ANALYSIS OF RAILWAY TRAFFIC CAPACITY IN BANDUNG - CICALENGKA

a Yunanda Raharjanto

ABSTRACT

Theoretical Framework: Constructing a double track and revitalizing or upgrading stations on the Kiaracondong-Cicalengka segment, the Bandung-Cicalengka route has changed routes and stations.

Purposes: The research objective, which is the focus of this study, is the analysis of cross capacity on the Bandung - Cicalengka railway line, the Kiaracondong - Cicalengka segment.

Method: The materials in this research are secondary data and primary data. Secondary data is done by taking inventory of existing data at PT. Kereta Api (Persero) is the operator, and the government, the Directorate General of Railways of the Ministry of Transportation, is the regulator. Primary data was collected by conducting direct surveys at the research location.

Results: The study results show that, theoretically, the calculation of railway traffic capacity for each road plot on the Bandung - Cicalengka route has yet to experience saturation and can be added to train trips as needed.

Keywords: Traffic Capacity, Passenger Satisfaction, Train Operation Patterns, Train Travel Graph.

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ANÁLISE DA CAPACIDADE DE TRÁFEGO FERROVIÁRIO EM BANDUNG - CICALENGKA

RESUMO

Quadro teórico: Construindo uma via dupla e revitalizando ou melhorando estações no segmento Kiaracondong-Cicalengka, a rota Bandung-Cicalengka mudou de rotas e estações.

Finalidades: O objetivo da pesquisa, que é o foco deste estudo, é a análise da capacidade cruzada na linha ferroviária Bandung - Cicalengka, o segmento Kiaracondong - Cicalengka.

Método: Os materiais desta pesquisa são dados secundários e dados primários. Os dados secundários são feitos através do inventário dos dados existentes na PT. Kereta Api (Persero) é

a PhD from the Faculty of Social and Political Sciences, Universitas Muhammadiyah Jakarta, Indonesia, Professor of Rail Transport Management Land Transport Polytechnic-STTD, Indonesia.
Email: yunanda.raharjanto@student.umj.ac.id, Orcid: https://orcid.org/0009-0009-3378-5178
a operadora, e o governo, a Direção Geral de Caminhos de Ferro do Ministério dos Transportes, é o regulador. Os dados primários foram coletados por meio de pesquisas diretas no local da pesquisa.

**Resultados:** Os resultados do estudo mostram que, teoricamente, o cálculo da capacidade de tráfego ferroviário para cada parcela de estrada na rota Bandung - Cicalengka ainda não está saturado e pode ser adicionado às viagens de trem conforme necessário.

**Palavras-chave:** Capacidade de tráfego, Satisfação dos passageiros, Padrões de operação do trem, Gráfico de viagens de trem.

### 1 INTRODUCTION

Transportation as the backbone of development determines the economic growth of a country, and rail is a mode of transportation that must be developed [1]. Unfortunately, the development of railways in Indonesia is still relatively slow. For 70 years (1939-2009), there was a tendency for the railroad infrastructure to operate [2]. In addition, the punctuality of trains in Indonesia is still relatively low [3].

The delays in the railway sector are not only in the development of infrastructure, facilities and number of passengers but also in the development of human resources [4] and various methods related to planning, designing and operating trains. One method that is very important and still under development is the method for determining the capacity of a rail line, even though capacity is a very vital thing because it affects service to rail users.

To provide good service and satisfaction, infrastructure must be planned and designed according to future capacity requirements [5] [15], [16]. Until now, the method of rail capacity used in Indonesia uses methods from other countries modified as product innovation [17].

One factor affecting the capacity of the railway line is headway, where the magnitude of headway has been determined based on the Train Travel Chart or Railway Time Table (GAPEKA). However, in practice, there are still shifts or delays (delays) in train trips due to various factors, so the real capacity is generally lower than planned. Railroad capacity that is not following the plan causes a discrepancy in the planning steps of the train journey.

The capacity of the railway line needs to be increased, considering that rail transportation has advantages in terms of speed and transport capacity and is free from congestion, so rail-based transportation needs to be developed to support the economy in terms of the transportation of people and goods.
Bandung Class 1 Railway Engineering Center, the Directorate General of Railways of the Ministry of Transportation, in this case, is carrying out construction of the double track and upgrading or renovating stations to support the community's need for public transportation services in the area of Operational Area 2 Bandung (PT.KAI), especially the Bandung - Cicalengka route is under construction double track. On the Kiaraccondong – Gedegebe and Haurpugur – Cicalengka road plots, 4 stations have been built, namely Gedegebe Station, Cimekar Station, Rancaekek Station, and Haurpugur Station. Meanwhile, Cicalengka Station is still under construction. To study the results of this development, we conducted a study on cross-capacity analysis on the Bandung - Cicalengka railway line, the Kiaraccondong - Cicalengka segment.

The research objective, which is the focus of this study, is the analysis of cross capacity on the Bandung - Cicalengka railway line, the Kiaraccondong - Cicalengka segment.

2 LITERATURE REVIEW
2.1 RAILWAY LINE CAPACITY

Railway line capacity is the maximum capacity of a railroad to accommodate several train trips within 24 hours or a certain period. In addition, it is also known that station capacity is the maximum capacity of a station to accommodate several train trips within 24 hours or a certain period [2].

In general, capacity is the ability to flow vehicles in a unit of time. However, railroad capacity is more difficult to define, considering that railroad capacity is influenced by infrastructure, scheduling and availability of facilities [6]. International Union of Railways (UIC) (2004) redefines that the capacity of the railroad is not certain. However, the capacity of the railroad is affected by the use (utilized) of the railroad in question.

The capacity method is very complex because many things affect it. The importance of developing a railway capacity method following conditions in a country is evidenced in Denmark, which developed a railway capacity method over 4-5 years [6]. This was also carried out in Australia and found that the factors influencing capacity are traffic (traffic heterogeneity and the direction of traffic served; the length of the training series; dwell times from trains; track conditions and signaling) [7].
Subsequent research stated that determining the capacity of a railroad is more difficult because it depends on the infrastructure and schedule of the trains. Over the years, the capacity of a railroad has been determined in various ways, namely:

- a. The capacity of infrastructure depends on the ability to operate trains with acceptable timeliness;
- b. capacity can be defined as the ability of the infrastructure to bear the load of one or more schedules;
- c. capacity cannot be fully defined, given that the reliability of the railroad infrastructure depends on its use [8].

Some of the parameters are the number of trains, delays or delays, stability, heterogeneity, and average speed are related to each other and also affect the size of the lane capacity.

2.2 RAILWAY LINE CAPACITY VARIABLE

Research on the relationship variables between railroads and railroads on the railroad capacity has been disclosed as it is known that the capacity of the railway line is the relationship between the speed of the train, the speed track (planned speed), distance, and time. There are two categories of main variables, namely variables track which includes: the amount of track, maximum speed track, signal system, track leaning ratio, radius minimal, and track resistance (tunnels, crossings and slopes), while the variables of the train include: load capacity, a maximum weight of the train, the maximum length of the train, the ability of the driver, the tensile strength of the locomotive. These two variables will affect the amount of traffic capacity in terms of contribution to travel time [10].

Meanwhile, the capacity of railroads in Indonesia is a function of interrelated factors, headway, frequency, density and speed, and distance between stations. The various variables that affect capacity are speed which is distinguished between the speed of the facility and the speed of the infrastructure design, and the signaling system used, which affects the service time (route preparation) in train operations. The capacity cannot be fully utilized due to the use of some of the capacity for maintenance activities for the railway line and the improvement of operating patterns (scheduling). The use of capacity for non-operational activities greatly affects the capacity of the existing railroad lines and
the minimum use of capacity for services so that services to passengers and goods cannot be maximized [9] [10] [11].

One of the steps to optimize the use of railroad capacity is to maximize the planning of train travel schedules, or Gapeka (railway travel charts or railway time table). Gapeka is a guideline for managing the implementation of train travel which is depicted in the form of a line indicating the station, time, distance, speed and position of the train journey starting from departure, crossing, overtaking and stopping, which is graphically depicted for controlling train travel. Headway is the interval between arriving or departing trains with the next train. Time unit headway in minutes. Headway is also defined as the distance between the two ends of two trains running in the same direction on the same destination line. Headway minimum is the minimum distance possible with the travel speed following the signal and security system [8]. Besides, headway, also known as the frequency of train trips, namely the number of train trips on a railroad line within 24 hours or in a certain period with units of train frequency, is the number of trains in a unit of time [2].

Based on several previous studies, it is known that various factors affect the amount of railroad line capacity, namely: number of trains, heterogeneity, stability, speed, infrastructure, operation, train length, time delay, junction, intermediate signals, resource, scheduling, number of paths, length track, signal distance, stop and maintenance.

3 METHOD

The materials in this research are secondary data and primary data. Secondary data is done by taking inventory of existing data at PT. Kereta Api (Persero) is the operator, and the government, the Directorate General of Railways of the Ministry of Transportation, is the regulator. Primary data was collected by conducting direct surveys at the research location. The research location is determined based on the location that can represent the two conditions of the railroad tracks: single track and double track. The research location was determined based on these considerations, namely the Bandung - Cicalengka route and the Kiaraccondong - Cicalengka segment.

In conducting research, the process of analysis and the course of research is carried out as follows:

(a). Secondary data collection;
(b). Primary data collection;

(c). Primary data analysis uses the current capacity formula;
(d). Comparing the value of the Capacity of the railroad between the planned Capacity according to Topeka and the actual Capacity based on primary data;

4 RESULTS AND DISCUSSION
4.1 ANALYSIS OF THE FORMULA FOR CALCULATING THE CAPACITY OF RAILROADS IN INDONESIA

The formula for calculating the Capacity of railroads in Indonesia currently uses the following formula or equation:

1. For single track

\[ K = \frac{1440}{H} \times \eta \]

2. For double track

\[ K = \frac{1440}{H} \times 2 \times \eta \]

Where:

- \( K \) = Capacity on the calculated road plot or cross capacity if the lowest \( K \) value is taken
- 1440 = total time for 24 hours (24 x 60)
- the = multiplier factor after deducting the time factor for maintenance and time due to the pattern of train travel operations, 60% for single track and 70% for double track.
- \( H \) = headway (minute)
- ta-b = train travel time between station A and station B (minutes)
- tp = travel time from before the front signal of station A for the second train (distance 3 km) (minutes)
- C = block and signal service time (minutes)

The efficiency factor is the multiplier factor after deducting the time factor for maintenance and the time due to train travel patterns. On a single line, the traffic capacity is 60% (reduced by 40%), with the following reduction details: 20% for maintenance and 20% for lost time because it is difficult or rare to minimize good time in headway minimum for two or more one-way trains. It is difficult to minimize the time to wait for crossing and or overtaking. The average speed on a single track is very low; the more trains, which means the more frequent crossings and/or overtaking, the lower the average speed or, the longer the average travel time (if the average speed or travel time exceeds...
30%, should be used as a twin or multiple lane). While on double track, the traffic capacity is 70% (reduced by 30%) with the following reduction details: 20% for maintenance and 10% time lost because it cannot minimize the time in the minimum headway for two trains or more one-way trains.

The equation above shows that factors affect the capacity value, namely headway, the number of paths and efficiency values. Efficiency values are determined for a single line of 60% and a double path of 70% to accommodate maintenance and lost time. However, based on previous research, it is known that various factors affect the size of the railroad line capacity, namely: the number of trains, heterogeneity, stability, speed, infrastructure, operation, train length, time delay, junction, intermediate signals, resource, scheduling, number of paths, length track, signal distance, stops and maintenance up to Further research is needed to find out how much influence these factors have on Capacity in order to develop the current capacity calculation model.

Headway minimum can be influenced by several factors, including the track system passed by the trains, single track and double track and the block connection system used [10][11]. To calculate the theoretical headway, several formulas can be used according to the criteria:

1) Hubungan blok manual

\[ H = \frac{60 \times (SAB+B)}{V} + 1 \]

*Source: Supriadi, 2008*

2) Hubungan Blok Otomatik Tertutup

\[ H = \frac{60 \times (SAB+B)}{V} + 0.25 \]

*Source: Supriadi, 2008*

4) Hubungan Blok Otomatik Tertutup

\[ H = \frac{60 \times (SAB+B)}{V} + 0.25 \]

*Source: Supriadi, 2008*

Information:

- \( H \) = Headway (minute)
- \( SAB \) = longest distance between two stations on the route concerned (km)
- \( B \) = distance between two successive signal blocks (km)
- \( IN \) = Graphical average speed (km/h)
- 1, 0.25 = block service time
Based on the results of an analysis of the 2023 Railroad Travel Chart (GAPEKA) data and survey data, it is known that the Capacity of the railroad tracks, speed and time delay of the Bandung-Cicalengka route are presented in Table 1.

Table 1. The Capacity of the Bandung-Cicalengka railroad line

<table>
<thead>
<tr>
<th>NO</th>
<th>Lintas</th>
<th>Petak jalan</th>
<th>Perjalanan kereta api (KA)</th>
<th>Kapasitas lintas supriadi (KA)</th>
<th>Kapasitas lintas metode 2 (KA)</th>
<th>Kapasitas lintas GAPEKA 2023</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bd - Cth</td>
<td>2,638</td>
<td>76</td>
<td>450</td>
<td>477</td>
<td>296</td>
</tr>
<tr>
<td>2</td>
<td>Cth - Kac</td>
<td>2,352</td>
<td>76</td>
<td>473</td>
<td>502</td>
<td>296</td>
</tr>
<tr>
<td>3</td>
<td>Kac - Gdb</td>
<td>5,208</td>
<td>77</td>
<td>108</td>
<td>135</td>
<td>131</td>
</tr>
<tr>
<td>4</td>
<td>Gdb - Cmk</td>
<td>2,798</td>
<td>76</td>
<td>441</td>
<td>465</td>
<td>314</td>
</tr>
<tr>
<td>5</td>
<td>Cmk - Rck</td>
<td>4,847</td>
<td>76</td>
<td>331</td>
<td>344</td>
<td>314</td>
</tr>
<tr>
<td>6</td>
<td>Rck - Hrp</td>
<td>5,173</td>
<td>76</td>
<td>318</td>
<td>330</td>
<td>314</td>
</tr>
<tr>
<td>7</td>
<td>Hrp - Cdl</td>
<td>4,121</td>
<td>76</td>
<td>131</td>
<td>161</td>
<td>123</td>
</tr>
</tbody>
</table>

Source: Analysis, 2023

From the table above, it is known that the type of line, the distance between stations, speed, Capacity and delay are as follows:

a. Path type

There are 2 (two) types of lanes on the Kroya-Kutoarjo-Yogyakarta route, namely the single track (single track) crossing Kiaraccondong-Gedebeage, Haurpugur-Cicalengka and double track (double track) across Bandung-Kiaraccondong, Gedebeage-Haurpugur.

b. Distance between stations

There are 8 train stations on the Bandung-Cicalengka route. The shortest distance between the stations between Cikudapateuh Station and Kiaraccondong Station is 2,352 km, and the longest between Kiaraccondong Station and Gedebeage Station is 5,208 km.

c. Average speed

On the single track, the average speed at that time (survey) was 75 km/hour, while on the double track, the average speed at that time (survey) was 80 km/hour.

d. Capacity

On a single line, the average Capacity is 77 trains/day from the planned 130 trains/day in Gapeka.

On the double track, the average Capacity during the survey was 77 trains/day from the planned 2023 Gapeka of 296 trains/day.
4.2 ANALYSIS OF TRAFFIC VOLUME AND CAPACITY

Based on the results of data processing, it is known that the volume of trains on the Bandung-Cicalengka line is 77 KA/day; there is still an idle capacity of the line shown in Table 2.

Table 2. Idle Capacity on the Bandung-Cicalengka route

<table>
<thead>
<tr>
<th>NO</th>
<th>Lintas</th>
<th>Petak jalan (km)</th>
<th>Perjalanan kereta api (KA)</th>
<th>kapasitas lintas GAPEKA</th>
<th>Idle capacity GAPEKA 2023</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bd - Cth</td>
<td>2,638</td>
<td>76</td>
<td>296</td>
<td>220</td>
</tr>
<tr>
<td>2</td>
<td>Cth - Kac</td>
<td>2,352</td>
<td>76</td>
<td>296</td>
<td>220</td>
</tr>
<tr>
<td>3</td>
<td>Kac - Gdb</td>
<td>5,208</td>
<td>77</td>
<td>131</td>
<td>54</td>
</tr>
<tr>
<td>4</td>
<td>Gdb - Cmk</td>
<td>2,796</td>
<td>76</td>
<td>314</td>
<td>238</td>
</tr>
<tr>
<td>5</td>
<td>Cmk - Rck</td>
<td>4,847</td>
<td>76</td>
<td>314</td>
<td>238</td>
</tr>
<tr>
<td>6</td>
<td>Rck - Hrp</td>
<td>5,173</td>
<td>76</td>
<td>121</td>
<td>45</td>
</tr>
<tr>
<td>7</td>
<td>Hrp - Cd</td>
<td>4,121</td>
<td>76</td>
<td>121</td>
<td>45</td>
</tr>
</tbody>
</table>

Source: Data Processing, 2023

Table 2 shows that the actual speed varies and is much lower than planned. The speed deviation between realization and plan on a single track is greater than on a double track. This shows that travel arrangements for the stability of travel on a single track are more difficult than on a double track because, on a single track, the traffic is used alternately from two directions, while on the double track, the lanes are used one way or each unless an accident or disturbance occurs.

From Table 1 it can be seen the following:

a. Single track capacity is lower than double track;
b. Actual Capacity on double-track is close to what Gapeka planned for 2023; this shows that maintaining stability on double-track is easier than on single-track;
c. The tendency of capacity realization to decrease on lines approaching large stations; this is possible due to queues waiting before entering a station which is a station for passengers to go up and down related to station capacity (number of emplacements);
d. Capacity utilization is still low both on the single track and on the double track, namely the volume of 77 trains per day for the Bandung-Cicalengka line;
e. That the existing traffic capacity has not been used optimally, and additional trips can still be added if needed, namely a maximum of 45 train trips/day that can be added.
5 CONCLUSION

The following conclusions are obtained from the description and results of the analysis that has been carried out through a series of discussions.

a. The formula for calculating the Capacity of railroads in Indonesia consists of factors headway, number of paths and efficiency values (used for maintenance and lost time). The results of previous studies stated that various factors affect the size of the railroad line capacity, namely: the number of trains, heterogeneity, stability, speed, infrastructure, operation, train length, time delay, junction, intermediate signals, resources, scheduling, number of paths, length track, signal distance, stops and maintenance, so further research is needed to find out how much influence these factors have on Capacity in order to develop capacity calculation models currently used in Indonesia.

b. The existing traffic capacity has yet to be used optimally, and additional trips can still be added if needed. Namely, a maximum of 45 train trips/day can be added.

c. Capacity utilization is still low, namely on single lines, the average Capacity is 77 trains/day from the planned 130 trains in Gapeka/day, while on the double track, the average Capacity during the survey is 77 trains/day from the planned 2023 Gapeka of 296 KA/day.
REFERENCES


