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# ANALYSIS OF TRAIN TRAVEL PATTERNS CASE STUDY OF BOGOR DOUBLE TRACK CONSTRUCTION - SUKABUMI

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**ABSTRACT**
In this study the aim is to analyze the problem of train travel that occurs with the change from single track to double track as well as changes in the layout of the emplacements, which increase the frequency of passenger and freight train trips. The data used in this study are primary and secondary. Primary data includes existing data on the Bogor-Sukabumi operation pattern obtained by interviewing West Java BTP and KAI employees. Secondary data includes data on train star formation, the type and number of trains, signal service time, and the speed of passenger and freight trains. In the planning of road plots in the Detailed Design of Double Tracks Between Bogor - Cigombong, it is not directly affected by traffic capacity. This is because road plots can be divided into several block plots, which is very different from the single-lane system. To reduce Headway or the same as to increase traffic capacity, simply by adding IB (Intermediate Block) between the distances of AB stations (AB (km) S) in the formula, if 1 (one) IB is installed, then the distance of the road plot is divided by two, if 2 (two) IBs are installed, then the distance of the road plot is divided by three and so on. The analysis of the study of operational patterns on the Bogor-Sukabumi line shows that with the plan to increase the frequency of trains and the construction of a double track, there will be a decrease in the Headway from 10.38 to 7.1.

**Keywords:** stations, trains, development.

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## INTRODUCTION

The train is a mode of transportation that cannot be separated from the lives of Indonesian people, who play an important role in developing all sectors of Indonesia (Alfeno & Devi, 2017). The train is a means of transportation in the form of a vehicle that will or is moving on the railroad with the power of motion, either running alone or coupled with other railroad facilities related to training travel (Hidayat, 2019). By using its path that is different from other transportation, trains are free from congestion (Aminah, 2018). The timeliness of train travel is managed in such a way with a good management system to solve problems related to departure or arrival times (Sandy & Leliana, 2021). Another advantage of this transportation is that it can carry passengers and goods in large quantities or capacities (Transportation, 2011). Given the important role of the railroad, it is necessary to develop and improve facilities and infrastructure as a determinant of the success of the rail transportation system (Siregar et al., 2020).

Presidential Regulation 58 of 2017 concerning the Acceleration of National Strategic Projects (PSN), one of the contents of which concerns the project for the construction of inter-city rail facilities and infrastructure for the development of the South Java double track, which includes the Provinces of West Java, Central Java, East Java and the Special Region of Yogyakarta (Yudhanto, 2021). The developments being carried out include a double-track railway between Bogor-Sukabumi

which is part of the Bogor-Yogyakarta line with a track length of about 57 km. There are several stations on the Bogor-Sukabumi railway line, namely Paledang Station, Batu Tulis Station, Ciomas Station, Maseng Station, Cigombong Station, Cicurug Station, Parungkuda Station, Cibadak Station, Karang Tengah Station, Cisaat Station and Sukabumi Station (Farhan Syahfarul Maghribi, 2022).

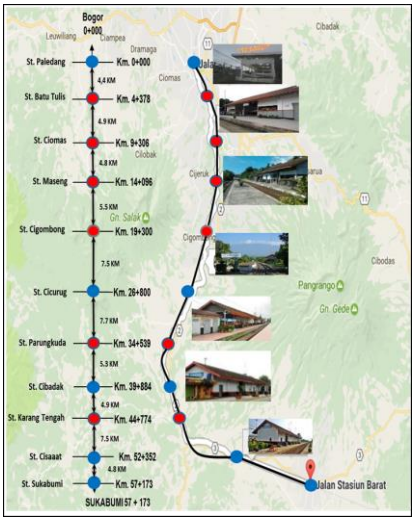


**Figure 1. Construction of the Bogor-Sukabumi double track**
Source: West Java BTP 2022

The Jakarta-Bogor-Sukabumi route has been connected by rail transportation. The 55 km Jakarta-Bogor line has been double-tracked and electrified, while the 57 km Bogor-Sukabumi line is still developing a double-track line (Fajar Ramadhan, 2021). The construction of the double track is driven by the condition of the highway connecting Sukabumi-Bogor-Jakarta, which is already saturated with a travel time of 6 hours, approximately 112 km from Jakarta to Sukabumi and vice versa, the travel time which should only be 4 hours due to traffic jams up to a maximum of 2 hours. Therefore, the thing behind this development is to reduce the density of highway traffic, especially from Jakarta-Bogor-Sukabumi, minimize the cost of transporting goods/national logistics distribution, and increase the frequency of passenger and goods train trips. In addition, the southern part of West Java, especially the Bogor and Sukabumi regions, has a lot of economic potential such as trade, industry, tourism, property, food and so on (Chandra & Munthe, 2012).

The Ministry of Transportation (Kemenhub) targets the construction of phase 1 of the Bogor-Sukabumi double-track railway, namely from Bogor-Cigombong, targeted for completion in March 2022. For now, the construction is on the Partial double-track railway between Bogor Paledang Station to Cicurug Station with a percentage of 98.81% with physical progress as of February 20, 2022. Completing phase 1 of the Bogor-Cigombong double-track project can make passenger and freight transport more productive. Adding the revitalization and construction of the Bogor-Sukabumi double-track railway, the community needs it, given the high demand for passenger and goods mobility between the two cities. The Bogor-Sukabumi double-track train will cut travel time from 2 hours to just 1 hour and 20 minutes. Then, increasing the frequency of passenger trains from 6 trips to 12 trips and the frequency of freight trains from 2 trips to 8 trips, increasing the number of trains

from 6 to 8 circuits, increasing the total passenger capacity from 2,844 people/day to 5,688 people/day and cargo transport capacity. from 648 tonnes/day to 2,592 tonnes/day (Railways, 2021).

The density of trains crossing Gedebage-Cicalengka requires special attention in developing the railway infrastructure and its operational pattern for the future development of the railway. The operational pattern study was carried out by means of a survey to obtain data used to study the operating pattern of the Gedebage-Cicalengka double-track railway. With the plan to increase the frequency of trains and the construction of a double track, there will be an increase in the average Headway from 9.5 to 11, cross capacity by 200% from an average of 96.5 to 193.5 (Siregar et al., 2020).

The growing population and the shifting of population movements from the suburbs to the city center will result in increasing requests for rail transportation services to the city center. Thus, an analysis of the potential demand, the need for new facilities and operating patterns are needed. This research was conducted by interviewing survey passengers of the Lembah Anai train relation between Kayu Anam Station and Minangkabau International Airport Station. The actual demand potential was carried out by a survey on trains from 644 respondents, 85.5% agreed with the extension of the Lembah Anai Railway relationship, and as many as 88% were willing to choose the rail mode. In the demand analysis, potentially a stated preference survey was carried out in Pauh District. Out of 2636 respondents, 86.7% were willing to move from private and public transportation modes to rail modes (Nurfadhila et al., 2020).

To optimize the operation of trains at Gubeng Station, one of the most important variables is the pattern of operation related to the interlocking system. This study aims to analyze and provide an overview of the railroad tracks which will guide all train movements. The analysis of train operation patterns considers the typical layout and length of the lines at the station, the arrangement of train traffic at the station and the routes of train travel at the station. The operating pattern of the trains that pass-through Surabaya Gubeng Station has six lines and 19 routes that can be formed based on the Local Security Service Regulations. Not all routes are used with a total of 11 routes, a Conflict Rate (CR) value of 95.02% is obtained, the movement of trains is mutually conflict, and 4.98% of train movements do not conflict with each other (Hanif et al., 2020).

## METHODS

Research on analysis of train travel patterns for case studies on the construction of the Bogor-Sukabumi double track crossing Bogor-Yogyakarta has been carried out in Operation Area 1 Jakarta on Jalan Pegangsaan Timur No.15-16 RT.1/RW.1 Pegangsaan, RT.1/RW.5, Menteng, Kec. Menteng, City of Central Jakarta, Special Capital Region, Jakarta 10310. The time for research is February-November 2022.

In this study, we will analyze the problem of train travel that occurs with the change from single track to double track and changes in the layout of the emplacements, which increase the frequency of passenger and freight train trips. The data used in this study are primary and secondary data (Kulon & Barat, 2017). Primary data includes existing data on the Bogor-Sukabumi operation pattern obtained by interviewing West Java BTP and KAI employees. Secondary data includes data

on train star formation, the type and number of trains, signal service time, and the speed of passenger and freight trains.

The stages of this research identify the problems with train travel that occur if the capacity of the Bogor-Sukabumi line segment changes from a single track to a double track, including increasing the infrastructure capacity. The primary and secondary data that have been obtained are then analyzed and processed to calculate the cross-plan capacity, which is then adjusted to the maximum cross-capacity; if it is still sufficient to accommodate trains, then it can be forwarded to the determination of the pattern that has been selected along with the appropriate GAPEKA can be determined as the recommended pattern. However, if the value exceeds the maximum capacity, data processing is done again by finding a solution to the problem. Furthermore, conclusions can be drawn from this research which can be used as a reference in realizing government programs on rail transportation so that the best service can be channeled to the community.

## RESULTS AND DISCUSSION

### 1. Track Pattern

Based on the existing operational conditions of the current line, the development plan for the Bogor-Sukabumi double track, in general, can be divided into three segments, namely:

a. Cigombong – Cicurug
b. Ciomas – Maseng – Cigombong
c. Bogor Paledang – Slate – Ciomas

### 2. Road Plots and Stations

The number of road plots in the Bogor - Sukabumi Double Line BED crossroads is eight, with a total distance of 57.173 km, as shown in the table below.

**Table 1. The road plot is in the Bogor – Sukabumi Double Lane BED crossroad**

| No | Station | Function | KM | Spped (Km/H) | | Distance | Headway (Secon) | Acceleration (Minutes) | Decelaration (Minutes) | Cross Capacity |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Maximum Operaton | Operation | | | | | |
| 1 | Bogor | Down/up pnp | 0 | | | 4.378 | 9.4 | 0.5 | 0.5 | 83 |
| 2. | Batu tulis | Operation | 4.378 | | | | | | | |
| 3. | Maseng | Down/up pnp | 14.096 | | | 9.718 | 17.8 | 0.5 | 0.5 | 46 |
| 4. | Cigombong | Down/up pnp | 19.622 | | | 5.526 | 11.2 | 1.0 | 1.0 | 65 |
| 5. | Cicurug | Down/up pnp | 26.715 | | | 7.093 | 13.7 | 1.0 | 1.0 | 55 |
| 6. | Parangkuda | Down/up pnp | 34.359 | | | 7.644 | 14.6 | 1.0 | 1.0 | 52 |
| 7. | Cibadak | Down/up pnp | 39.884 | | | 5.525 | 11.2 | 1.0 | 1.0 | 65 |
| 8. | Karang tengah | | 44.774 | | | 4.89 | 10.2 | 0.5 | 0.5 | 77 |
| 9. | Cisaat | Down/up pnp | 52.352 | | | 7.578 | 14.5 | 0.5 | 0.5 | 56 |
| 10. | Sukabumi | Down/up pnp | 57.173 | | | 4.821 | 10.1 | 1.0 | 1.0 | 71 |

### 3. Path Layout

The layout of the track (emplacement) at the stations on the BED Double Line route Bogor - Sukabumi has as many as 12 stations with the layout of each track. Here is a picture of each station:

**a. Bogor Paledang Station**

This station is located at KM 0+404 and is not operational/doesn't exist yet.

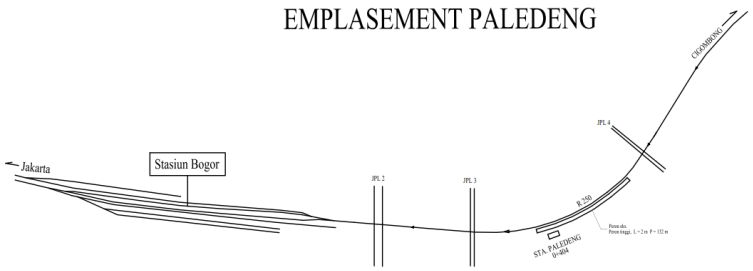


**Figure 2. Paledeng Emplacement**

**b. Batuwritten Station**

As a station without operations, this station cannot carry out crossing or overtaking. It can be referred to as a *Block Post*.

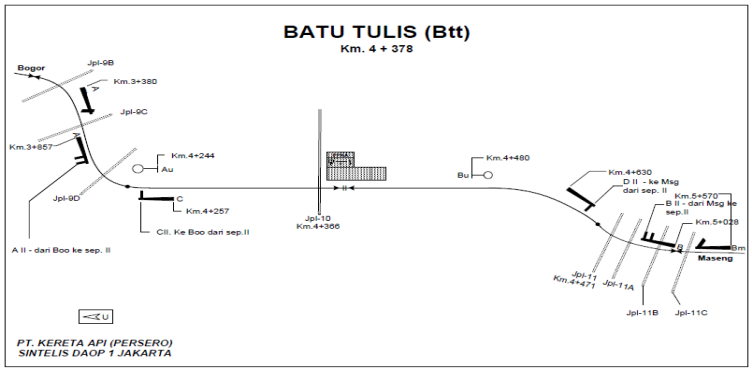


**Figure 3. Slate Emplacement**

**c. Masen Station**

As an operating station, this station can carry out crossing or overtaking.

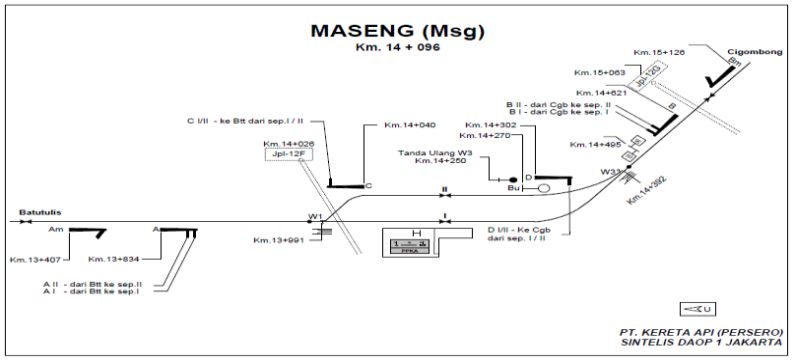


**Figure 4. Maseng Emplacement**

**d. Cigombong Station**

As an operating station, this station can carry out crossing or overtaking.

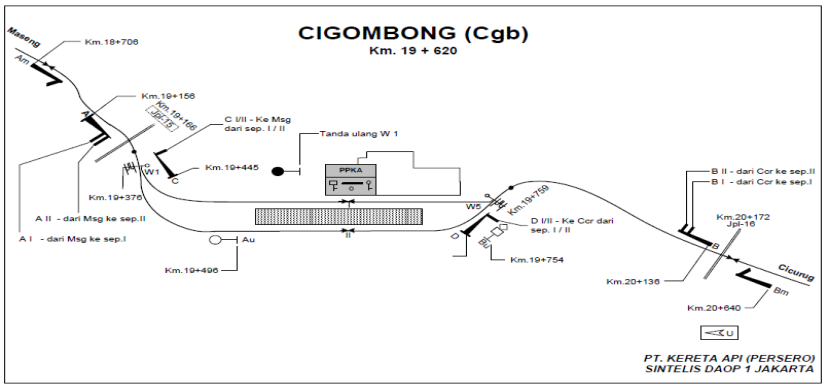


**Figure 5. Cigombong Emplacement**

**4. Study of Operational Patterns After DED**

**1) Road Plot Planning n**

The road plots that are on the Bogor - Cigombong Dual Line DED crossroads with a distance of 19.62 km, of which there are three roadblocks, the furthest road plot between Batu Tulis station and Maseng station is 9,718 km, and the closest road plot is between Bogor Paledang station - Bogor Station Slate is 4.378 Km away. In planning the road plots in the Detailed Design of the Double Lane Between Bogor - Cigombong, it is not directly affected by traffic capacity. This is because the road plots can be divided into several block plots, which is very different from the single-lane system. To reduce Headway or the same as to increase traffic capacity, simply by adding IB (*Intermediate Block* ) between the distances of AB stations (AB (km) S ) in the formula, if 1 (one) IB is installed, then the distance of the road plot is divided by two, if 2 (two) IBs are installed, then the distance of the road plot is divided by three and so on.

**2) Number of Road Plots**

The number of road plots that originally, there were four road plots; if it were made into a double lane, two plots would suffice roads, namely the Bogor Paledang – Cigombong road plot, as shown in the table below:

**3) Operating Stations and Bus Stops**

Operation Stations and stations without Fasop or Bus Stops see the table above and details as follows:

**Table 2. Functions of the Bogor - Sukabumi Cross Station**

| Station | km | function |
|---|---|---|
| Bogor Paledang | 0+400 | Down/up pnp |
| Tukis Stone | 4+378 | Operation |
| Maseng | 14+096 | Down/up pnp |
| Cigombong | 19+622 | Down/up pnp |
| Cicurug | 26+715 | Down/up pnp |
| Parungkuda | 34+359 | Down/up pnp |
| Cibadak | 39+884 | Down/up pnp |

| Station | km | function |
|---|---|---|
| Central Reef | 44+774 | Operation |
| Cisaat | 52+352 | Down/up pnp |
| Sukabumi | 57+173 | Down/up pnp |

**4) Stations, Line Layout and Operational Patterns**

At stations that are planned to have passengers getting on and off, a common platform must be provided with a platform width of at least 3 meters.

Stations, Track Layouts and Operational Patterns are only for related Stations, Track Layouts and Operational Patterns with the Bogor - Cigombong Double Line DED study, as follows:

**a. BOGOR PALEDANG Station**

Paledang Station is the initial departure and final arrival station for trains passengers from/to Sukabumi, then a minimum of 2 lanes are needed at Paledang Station to dispatch and receive the arrival of the passenger train, as well as required two additional lines to serve freight trains from/to Jakarta and the process of shutting down passenger train locomotives (Muhamad Hafiz Azdam et al., 2022).

When the operating hours of passenger trains are over, 3 of the four lines will be at Paledang station can function as a stabling place for passenger trains, where the next day, the train These passengers will operate again starting from Paledang Station. And the remaining lane is unused and is used for freight train services from/to Jakarta.

a) For path layout, see the image below.

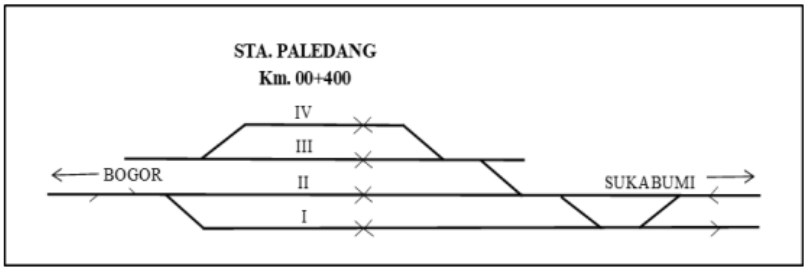


**Figure 6. The layout of the Paledang Station Line**

b) Operation Pattern

There are four train lines, and the use of each of the four lines is as follows :

1) Line III and line IV for KRD/KRL trains from the direction of Sukabumi to the final destination station Paledang and back to Sukabumi

2) Lines I and II are highways toward Sukabumi and do not stop on this route.

**b. BATUTULIS Station/Stop/Stop**

a) This station is a Stop/Stop.

b) Path layout, see the image below

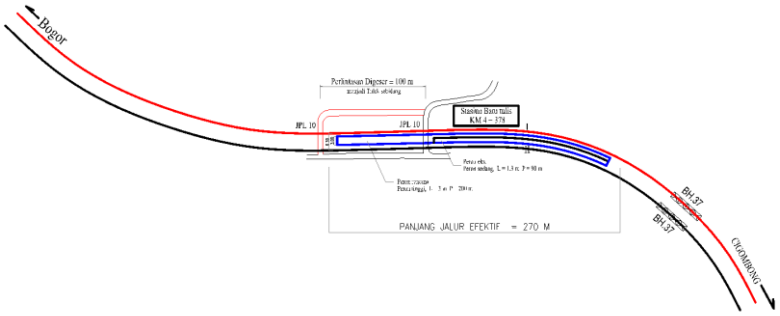


**Figure 7. The layout of the Batutulis Stop / Hatle Line**

If you look at the two alternatives above, if you still maintain the effective path length as in alternative 2, then it does not meet the requirements for the pattern of operation, which is for one train set, an effective passenger length of only 130 m. This is due to the effective length not fulfilling the service of one series of trains that is 140 m. Thus, an alternative one is chosen by extending the path effective to 270 m. The consequence of extending the effective path is road relocation. Provinces that function as class III collector roads a Drs. Saleh Danasamita became a crossroads, not a plot.

**c. MASENG Station/Stop/Stop**

This station is a Stop/Stop. The effective line length at this station is 399 m. Path layout, see the image below

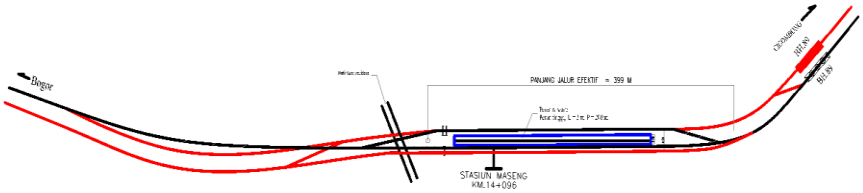


**Figure 8. Maseng Stop Line Layout**

**d. CIGOMBONG Station**

This station is still used as a stop station/bus stop. The effective path length of this station is 350 m. The track layout is presented as follows:

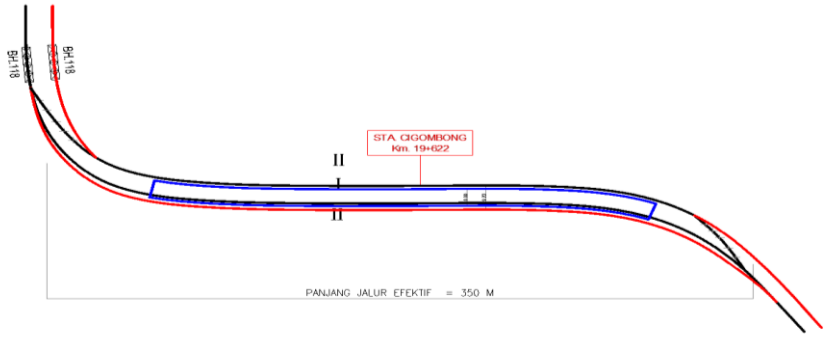


**Figure 9. The layout of the Cigombong Station Line**

**e. Operations Station**

Operation Stations and stations without Fasop or Bus Stops see the table above and the details as follows:

**Table 3. Operation Stations**

| Station | km | function |
|---|---|---|
| Bogor Paledang | 0+400 | Down/up pnp |
| Tukis Stone | 4+378 | Operation |
| Maseng | 14+096 | Down/up pnp |
| Cigombong | 19+622 | Down/up pnp |
| Cicurug | 26+715 | Down/up pnp |
| Parungkuda | 34+359 | Down/up pnp |
| Cibadak | 39+884 | Down/up pnp |
| Central Reef | 44+774 | Operation |
| Cisaat | 52+352 | Down/up pnp |
| Sukabumi | 57+173 | Down/up pnp |

**Table 4. Train numbers, schedules, number and km of train travel time Local Bogor – Sukabumi According to Gapeka 2017**

| Number Serial | Number ka | KA Name | Cross | Distance | O'clock leave | O'clock come | WP O'clock | KEC AVERAGE |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1 | 389 | PANGRANGO | SI-BOO | 57.2 | 05.15 | 07.18 | 02.03 | 27.9 |
| 2 | 390 | | BOO-SI | 57.2 | 07.50 | 09.54 | 02.04 | 27.7 |
| 3 | 391 | | SI-BOO | 57.2 | 10.25 | 12.28 | 02.03 | 27.9 |
| 4 | 392 | | BOO-SI | 57.2 | 13.10 | 15.13 | 02.03 | 27.9 |
| 5 | 393 | | SI - 800 | 57.2 | 15.45 | 17.48 | 02.03 | 27.9 |
| 6 | 394 | | BOO-SI | 57.2 | 18.30 | 20.36 | 02.06 | 27.2 |
| **The Number KA and KM-KA** | | | | 343 | | | | **27.7** |

**Table 5. Number, Schedule, Number and KM of Train Travel Time for Freight Trains Transportation of Mineral Water According to Gapeka 2017**

| number Serial | number ka | KA Name | Cross | Distance | O'clock leave | O'clock come | WP O'Clock | KEC AVERAGE |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 8 |
| 1 | 2665 | CICURUG | CCR-KPB | 86.6 | 19.45 | 22.05 | 02.20 | 37.1 |
| 2 | 2666 | | KPB - CCR | 86.6 | 03.25 | 05.46 | 02.21 | 36.9 |
| 2 | **The Number KA and KM-KA** | | | **173** | | | | 37.0 |

**5. Transport Target Plan**

Transport target plan data is taken from the FS related to the previous BED, which according to the FS study up to 2049, are as follows:

### 1) Transport Forecast

Based on survey results and data from PT. Semen Jawa, the volume of cement transportation in the future is as follows :

**Tabel 6. Transportation Potential with OD Matrix in 2020 - 2045**

**Matrix OD Tahun 2020**

| Logit_1_2019 | Central Jakarta | North Jakarta | West Jakarta | South Jakarta | East Jakarta | Bogor | Sukabumi | Bandung | Bekasi | Banten |
|---|---|---|---|---|---|---|---|---|---|---|
| Central Jakarta | 0 | 19,757,900 | 13,947,665 | 17,145,724 | 26,783,909 | 18,384,814 | 2,858,455 | 12,945,832 | 8,102,772 | 2,723,161 |
| North Jakarta | 16,311,785 | 0 | 20,888,305 | 8,728,411 | 33,256,031 | 14,344,609 | 4,769,885 | 12,155,492 | 19,393,465 | 2,253,281 |
| West Jakarta | 13,252,210 | 15,081,590 | 0 | 12,500,853 | 12,418,282 | 15,085,876 | 4,753,879 | 9,732,808 | 12,499,985 | 2,398,056 |
| South Jakarta | 12,028,842 | 8,540,391 | 13,265,827 | 0 | 21,192,350 | 37,989,972 | 4,255,503 | 16,059,016 | 14,784,829 | 1,770,654 |
| East Jakarta | 20,574,517 | 25,915,505 | 15,714,662 | 17,849,043 | 0 | 30,079,984 | 7,050,565 | 15,122,520 | 27,446,922 | 2,551,688 |
| Bogor | 10,170,526 | 13,252,393 | 15,525,816 | 63,317,016 | 30,628,430 | 0 | 28,816,405 | 19,680,939 | 49,289,228 | 2,095,414 |
| Sukabumi | 1,778,890 | 3,075,076 | 2,700,409 | 4,385,149 | 5,499,320 | 23,049,729 | 0 | 18,468,745 | 13,138,035 | 1,773,560 |
| Bandung | 15,162,444 | 16,827,588 | 15,574,810 | 15,440,621 | 20,277,861 | 25,834,735 | 30,768,826 | 0 | 25,605,363 | 1,591,369 |
| Bekasi | 9,969,548 | 20,268,353 | 14,810,425 | 17,700,829 | 38,784,035 | 58,588,784 | 27,919,873 | 27,794,670 | 0 | 2,545,316 |
| Banten | 1,403,497 | 1,534,985 | 1,725,916 | 1,571,615 | 1,613,392 | 1,693,838 | 1,486,506 | 2,665,664 | 2,067,990 | 0 |

*Sumber awal ATTN 2011*

**Matrix OD Tahun 2025**

| Logit_1_2024 | Central Jakarta | North Jakarta | West Jakarta | South Jakarta | East Jakarta | Bogor | Sukabumi | Bandung | Bekasi | Banten |
|---|---|---|---|---|---|---|---|---|---|---|
| Central Jakarta | 0 | 25,216,643 | 17,801,147 | 21,882,771 | 34,183,809 | 23,464,199 | 3,648,193 | 16,522,526 | 10,341,418 | 3,475,520 |
| North Jakarta | 20,818,430 | 0 | 26,659,359 | 11,139,911 | 42,444,059 | 18,307,760 | 6,087,717 | 15,513,830 | 24,751,522 | 2,875,820 |
| West Jakarta | 16,913,551 | 19,248,356 | 0 | 15,954,608 | 15,849,224 | 19,253,825 | 6,067,289 | 12,421,803 | 15,953,500 | 3,060,594 |
| South Jakarta | 15,352,189 | 10,899,943 | 16,930,930 | 0 | 27,047,406 | 48,485,901 | 5,431,220 | 20,495,826 | 18,869,605 | 2,259,853 |
| East Jakarta | 26,258,876 | 33,075,481 | 20,056,334 | 22,780,405 | 0 | 38,390,529 | 8,998,506 | 19,300,593 | 35,030,001 | 3,256,673 |
| Bogor | 12,980,455 | 16,913,785 | 19,815,313 | 80,810,340 | 39,090,500 | 0 | 36,777,846 | 25,118,420 | 62,906,933 | 2,674,338 |
| Sukabumi | 2,270,364 | 3,924,663 | 3,446,483 | 5,596,685 | 7,018,680 | 29,417,945 | 0 | 23,571,319 | 16,767,832 | 2,263,562 |
| Bandung | 19,351,547 | 21,476,740 | 19,877,843 | 19,706,580 | 25,880,260 | 32,972,396 | 39,269,686 | 0 | 32,679,653 | 2,031,035 |
| Bekasi | 12,723,950 | 25,868,125 | 18,902,272 | 22,591,241 | 49,499,349 | 74,775,785 | 35,633,619 | 35,473,825 | 0 | 3,248,540 |
| Banten | 1,791,257 | 1,959,073 | 2,202,754 | 2,005,824 | 2,059,143 | 2,161,814 | 1,897,200 | 3,402,138 | 2,639,338 | 0 |

*Sumber awal ATTN 2011*

**Matrix OD Tahun 2035**

| Logit_1_2034 | Central Jakarta | North Jakarta | West Jakarta | South Jakarta | East Jakarta | Bogor | Sukabumi | Bandung | Bekasi | Banten |
|---|---|---|---|---|---|---|---|---|---|---|
| Central Jakarta | 0 | 41,075,255 | 28,996,193 | 35,644,728 | 55,681,822 | 38,220,707 | 5,942,522 | 26,913,455 | 16,845,080 | 5,661,256 |
| North Jakarta | 33,911,029 | 0 | 43,425,286 | 18,145,740 | 69,136,899 | 29,821,412 | 9,916,249 | 25,270,394 | 40,317,620 | 4,684,408 |
| West Jakarta | 27,550,392 | 31,353,543 | 0 | 25,988,376 | 25,816,716 | 31,362,453 | 9,882,974 | 20,233,808 | 25,986,570 | 4,985,386 |
| South Jakarta | 25,007,098 | 17,754,859 | 27,578,701 | 0 | 44,057,374 | 78,978,423 | 8,846,885 | 33,385,541 | 30,736,598 | 3,681,062 |
| East Jakarta | 42,772,942 | 53,876,474 | 32,669,654 | 37,106,879 | 0 | 62,534,126 | 14,657,618 | 31,438,632 | 57,060,180 | 5,304,777 |
| Bogor | 21,143,793 | 27,550,774 | 32,277,057 | 131,631,528 | 63,674,306 | 0 | 59,907,236 | 40,915,260 | 102,468,766 | 4,356,215 |
| Sukabumi | 3,698,184 | 6,392,862 | 5,613,957 | 9,116,411 | 11,432,691 | 47,918,732 | 0 | 38,395,195 | 27,313,031 | 3,687,104 |
| Bandung | 31,521,632 | 34,983,346 | 32,378,911 | 32,099,942 | 42,156,216 | 53,708,559 | 63,966,180 | 0 | 53,231,710 | 3,308,342 |
| Bekasi | 20,725,974 | 42,136,450 | 30,789,809 | 36,798,752 | 80,629,223 | 121,801,875 | 58,043,410 | 57,783,124 | 0 | 5,291,529 |
| Banten | 2,917,769 | 3,191,123 | 3,588,055 | 3,267,275 | 3,354,126 | 3,521,368 | 3,090,339 | 5,541,724 | 4,299,203 | 0 |

*Sumber awal ATTN 2011*

**Matrix OD Tahun 2040**

| Logit_1_2034 | Central Jakarta | North Jakarta | West Jakarta | South Jakarta | East Jakarta | Bogor | Sukabumi | Bandung | Bekasi | Banten |
|---|---|---|---|---|---|---|---|---|---|---|
| Central Jakarta | 0 | 52,423,590 | 37,007,306 | 45,492,709 | 71,065,683 | 48,780,384 | 7,584,332 | 34,349,146 | 21,499,066 | 7,225,356 |
| North Jakarta | 43,280,021 | 0 | 55,422,892 | 23,159,074 | 88,238,149 | 38,060,518 | 12,655,926 | 32,252,138 | 51,456,636 | 5,978,624 |
| West Jakarta | 35,162,058 | 40,015,949 | 0 | 33,168,485 | 32,949,398 | 40,027,320 | 12,613,457 | 25,824,036 | 33,166,181 | 6,362,756 |
| South Jakarta | 31,916,099 | 22,660,199 | 35,198,187 | 0 | 56,229,614 | 100,798,705 | 11,291,117 | 42,609,350 | 39,228,553 | 4,698,072 |
| East Jakarta | 54,590,317 | 68,761,551 | 41,695,678 | 47,358,826 | 0 | 79,811,152 | 18,707,247 | 40,124,547 | 72,824,856 | 6,770,389 |
| Bogor | 26,985,433 | 35,162,545 | 41,194,612 | 167,998,893 | 81,266,343 | 0 | 76,458,501 | 52,219,391 | 130,778,996 | 5,559,757 |
| Sukabumi | 4,719,924 | 8,159,092 | 7,164,990 | 11,635,107 | 14,591,332 | 61,157,794 | 0 | 49,003,079 | 34,859,118 | 4,705,783 |
| Bandung | 40,230,477 | 44,648,600 | 41,324,608 | 40,968,564 | 53,803,202 | 68,547,243 | 81,638,856 | 0 | 67,938,651 | 4,222,376 |
| Bekasi | 26,452,178 | 53,777,974 | 39,296,466 | 46,965,568 | 102,905,591 | 155,453,487 | 74,079,735 | 73,747,535 | 0 | 6,753,481 |
| Banten | 3,723,895 | 4,072,772 | 4,579,368 | 4,169,963 | 4,280,809 | 4,494,257 | 3,944,142 | 7,072,800 | 5,486,994 | 0 |

*Sumber awal ATTN 2011*

**Matrix OD Tahun 2045**

| Logit_1_2034 | Central Jakarta | North Jakarta | West Jakarta | South Jakarta | East Jakarta | Bogor | Sukabumi | Bandung | Bekasi | Banten |
|---|---|---|---|---|---|---|---|---|---|---|
| Central Jakarta | 0 | 66,907,261 | 47,231,743 | 58,061,506 | 90,699,821 | 62,257,504 | 9,679,743 | 43,839,181 | 27,438,861 | 9,221,589 |
| North Jakarta | 55,237,493 | 0 | 70,735,216 | 29,557,499 | 112,616,723 | 48,575,937 | 16,152,525 | 41,162,809 | 65,673,155 | 7,630,408 |
| West Jakarta | 44,876,686 | 51,071,618 | 0 | 42,332,325 | 42,052,710 | 51,086,131 | 16,098,323 | 32,958,742 | 42,329,385 | 8,120,668 |
| South Jakarta | 40,733,928 | 28,920,794 | 44,922,797 | 0 | 71,764,820 | 128,647,529 | 14,410,644 | 54,381,528 | 50,066,679 | 5,996,062 |
| East Jakarta | 69,672,616 | 87,759,099 | 53,215,425 | 60,443,196 | 0 | 101,861,502 | 23,875,715 | 51,210,219 | 92,945,021 | 8,640,923 |
| Bogor | 34,441,011 | 44,877,308 | 52,575,924 | 214,413,889 | 103,718,735 | 0 | 97,582,575 | 66,646,646 | 166,910,822 | 7,095,816 |
| Sukabumi | 6,023,952 | 10,413,299 | 9,144,544 | 14,849,672 | 18,622,648 | 78,054,565 | 0 | 62,541,726 | 44,490,050 | 6,005,904 |
| Bandung | 51,345,416 | 56,984,185 | 52,741,835 | 52,287,423 | 68,668,034 | 87,485,582 | 104,194,167 | 0 | 86,708,847 | 5,388,941 |
| Bekasi | 33,760,427 | 68,635,837 | 50,153,355 | 59,941,289 | 131,336,508 | 198,402,420 | 94,546,599 | 94,122,619 | 0 | 8,619,343 |
| Banten | 4,752,738 | 5,198,004 | 5,844,563 | 5,322,047 | 5,463,518 | 5,735,937 | 5,033,836 | 9,026,884 | 7,002,949 | 0 |

*Sumber awal ATTN 2011*

**2) Number of trains**

The table below shows the transportation potential data obtained from the estimated frequency requirements Trains in 2045 will be 290 trains with details of 230 passenger trains star formation one locomotive + 6 trains (5K3 and 1 KP), 38 Aqua freight trains with stamformasi one locomotive + 7 carriages, and 22 cement freight trains with one locomotive + 8 stamformation carriage.

**Table 7. List of Estimated Number of Bogor-Sukabumi Cross Trains for the Period 2020 to 2045**

| NO | Years | TOTAL | | | Average Trough KA | | | KA Amount | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SI DKI JAK 100 % | DKI JAK SI 100 % | SI DKI JAK 10 Average % | SI DKI JAK 10 % | AQUA CRG- JAKG | PT. SEMEN JAWA | KA PNP SI BOO | AQUA CRG JAKG | PT. SEMEN JAWA | sukabumi-bogor | |
| | | One Year | | | /day /direction | | | | | | | Two-way direction |
| | | Pnp Unit | | | Ton Unit | | | KA Unit | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| | | | | 0,1x (4+5)/2 | 5/300 | | | 6/300X60% | 7/400 | 8/400 | 9+10+11 | 12 2 |
| 1 | 2020 | 40,488,574 | 52,504,693 | 4,649,663 | 15,499 | 2,279 | 3,823 | 43 | 6 | 10 | 58 | 117 |
| 2 | 2025 | 51,674,820 | 67,010,771 | 5,934,280 | 19,781 | 2,908 | 3,917 | 55 | 7 | 10 | 72 | 144 |
| 3 | 2030 | 65,951,620 | 85,524,612 | 7,573,812 | 25,246 | 3,712 | 4,013 | 70 | 9 | 10 | 89 | 179 |
| 4 | 2035 | 84,172,837 | 109,153,485 | 9,666,316 | 32,221 | 4,738 | 4,112 | 90 | 12 | 10 | 112 | 223 |
| 5 | 2040 | 107,428,239 | 139,310,580 | 12,336,941 | 41,123 | 6,046 | 4,213 | 114 | 15 | 11 | 140 | 280 |
| 6 | 2045 | 108,556,236 | 140,773,341 | 12,466,479 | 41,555 | 7,717 | 4,316 | 115 | 19 | 11 | 146 | 291 |

Furthermore, to accommodate the transportation potential as shown in the table above, it is necessary to build a double track on the Bogor - Sukabumi route with details as follows :

**a. Train line between Bogor Station – Paledang Station**

To be able to accommodate the estimated demand for the frequency of trains in 2035 on railroad lines between Bogor Station - Paledang Station is still sufficiently served by a single line because, based on the explanation above, the operating pattern of passenger trains with cross-services Bogor - Sukabumi for early departures and late arrivals cannot be made from Bogor Station, so that those that pass the railroad line between Bogor Station - Station Paledang is only freight train from/to Jakarta.

**b. The railway line between Paledang Station – Sukabumi Station**

To accommodate the forecasted need for train frequency in 2035 on railroad lines between Paledang - Sukabumi Station, it is necessary to increase the traffic capacity by constructing a double track and adding six signal blocks at several points between stations, as described in the table below.

**Table 7. List of Estimated Train Frequency Needs in 2035**

| No | Station | Km | Speed (Gapeka 2017) | | Distance (Km) | Headway (Minutes/Ka) | Acceleration (Minutes) | Deceleration (Minutes) | Cross Capacity | Frequency Ka (2035 years) | Remaining Capacity | Des |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Maximum Operation | Operation | | | | | | | | |
| 1 | Bogor | 0.000 | | 5 | 0.400 | 7.3 | 0.0 | 0.0 | 118 | 44 | 74 | Single Track |
| 2 | Paledang | 0.400 | | | 3,978 | 7.3 | 0,5 | 0.5 | 243 | 224 | 19 | |
| 3 | Batu Tulis | 4,378 | | | 5.019 | 8.9 | 0.0 | 0.0 | 226 | 224 | 2 | |
| 4 | Sinyal Blok | 9.397 | | | 4,369 | 7.9 | 0.5 | 0.5 | 227 | 224 | 3 | |
| 5 | Maseng | 13,766 | | | 2.928 | 5.6 | 0.5 | 0.5 | 304 | 224 | 80 | |
| 6 | Sinyal Blok | 16.694 | | | 2.928 | 5.6 | 0.5 | 0.5 | 304 | 224 | 80 | |
| 7 | Cigombong | 19.622 | | | 3.547 | 6.6 | 0.5 | 0.5 | 265 | 224 | 41 | |
| 8 | Sinyal Blok | 23.169 | 40 | 38 | 3.547 | 6.6 | 0.5 | 0.5 | 265 | 224 | 41 | Garuda Line |
| 9 | Cicurug | 26.715 | | | 3.822 | 7.0 | 0.5 | 0.5 | 251 | 200 | 51 | |
| 10 | Sinyal Blok | 30.537 | | | 3.822 | 7.0 | 0.5 | 0.5 | 251 | 200 | 51 | |
| 11 | Parangkuda | 34.359 | | | 2.763 | 5.4 | 0.5 | 0.5 | 317 | 200 | 117 | |
| 12 | Sinyal Blok | 37.122 | | | 2.763 | 5.4 | 0.5 | 0.5 | 317 | 200 | 117 | |
| 13 | Cibadak | 39.884 | | | 4.890 | 8.7 | 0.5 | 0.5 | 207 | 200 | 7 | |
| 14 | Karang Tengah | 44.774 | | | | | | | | | | |
| 15 | Sinyal Blok | 48.563 | | | 3.789 | 7.0 | 0.0 | 0.0 | 289 | 200 | 89 | |
| 16 | Cisaat | 52.352 | | | 3.789 | 7.0 | 0.5 | 0.5 | 253 | 180 | 73 | |
| 17 | Sukabumi | 57.173 | | | 4.821 | 8.6 | 1.0 | 1.0 | 190 | 180 | 10 | |

Based on the table above, it can be explained as follows:

**a) The rail line between Bogor Station - Paledang Station**

To be able to accommodate the estimated demand for train frequency in 2035 on the railway line between Bogor Station - Station Paledang is still sufficiently served by a single line because it is based on the explanation as stated in letter c above, the operating pattern passenger trains with the Bogor - Sukabumi service route for early departures and late arrivals are not can be done from Bogor Station so that only trains pass through the train line between Bogor Station - Paledang Station Goods from/to Jakarta.

**b) The railway line between Paledang Station – Sukabumi Station**

To accommodate the forecasted need for train frequency in 2035 on the railway line between Paledang Station - Sukabumi Station, it is necessary to increase the traffic capacity using the construction of a double track and the addition of 6 signal blocks at several between stations as explained in the table above.

**Table 8. List of Estimated Train Frequency Needs in 2045**

| No | Station | Km | Speed (Gapeka 2017) | | Distance (Km) | Headway (Minutes/Ka) | Acceleration (Minutes) | Deceleration (Minutes) | Cross Capacity | Frequency Ka (2035 years) | Remaining Capacity | Des |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Maximum Operation | Operation | | | | | | | | |
| 1 | Bogor | 0.000 | | 5 | 0.400 | 7.3 | 0.0 | 0.0 | 118 | 44 | 74 | Single Track |
| 2 | Paledang | 0.400 | | | 3,978 | 7.3 | 0,5 | 0.5 | 243 | 224 | 19 | |
| 3 | Batu Tulis | 4,378 | | | 5.019 | 8.9 | 0.0 | 0.0 | 226 | 224 | 2 | |
| 4 | Sinyal Blok | 9.397 | | | 4,369 | 7.9 | 0.5 | 0.5 | 227 | 224 | 3 | |
| 5 | Maseng | 13,766 | | | 2.928 | 5.6 | 0.5 | 0.5 | 304 | 224 | 80 | |
| 6 | Sinyal Blok | 16.694 | | | 2.928 | 5.6 | 0.5 | 0.5 | 304 | 224 | 80 | |
| 7 | Cigombong | 19.622 | | | 3.547 | 6.6 | 0.5 | 0.5 | 265 | 224 | 41 | |
| 8 | Sinyal Blok | 23.169 | | | 3.547 | 6.6 | 0.5 | 0.5 | 265 | 224 | 41 | |
| 9 | Cicurug | 26.715 | | | 3.822 | 7.0 | 0.5 | 0.5 | 251 | 200 | 51 | |
| 10 | Sinyal Blok | 30.537 | | | 3.822 | 7.0 | 0.5 | 0.5 | 251 | 200 | 51 | |
| 11 | Parangkuda | 34.359 | | | 2.763 | 5.4 | 0.5 | 0.5 | 317 | 200 | 117 | |
| 12 | Sinyal Blok | 37.122 | | | 2.763 | 5.4 | 0.5 | 0.5 | 317 | 200 | 117 | |
| 13 | Cibadak | 39.884 | | | 4.890 | 8.7 | 0.5 | 0.5 | 207 | 200 | 7 | Garuda Line |
| 14 | Karang Tengah | 44.774 | | | | | | | | | | |
| 15 | Parangkuda | | 40 | 38 | 2.763 | 5.4 | 0.5 | 0.5 | 317 | 270 | 47 | |
| 16 | Sinyal Blok | 37.122 | | | 2.763 | 5.4 | 0.5 | 0.5 | 317 | 270 | 47 | |
| 17 | Cibadak | 39.884 | | | 2.445 | 4.9 | 0.5 | 0.5 | 334 | 270 | 74 | |
| 18 | Sinyal Blok | 42.329 | | | 2.445 | 4.9 | 0.5 | 0.5 | 415 | 271 | 144 | |
| 19 | Karang Tengah | 44.774 | | | 4.126 | 0.0 | 0.0 | 0.0 | 272 | 270 | 2 | |
| 20 | Sinyal Blok | 48.900 | | | 3.452 | 6.5 | 0.5 | 0.5 | 271 | 270 | 1 | |
| 21 | Cisaat | 52.352 | | | 2.411 | .8 | 0.5 | 0.5 | 347 | 231 | 117 | |
| 22 | Sinyal Blok | 54.763 | | | | | | | | | | |
| 23 | Sukabumi | 57.173 | | | 2.411 | 4.8 | 0.5 | 0.5 | 347 | 231 | 116 | |

Based on the table above, it is necessary to accommodate the forecast of train frequency needs in 2045 additional traffic capacity by adding six signal blocks and shifting five signal blocks in some between stations, as explained in the table above.

**Table 9. Train Travel Time from Bogor – Sukabumi**

| NO | STATION | FUNCTION | KM | SPEED (KM/HOURS) (GAPEKA 2017) | | DISTANCE (KM) | HEADWAY (MINUTE/KA) | ACCELERATION (minute) | DECELERATION (minute) | TRAVELING TIME (minute) | WAITING TIME (minute) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MAXIMUM OPERATION | OPERATION | | | | | | |
| 1 | Bogor | Down / up pnp | 0 | 40 | 38 | 4.378 | 9.4 | 0.5 | 0.5 | 7.9 | - |
| 2 | Batu Tulis | Operation | 4.378 | | | 9.718 | 17.8 | 0.5 | 0.5 | 16.3 | 2 |
| 3 | Maseng | Down / up pnp | 14.096 | | | 5.526 | 11.2 | 1.0 | 1.0 | 10.7 | 2 |
| 4 | Cigombong | Down / up pnp | 19.622 | | | 7.093 | 13.7 | 1.0 | 1.0 | 13.2 | 2 |
| 5 | Cicurug | Down / up pnp | 26.715 | | | 7.644 | 14.6 | 1.0 | 1.0 | 14.1 | 2 |
| 6 | Parangkuda | | 34.359 | | | 5.525 | 11.2 | 1.0 | 1.0 | 10.7 | 2 |
| 7 | Cibadak | | 39.884 | | | 4.89 | 10.2 | 0.5 | 0.5 | 8.7 | - |
| 8 | Karang Tengah | | 44.774 | | | | | | | | |

| NO | STATION | FUNCTION | KM | SPEED (KM/HOURS) (GAPEKA 2017) | | DISTANCE (KM) | HEADWAY (MINUTE/KA) | ACCELERATION (minute) | DECELERATION (minute) | TRAVELING TIME (minute) | WAITING TIME (minute) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MAXIMUM OPERATION | OPERATION | | | | | | |
| 8 | Karang Tengah | Operation | 44.774 | 40 | 38 | 7.578 | 14 5 | 0.5 | 0.5 | 13.0 | 2 |
| 9 | Cisaat | Down / up pnp | 52.352 | | | 4.821 | 10 1 | 1.0 | 1.0 | 9.6 | 15 |
| 10 | Sukabumi | Down / up pnp | 57.173 | | | | | | | | |
| TRAVEL TIME & WAITING TIME FOR PALEDANG - SUKABUMI PASSENGER TRAIN (MINUTES) | | | | | | | | | | **104** | **27** |

The table above shows that the travel time for the train from Bogor - Sukabumi is 104 minutes, with a waiting time of 27 minutes, so the needs of the training series can be identified to accommodate potential passenger growth, as shown in the table below.

**Table 10. Needs for the Paledang – Sukabumi Cross Passenger Train Series**

| No | Years | Travel Time (Minutes) | Waiting Time (Minutes) | Frequency Per Day Per Circuit | Network Requirements | Backup 5 % | Need | Train Stabling Needs (Meters) | Locomotive Stabling Needs (Meters) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2020 | 86 | 104 | 27 | 9 | 1 | 10 | 1200 | 200 |
| 2 | 2025 | 110 | 104 | 27 | 12 | 1 | 13 | 1560 | 260 |
| 3 | 2030 | 140 | 104 | 27 | 15 | 1 | 16 | 1920 | 320 |
| 4 | 2035 | 180 | 104 | 27 | 20 | 1 | 21 | 2520 | 420 |
| 5 | 2040 | 228 | 104 | 27 | 25 | 1 | 26 | 3120 | 520 |
| 6 | 2045 | 230 | 104 | 27 | 25 | 1 | 26 | 3120 | 250 |

The table above shows that the needs of the cross-Paledang passenger train series – Sukabumi in 2035 is as many as 21 series with details of 20 series operating (20 locomotives + 20 KP) with one spare circuit (1 locomotive + 125 K3 + 25 KP) as well as stabling requirements for trains > 2520 m and locomotive stabling > 420, whereas, in 2045, 26 sets of trains are needed with details of 25 series operational (25 locomotives + 125 K3 + 25 KP) and one reserve circuit (1 locomotive + 125 K3 + 25 KP) as well as stabling requirements for trains > 3120 meters and stabling locomotive > 520 m.

## CONCLUSION

The analysis of the study of operational patterns on the Bogor-Sukabumi line shows that with the plan to increase the frequency of trains and the construction of a double track, there will be a decrease in the Headway from 10.38 to 7.1. Another benefit generated by the construction of the double track will increase the traffic capacity by 350% from an average of 58 to 276. The operating pattern of Batu Tulis Station and Karang Tengah Station is an Operational Station while Bogor Paledang Station, Maseng Station, Cigombong Station, Cicurug Station, Parungkuda Station, Cibadak Station, Cisaat Station, Sukabumi Station.

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