1.811	80	100
00:30	01:40	Cipete Raya	1.292	85	100
00:30	01:50	Haji Nawi	1.217	65	100
00:30	01:50	Blok A	1.267	85	100
00:50	01:20	Blok M	631	60	100
00:30	02:00	ASEAN	1.526	70	100
00:30	01:20	Senayan	814	70	80
00:40	01:50	Istora	1.314	70	80
00:40	01:20	Bendungan Hilir	775	70	80
00:40	01:30	Setiabudi	913	70	80
00:40	02:10	Dukuh Atas	1.073	70	80
-		Bundaran HI			
28:30		**Total**	**14.651**		

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3.1.2 Trainset Roundtrip Time

Based on the table before, it can calculate the train roundtrip time, like the flow chart below.

Figure 1. Existing Trainset Roundtrip Time
Source: Personal Analysis

3.1.3 Determining The Headway and Trainset Requirement

To determine the headway and to calculate the trainset requirement, it can be solved by using the trainset roundtrip time, like the table below.

Table 2. Trainset Requirement of Existing MRT Jakarta Phase 1

Lebak Bulus – Bundaran HI					
Roundtrip Time (minute)	Travel Time (1 direction)			28,5	
	Turnback at LBB			8	
	Turnback at BHI			5	
	Total			**70**	
Headway (minute)	10	7	5	3	1,5
Formula	$\text{Trainset} = \frac{\text{Roundtrip Time}}{\text{Headway}}$ (with roundup)				
Trainset	7	10	14	24	47

Based on the table above, right now MRT Jakarta applied the 5-minute headway with 14 operational trainsets on peak hour and 10-minute headway with 7 trainsets on off-peak hour. Depending on this operational pattern, there are 283 railway trips on a day.

3.2 Planning the Operation Pattern of MRT Jakarta (Lebak Bulus – Kota)

3.2.1 Basic Design of MRT Jakarta Phase 2A Construction

MRT Jakarta phase 2 is planned to be constructed from Bundaran HI – Kota which has length 5,8 km and a total of 7 stations, including Thamrin Station, Monas Station, Harmoni Station, Sawah Besar Station, Mangga Besar Station, and Kota Station. The construction is started in 2021 and planned to be finish and will be operated in 2027.

3.2.2 Distance and Travel Time Estimation

The distance between stations and the travel time estimation of MRT Jakarta phase 2A can be seen on the table below.

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Table 3. Distance, Travel Time, and Speed of MRT Jakarta Phase 2A

Dwell Time	Travel Time	Station Name	Distance (m)	Max. Operation Speed (km/h)	Max. Line Speed (km/h)
00:50	01:10	Bundaran HI	820	70	80
00:50	01:20	Thamrin	850	70	80
00:40	01:40	Monas	1.270	70	80
00:50	01:00	Harmoni	620	70	80
00:35	01:20	Sawah Besar	1.000	70	80
00:35	01:10	Mangga Besar	670	70	80
00:35	01:00	Glodok	620	70	80
		Kota			
13:35		**Total**	**5.850**		

Based on the table, can be known that the total travel time on phase 2A is 13 minutes 35 seconds. So, if it added up with the total travel time on phase 1 it will be 42 minutes 5 seconds.

3.2.3 Trainset Roundtrip Time Estimation

After knowing the total travel time, it can calculate of the train roundtrip time estimation, like the flow chart below.

Figure 2. Trainset Roundtrip Time for Lebak Bulus – Kota Line
Source: Personal Analysis

3.2.4 Estimation of Headway and Trainset Requirement

To calculate the estimation of headway and trainset requirement, it can be solved by using the trainset roundtrip time, like the table below.

Table 4. Trainset Requirement of MRT Jakarta Lebak Bulus – Kota Line

Lebak Bulus – Kota					
Roundtrip Time (minute)	Travel Time (1 direction)		42,08		
	Turnback at LBB		8		
	Turnback at Kota		5		
	Total		**97,17**		
Headway (minute)	10	7	5	3	1,5
Formula	$\text{Trainset} = \frac{\text{Roundtrip Time}}{\text{Headway}}$ (with roundup)				
Trainset	10	14	20	33	65

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The option of applicable headway and most capable trainset requirement could depends by MRT Jakarta's minimum headway provision which is the minimum headway that can be implemented on MRT Jakarta railway operation is 3 minutes. It also depends on trainset stabling capacity, which is based on the MRT Jakarta phase 2A (Lebak Bulus – Kota) basic design there are only 20 spaces that are possible to used for the trainset stabling area.

3.2.5 Trainset Capacity

MRT Jakarta has 16 trainsets that have 6 cars for each trainset. The capacity of each trainset is shown by its load factor, like the table below.

Table 5. Trainset Capacity and Load Factor

3.2.6 Line Capacity Calculation

Based on the urban railway line capacity formula, it can calculate the maximum line capacity of the MRT Jakarta Lebak Bulus – Kota Line Capacity.

$$\frac{T}{H_c} = 3600$$

$$= \frac{3600}{180} = 20\ railway\ trip/\cancel{hour}/direction$$

3.2.7 The Passengers Number Estimation

The passengers number estimation data is collected by MRT Jakarta survey consultant, that is Oriental Consultant Global (OCG).

Table 6. Passengers Number Estimation of MRT Jakarta Services

Line	Passengers Number			PHPDT		
	2025	2027	2030	2025	2027	2030
Lebak Bulus – Bundaran HI	355.500	359.500	411.500	18.100	19.000	28.300
Lebak Bulus – Monas	405.000	410.000	608.500	18.100	19.000	28.300
Lebak Bulus – Kota	567.800	589.800	803.800	18.100	19.000	28.300
Lebak Bulus – Ancol Barat	N/A	N/A	N/A	N/A	N/A	N/A

3.2.8 Determining The Headway

Based on the data that obtained by whole analysis above, it can be known

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the minimum headway that could be implemented later.

Table 7. Capacity and Passenger Density Level

Line	Number of Passenger		PHPDT		Cycle Time (Minutes)	Headway (Minutes)	Number of TS
	2027	2030	2027	2030			
LBB – KOTA	589.800	803.800	19.000	28.300	97,17	10	10
						7	14
						5	20
						3	33
						1,5	65

Headway (Minutes)	Number of TS	Frequency (Train/Hour)	Static Capacity 6 Car			
			2027		2030	
			AW1			
			Capacity (Pax/H)	Congestion Rate	Capacity (Pax/H)	Congestion Rate
10	10	6	5.616	338%	5.616	504%
7	14	9	8.424	226%	8.023	336%
5	20	12	11.232	169%	11.232	252%
3	33	20	18.720	101%	18.720	151%
1,5	65	40	37.440	51%	37.440	76%

Based on the table above, the most applicable or optimal headway can known by compare the advantage and disadvantages of each headway time.

Table 8. Comparation of Headway Option

According to the table above, so headway that most applicable for MRT Jakarta Lebak Bulus – Kota Line is 5 minutes.

3.2.9 Determining The Operation Pattern

Based on the whole analysis above, it can be determine the operational pattern of MRT Jakarta Lebak Bulus – Kota line, there are:

a. Operational hours of MRT Jakarta services on 05.00 – 00.00 WIB;
b. Implemented headway are 5 minutes on peak hour with 20 operational trainsets and 10 minutes on off-peak hour with 10 operational trainsets;
c. There are 20 spaces for stabling area that will be used, including:
    a. Lebak Bulus MRT Depot;
    b. Lebak Bulus Station uptrack (direct to Kota);
    c. Blok M Station downtrack (direct to Kota);
    d. Bundaran HI Station uptrack (direct to Kota);
    e. Kota Station uptrack (direct to Lebak Bulus);
    f. Kota Station downtrack (direct to Lebak Bulus);

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g. Monas Station downtrack (direct to Lebak Bulus).

d. Applicable turnback time are 8 minutes at Lebak Bulus Station and 5 minutes at Kota Station.

3.3 MRT Jakarta Lebak Bulus – Kota Line Train Travel Chart Planning

Based on the whole data that is obtained by doing all of the analysis before, it can create the Train Travel Chart for MRT Jakarta Lebak Bulus – Kota Line operational. The following pictures are the GAPEKA Weekday or train travel chart of MRT Jakarta Lebak Bulus – Kota line with weekday operational pattern.

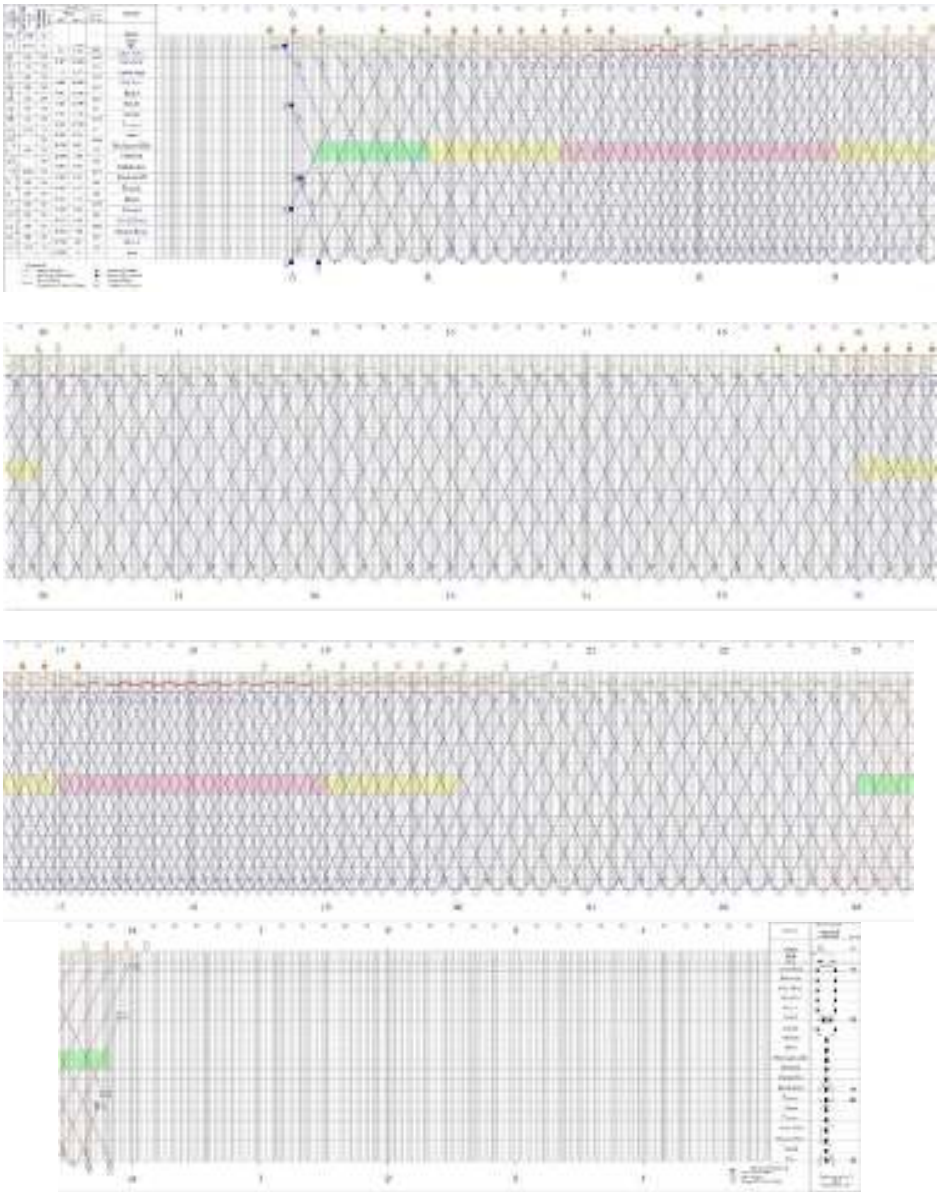

Figure 3. Train Travel Chart GAPEKA Weekday MRT Jakarta Lebak Bulus – Kota Line

Source: Personal Analysis

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4. Conclusion

Based on the discussion and result above, it can conclude several things, there are:

a. The optimum headway is between 5 – 10 minutes, it is based on MRT Jakarta minimum headway provision and SK Dirjen Perhubungan Darat No. 687/AJ.206/DRJD/2002;
b. Maximum line capacity that can be served by MRT Jakarta railroad is 20 railway trip/hour/direction or 760 railway trip on operational period time by a day;
c. Estimation of the passengers number is 589.800 passengers with number of PHPDT is 19.000 passengers;
d. Number of trainset requirement are 20 trainsets on peak hour and 10 trainsets on off-peak hour;
e. Operational pattern plan which implemented are:
    1) Operational hours of MRT Jakarta services on 05.00 – 00.00 WIB;
    2) Implemented headway are 5 minutes on peak hour and 10 minutes on off-peak hour;
    3) There are 20 spaces for stabling area that will be used, including:
        a) Lebak Bulus MRT Depot;
        b) Lebak Bulus Station uptrack (direct to Kota);
        c) Blok M Station downtrack (direct to Kota);
        d) Bundaran HI Station uptrack (direct to Kota);
        e) Kota Station uptrack (direct to Lebak Bulus);
        f) Kota Station downtrack (direct to Lebak Bulus);
        g) Monas Station downtrack (direct to Lebak Bulus).
    4) Applicable turnback time are 8 minutes on Lebak Bulus Station and 5 minutes on Kota Stations.
f. The Train Travel Chart that is created are GAPEKA Weekday which is including peak hour and off-peak hour operational pattern with a total of 290 train journey on a day.

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