GROSTLOG 2024
Global Research on Sustainable Transport & Logistics

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/altr

ANALYSIS OF CAPACITY DEVELOPMENT PLANNING BASED ON THE UPGRADING OF SINGLE TRACK TO DOUBLE TRACK ON THE PADALARANG-CICALENGKA LINE

Totok Suryono[1], Heriyanto Wibowo[2], Desi Fadilla Fitriani[3]
[1,2,3]Institut Transpotasi dan Logistk Trisakti, Jakarta, Indonesia
Corresponding author: desifadillafitriani@gmail.com

Abstract: PT. Kereta Api Indonesia (Persero) initiated capacity development planning on the Padalarang-Cicalengka Line in 2019 to meet projected passenger increases, using the Moving Average method over three years to forecast passenger numbers from 2019 to 2033. Results indicate significant fluctuations in passenger volume during the initial period, primarily due to the COVID-19 pandemic's impact. Post-2024, a steady increase is observed, with projections reaching 617,364 passengers by 2026 and stabilizing around 595,000 to 600,000 passengers through 2033. Infrastructure enhancements, such as the development of double-track segments and a shift to electronic signaling, are key factors contributing to capacity growth and operational reliability. While capacity trends are stabilizing, challenges remain in single-track segments that must be addressed to support sustainable growth. The implementation of double-track segments on the Haurpugur-Cicalengka route increased line capacity by 133%, aligning with the planned rail program. Additionally, adjustments in track layout design have been made to meet projected passenger demand and prevent overloading in coming years.
Keywords: *Line capacity planning, single track, double track, passenger projection, railway infrastructure, line capacity, Haurpugur-Cicalengka, electronic signaling*

Introduction

Indonesia is one of the world's most densely populated countries, with the population in West Java alone reaching 49,935,858. This large population makes transportation a primary need, essential for mobility. Among the most widely used transportation modes is rail, which provides a mass transit option on a dedicated, high-speed track, ensuring high levels of safety, security, and punctuality. These advantages have increased public interest in rail travel year by year.

ISSN: 2622-5778 (online)
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Railway development in Indonesia has progressed rapidly in various regions, including Bandung Operational Area 2, particularly along the Padalarang-Cicalengka line. This development encompasses long-distance passenger trains, local trains, and freight services, with demand risingannually. Advances in railway technology are seen in both rolling stock and infrastructure. One key infrastructural improvement involves railway tracks, which play a critical role in ensuring safe, efficient train operations across stations. For example, operational safety was underscored by the collision between Bandung Raya Train 350 and Turangga Train 654 at Km 181+700 on the Cicalengka-Haurpugur line segment. This incident highlighted vulnerabilities in signaling and track coordination, particularly on single-track lines, where opposing trains can share the same track. With limited systems and infrastructure, such accidents pose substantial material and humanrisks.

Advancing railway technology, particularly within Bandung Operational Area 2 and the Padalarang-Cicalengka line, is crucial to prevent similar accidents. One approach is to enhance line capacity and safety systems by upgrading from a single track to a double track. This development is expected to increase not only operational capacity but also travel safety and security along this line.

This study aims to identify key factors necessary for development, effective planning management processes, the impacts of such development, and the potential capacity increase resulting from upgrading single to double track. Planning and development on the Padalarang-Cicalengka line are therefore essential. Hence, this research, titled "**Capacity Development Planning Analysis Based on Upgrading from Single Track to Double Track on the Padalarang-Cicalengka Line**," was chosen to address these crucial topics.

Literatur Review

1. Literatur Review

This study builds on previous research, including:

a. Ir. Bambang Drajat, M.M; Ir. J.C Hosang, M.T; Ir. Tonny C.M. Korah, M.Si; Ir. Djajadi, M.M; Uriansah P., M.M (2017): Examining double-track construction at Cilame Stationthrough adjustments in track position and elevation. This research serves as a reference for understanding track structure and alignment.

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Advances in Transportation and Logistics Research
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b. Dian Setiawan, Rahardhita Latifiana, Sri Atmaja (2018): Investigating traffic regulation at Cicalengka Station to support the Bandung-Cibatu double-track line. This study provides insight into traffic management concepts for operational optimization.
c. Mohammad Nur (2019): Discussing capacity calculation models for rail lines in Northern Java, taking into account infrastructure and local conditions. This approach has been adopted to consider line capacity in this study.
d. Jimmy Jeremy and Nugroho Utomo (2020): Planning a double track on the Wonokromo-Sidoarjo line to meet RIPNAS transportation demands. Insights from this study have beenused for double-track planning..
e. Fadhlan Nurrachman (2023): Analyzing the replacement of mechanical with electric signals at Merapi Station to enhance capacity. This study is referenced to understand the impact of electric signaling on train frequency and schedule accuracy.

2. Single-Track System

In railways, a single-track system is one in which a single line is used for trains traveling in both directions alternately. This system has lower capacity and requires greater coordination to avoid crossing conflicts, as trains from opposite directions may arrive simultaneously. Consequently, travel frequency and average speed are reduced due to waiting for crossings or overtakes at designated stations, making this system more prone to delays.

3. Double-Track System

A double-track system consists of two parallel tracks, allowing continuous movementof trains in both directions without alternating. This setup increases line capacity and allows operational speeds closer to the maximum allowable, as trains don’t need to stop for crossings. Double-tracking also minimizes wait times and reduces operational disruptions, enabling more efficient scheduling to accommodate high train frequencies.

4. Headway and Rail Line Capacity

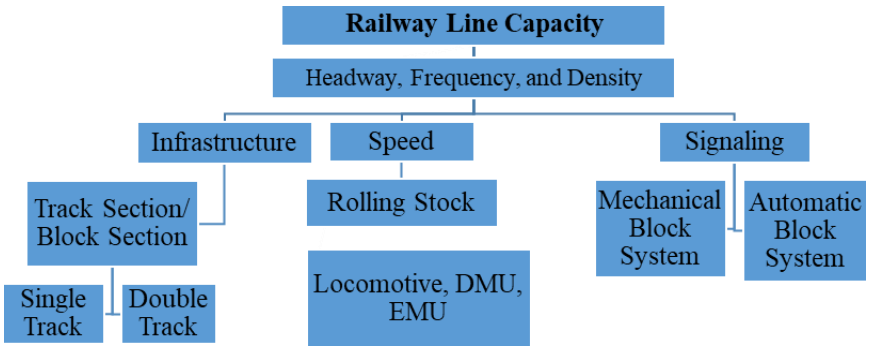

Figure 1 Railway Line Capacity

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Advances in Transportation and Logistics Research
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Headway

Headway is the minimum time interval between two successive trains operatingon the same track, ensuring safe passage without congestion or safety risks. Shorter headways allow higher train frequencies, increasing the number of trains that can pass through the line within a given timeframe..

a. Railway Line Capacity

Line capacity is the maximum number of trains that can traverse a track within a certain time period, typically measured daily. This capacity is influenced by factors suchas headway, signaling systems, train types and speeds, and infrastructure conditions likethe number of tracks (single or double). In Indonesia, line capacity is often limited on single-track routes outside major cities, restricting frequency and risking delays, thus necessitating careful infrastructure development planning.

Research Method

The research method is a scientific approach used to obtain valid data to develop and validate knowledge. This study applies a quantitative descriptive method to provide an initial understanding of specific phenomena and serve as a basis for further research (V. Surjarweni Wiratna, 2015). The quantitative method gathers and analyzes numerical data to answer research questions or test hypotheses, as well as to statistically measure and analyze the relationships between variables. Based on positivist philosophy, this method involves interconnected procedures to achieve analytical results that can be presented in tables and calculations. The sequence of research activities is outlined in a flowchart.:

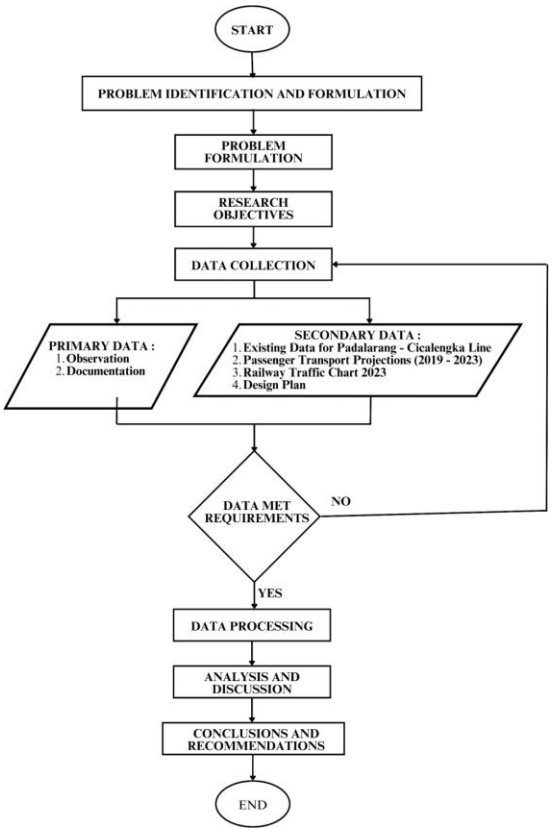

Figure 2 Research Path

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Results and Discussion

1. Proyeksi Angkutan Penumpang

Table 1 Passenger Transport Data from 2019-2023

YEAR	PASSENGER TRANSPORT (PEOPLE)
2019	839.756
2020	366.789
2021	295.042
2023	544.838
2024	729.674

Based on passenger data from 2019 to 2023, there was significant fluctuation. To predict the number of passengers in subsequent years, the researcher applied the Moving Average method with a 3-year period. The formula used is:

$$\textbf{Forecast (t)} = \frac{\sum_{i=1}^{n} Data\,(t-i)}{n}$$

Dimana :
Forecast (t) = Prediction for period t
n = Number of periods used in the moving average
Data (t-i) = Data from the previous period

Table 2 Calculation Results

YEAR	PASSENGER TRANSPORT (PEOPLE)
2024	523.185
2025	599.232
2026	617.364
2027	579.927
2028	598.841
2029	598.710
2030	592.493
2031	596.681
2032	595.962
2033	595.045

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Analisis Kondisi Existing dan Kondisi Pengembangan

a. Perhitungan Headway dan Kapasitas Lintas

Table 3 Existing Conditions and Development Conditions

No	Track Section	Existing Condition						Development Condition					
		Track	Signal	Headway (minutes)	Line Capacity (trains/day)	Trains Passing	Line Capacity Difference	Track	Signal	Headway (minutes)	Line Capacity (trains/day)	Trains Passing	Line Capacity Difference
1	Padalarang-Cimahi	Double	Elektrik	7	288	130	158	Double	Elektrik	7	288	130	158
2	Cimahi-Cimindi	Double	Elektrik	5	403	124	279	Double	Elektrik	5	403	130	273
3	Cimindi-Andir	Double	Elektrik	4	504	124	380	Double	Elektrik	4	504	130	374
4	Andir-Bandung	Double	Elektrik	4	504	124	380	Double	Elektrik	4	504	50	454
5	Andir-Ciroyom	Single	Elektrik	3	288	88	200	Single	Elektrik	3	288	88	200
6	Ciroyom-Bandung	Double	Elektrik	3	672	36	636	Double	Elektrik	3	672	36	636
7	Bandung-Cikudapateuh	Double	Elektrik	4	504	36	468	Double	Elektrik	4	504	167	337
8	Cikudapateuh-Kiaracondong	Double	Elektrik	4	504	89	415	Double	Elektrik	4	504	123	381
9	Kiaracondong-Gedebage	Double	Elektrik	6	336	89	247	Double	Elektrik	6	336	104	232
10	Gedebage-Rancaekek	Double	Elektrik	8	252	85	167	Double	Elektrik	8	252	90	162
11	Rancaekek-Haurpugur	Double	Elektrik	6	336	72	264	Double	Elektrik	6	336	78	258
12	Haurpugur-Cicalengka	Single	Mekanik	6	336	72	264	Double	Elektrik	6	336	78	258

According to the table comparing headway and line capacity calculations for the Padalarang-Cicalengka line, changes occur in the Andir-Ciroyom section and the Haurpugur-Cicalengka section. To determine the percentage increase, the following formula is used:

Haurpugur-Cicalengka Section
Increase = (Development Capacity − Existing Capacity) / (Existing Capacity) ×100 %
Increase = (336 - 144) / 144 ×100 %
Increase = 192/144 ×100 %
Increase = 1,333 × 100 %
Increase = 133 %

Based on the above calculation, the line capacity has increased by 133%. Implementing this requires support from optimized rolling stock and infrastructure, as well as enhanced safety and operational flexibility, to meet the projected passenger transport growth plan.

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b. Relationship Between Train Program and Line Capacity

Based on line capacity calculations, the resulting development capacity for the section is 336 trains per day. In accordance with regulations, 80% of this capacity is designated for train operations and 20% for maintenance.

Table 4 Railway Program 2023–2033

No	Track Section	Program 2023			Program 2024			Program 2025			Program 2026			Program 2027			Program 2028			Program 2029			Program 2030			Program 2031			Program 2032			Program 2033		
		KA Pnp	KA Brg	Total	KA Pnp	KA Brg	Total	KA Pnp	KA Brg	Total	KA Pnp	KA Brg	Total	KA Pnp	KA Brg	Total	KA Pnp	KA Brg	Total	KA Pnp	KA Brg	Total	KA Pnp	KA Brg	Total	KA Pnp	KA Brg	Total	KA Pnp	KA Brg	Total	KA Pnp	KA Brg	Total
1	Padalarang-Cimahi	76	4	80	126	4	130	157	4	161	188	4	192	219	4	223	250	4	254	281	4	285	312	4	316	343	4	347	374	4	378	405	4	409
2	Cimahi-Cimindi	76	4	80	126	4	130	157	4	161	188	4	192	219	4	223	250	4	254	281	4	285	312	4	316	343	4	347	374	4	378	405	4	409
3	Cimindi-Andir	76	4	80	126	4	130	157	4	161	188	4	192	219	4	223	250	4	254	281	4	285	312	4	316	343	4	347	374	4	378	405	4	409
4	Andir-Bandung	40	4	44	126	4	130	157	4	161	188	4	192	219	4	223	250	4	254	281	4	285	312	4	316	343	4	347	374	4	378	405	4	409
5	Andir-Cicayam	36	0	36	36	0	36	67	0	67	98	0	98	129	0	129	160	0	160	191	0	191	222	0	222	253	0	253	284	0	284	315	0	315
6	Cicayam-Bandung	36	0	36	36	0	36	67	0	67	98	0	98	129	0	129	160	0	160	191	0	191	222	0	222	253	0	253	284	0	284	315	0	315
7	Bandung-Cikudapateuh	83	6	89	161	6	167	192	6	198	223	6	229	254	6	260	285	6	291	316	6	322	347	6	353	378	6	384	409	6	415	440	6	446
8	Cikudapateuh-Kiaracondong	83	6	89	117	6	123	148	6	154	179	6	185	210	6	216	241	6	247	272	6	278	303	6	309	334	6	340	365	6	371	396	6	402
9	Kiaracondong-Gedebage	79	6	85	98	6	104	129	6	135	160	6	166	191	6	197	222	6	228	253	6	259	284	6	290	315	6	321	346	6	352	377	6	383
10	Gedebage-Rancaekek	70	2	72	84	6	90	115	8	123	146	10	156	177	12	189	208	14	222	239	16	255	270	18	288	301	20	321	332	22	354	363	24	387
11	Rancaekek-Haurpugur	70	2	72	76	2	78	107	2	109	138	2	140	169	2	171	200	2	202	231	2	233	262	2	264	293	2	295	324	2	326	355	2	357
12	Haurpugur-Cicalengka	70	2	72	76	2	78	107	2	109	138	2	140	169	2	171	200	2	202	231	2	233	262	2	264	293	2	295	324	2	326	355	2	357

In alignment with the available line capacity, this development meets the railway program planned by the operational unit for trains passing through Haurpugur and Cicalengka Stations. For the years 2023–2032, based on the calculated railway program and line capacity on the Haurpugur-Cicalengka segment, the existing capacity can still accommodate the demand without reaching saturation. However, if the projection for passenger and freight transport increases, additional railway programs and development planning will be necessary to meet future needs.

2. Design Plan Analysis

In this design plan analysis, a review of the track layout design is conducted, which includes upgrading the line from single to double track. Additionally, the analysis considers the transition from mechanical to electronic signaling on the Haurpugur-Cicalengka section. These changes are planned to enhance line capacity and operational efficiency, ensuring that track upgrades and signal transitions are implemented to support the future growth of the line.

ISSN: 2622-5778 (online)
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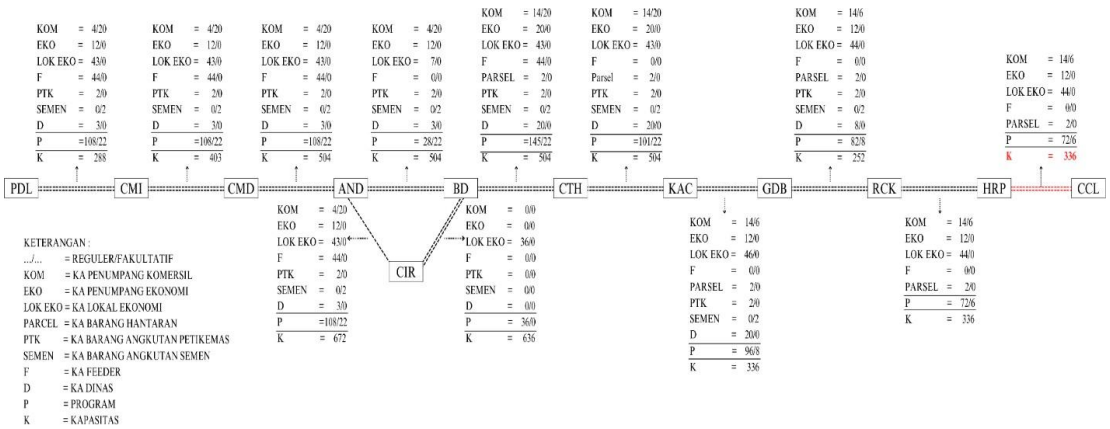

Figure 3 Line Capacity Map (Development)

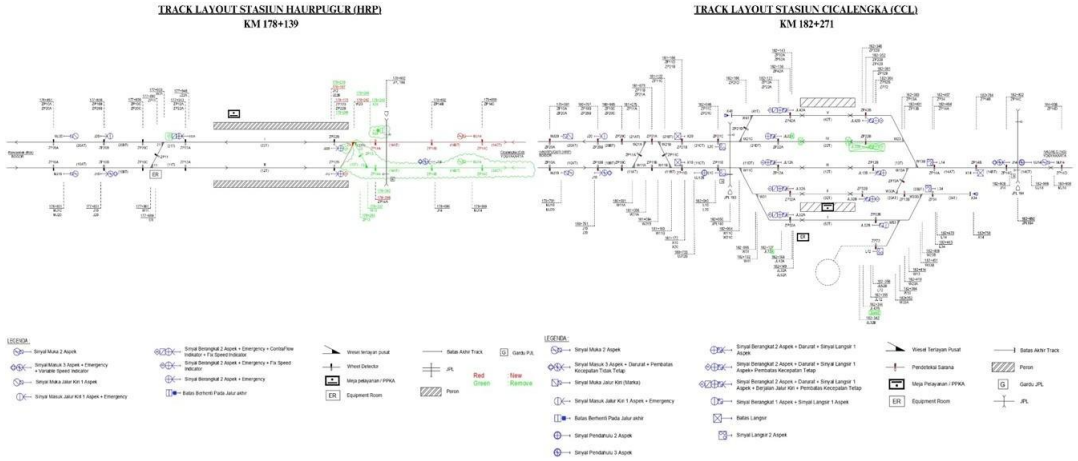

Figure 4 Track Layout Design Plan for Haurpugur Station and Cicalengka Station

Conclusion

Based on the results of the research titled "Analysis of Capacity Development Planning Based on the Upgrade from Single Track to Double Track on the Padalarang-Cicalengka Line," the following conclusions can be drawn:

1. Based on the forecasting calculations using the Moving Average method with a 3-year period for projecting passenger numbers from 2019 to 2033, the following conclusions can be made:
   a. Initial Passenger Fluctuations

      The number of passengers experienced significant fluctuations in the early period, particularly between 2019 and 2023. In 2019, the passenger count reached 839,756 individuals, which then drastically declined to 366,789 in 2020, likely due to the impact of the COVID-19 pandemic. This decline continued through 2021 but began to rise again in 2022 and 2023.

   b. Rising Trend After 2024

      Following the fluctuating initial period, projections for passenger numbers show a more stable upward trend from 2024 to 2026. In 2024, the projected number of passengers is 523,185, gradually increasing to a peak of 617,364 in 2026.

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
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c. Passenger Stability

From 2027 to 2033, the projected number of passengers indicates stability with slight fluctuations around the figures of 595,000 to 600,000, reflecting a stable operational period for the railways.

d. Impact of Infrastructure

The increased stability in passenger numbers after 2024 is attributed to infrastructure development, including the introduction of double tracks and the transition from mechanical to electrical signaling, enhancing capacity and operational reliability.

e. Potential Challenges

Despite the projections indicating stability, capacity challenges in some single-track areas may affect the ability to manage future passenger growth. Therefore, well-planned infrastructure development is essential to support sustained growth.

In conclusion, the passenger projections indicate an increase in the number of railway users after a drastic decline in the early period (2020-2021), stabilizing at around 595,000 to 600,000 passengers per year after 2026. The development of infrastructure and proper planning are key to maintaining passenger stability and addressing existing capacity challenges.

2. The implementation of double tracks results in an increase in line capacity of 133% (one hundred thirty-three percent) on the Haurpugur-Cicalengka section. This increase aligns with the railway programs that have been planned, ensuring that the line can accommodate higher operational needs.

3. Changes in the track layout design have occurred following the calculations of headway capacity and the railway program plans from 2023 to 2033 to meet projected passenger needs without overloading.

Implication

1. With the projected increase in passenger transport, it is necessary to optimize this by adding more train services.
2. With the realization of additional train services, an upgrade from single track to double track on the Haurpugur-Cicalengka line is essential.
3. There is a need for optimization in the double track development with adjustments to the track layout design at Haurpugur Station and Cicalengka Station.

Research Limitations

Limited time for data collection posed challenges for the researcher; however, this also encouraged a sharper focus on the most relevant key variables, ensuring that the research results contribute significantly to the understanding of the studied phenomenon and open avenues for future research.

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