Trans Jatim Scheduling with Headway Optimization and Branch and Bound Method

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**Abstract.** This study examines the scheduling of Trans Jatim Corridor I, which is currently not optimal in meeting passenger demand, leading to inefficient fleet utilization and service quality issues. The objective is to develop a new timetable based on headway and bus capacity. The process involves two stages: first, determining the optimal departure frequency using an optimization model; second, applying the Branch and Bound method to generate a headway distribution that minimizes crowding. The model divides operational hours into peak and off-peak periods. The results show that the model produces an adaptive and efficient daily timetable from Monday to Sunday, with even headways and optimized fleet allocation. For instance, Friday requires 49 buses, while Saturday only needs 36, reflecting demand fluctuations. Sensitivity analysis across various scenarios confirms the model’s robustness and ability to maintain comfortable occupancy levels. Overall, the proposed scheduling system enhances operational efficiency and improves service reliability for Trans Jatim Corridor I.

**Keywords:** Scheduling, Headway, Timetable, Crowding, Branch and bound

# INTRODUCTION

Public transportation is a critical sector that supports development and economic growth (Pyankova & Zakolyukina, 2024). It plays a vital role in facilitating the mobility of the population. Developing a reliable public transport system is a key strategy for achieving a sustainable and environmentally friendly mobility system (Torres & McArthur, 2024). An effective public transportation system can significantly reduce travel time and enhance overall urban mobility (Yusuf et al., 2024). Improving service quality is crucial for retaining and attracting users (Cheng & He, 2024). One of the main factors influencing service quality is the scheduling and headway management of bus arrivals (James, 2024). Adjusting bus schedules according to demand fluctuations, particularly during peak hours, can minimize waiting time at stops and make travel more efficient and predictable. Population growth and economic activity in urban areas have increased the demand for reliable and efficient public transportation. Surabaya Raya, the second-largest metropolitan area in Indonesia, comprising Surabaya, Sidoarjo, and Gresik has experienced a surge in population mobility. In response, the East Java Provincial Government launched the Trans Jatim service, a bus-based mass transportation system with strategic routes and affordable fares. This initiative has become an essential solution to address the mobility challenges in increasingly congested urban areas.

Between January and March 2025, the East Java Transportation Agency recorded a total of 1,603,554 passengers using Trans Jatim services across five corridors (Azmi, 2025). Among them, Corridor I reported the highest ridership, with 627,946 passengers or 39% of the total, highlighting the corridor’s critical importance. This study focuses on optimizing the scheduling system of Corridor I (Sidoarjo–Surabaya–Gresik). Although Corridor I currently operates with variable headways of 10 minutes during peak hours and 15 minutes during off-peak hours, issues such as passenger congestion during peak periods and low occupancy during off-peak times persist. In some cases, buses experience overcapacity, indicating that the current scheduling system has not fully adapted to demand fluctuations. Therefore, an optimized approach to headway and timetable planning is needed, one that accounts for daily demand distribution, fleet availability, and identification of critical time windows such as work hours and low-demand periods (Nesmachnow et al., 2023). Demand-based scheduling has been shown to reduce bus operating costs by up to 13.7% and lower total transportation system costs by 18%, demonstrating that real demand-based adjustments are an effective strategy for improving service efficiency and sustainability (Yu et al., 2024). Given that Corridor I serves over 39% of Trans Jatim’s total passengers, enhancing efficiency in this corridor is expected to yield significant systemic benefits. This study employs the branch and bound method to generate an optimized daily departure schedule for Trans Jatim Corridor I by distinguishing headways between peak and off-peak periods. The approach is grounded in one full week of historical data, allowing the model to more accurately capture passenger demand fluctuations (Pangia & Wiecek, 2025). Compared to methods such as Linear Programming or heuristic techniques, the branch and bound method offers superior flexibility in accommodating logical constraints and can be effectively adapted to real operational scenarios, including fleet limitations and directional demand imbalances. Its application has also been proven to reduce crowding and cut operational costs by more than 8% during peak periods This study addresses a research gap in previous works, which often rely on daily averages or single-direction service data, overlooking inter-day dynamics and bidirectional demand patterns. Moreover, this study contributes new insights by (1) developing Monday–Sunday daily schedules that respond to demand fluctuations, (2) simultaneously considering the characteristics of bidirectional demand, and (3) providing explicit recommendations for the ideal number of buses needed based on the optimized timetable. Thus, the proposed model not only mitigates crowding and balances frequency across time periods, but also offers an efficient and implementable operational solution to support the sustainable improvement of Trans Jatim services.

# Methods

This study utilizes both primary and secondary data to support the formulation and optimization process of the Trans Jatim Corridor I bus scheduling model. Primary data were obtained through direct communication with the East Java Provincial Transportation Agency via in-depth interviews to understand the current scheduling mechanism. Meanwhile, secondary data were collected from official documents, including operational schedules, passenger volumes, route structures, and the list of stops served by the Trans Jatim buses. Specifically, passenger demand data were gathered in real-time over a full week, from Monday to Sunday, between 05:00 and 21:00 Western Indonesian Time (WIB), using the official Trans Jatim application. The dataset includes the number of passengers boarding and alighting at each stop for both travel directions: Terminal Bunder to Terminal Porong and vice versa. The one-week data collection period was intended to accurately capture the dynamics of daily demand fluctuations as a foundation for designing a more responsive timetable. While the scheduling optimization was conducted for all seven days, this study presents a detailed analysis for Wednesday as a representative example. The data processing and modeling stages are outlined as follows:

1. Formulating the optimization model for departure scheduling.
   1. Defining data into decision variables:
2. represents the number of buses required from terminal .
3. is the variable indicating the departure frequency in period for route .
   1. Constructing an objective function aimed at minimizing bus crowding.
   2. Establishing constraint functions that reflect operational limitations, such as frequency allocation per period and maximum capacity.
4. Solving the scheduling model using the branch and bound method.
5. Analyzing the optimization results of the Trans Jatim schedule for each route during operational hours (05:00 – 21:00 WIB).
6. The solution process using the branch and bound method is supported by Python programming language.
7. Constructing the final departure timetable based on the optimal headway derived from the optimization process.

# RESULTS AND DISCUSSIONS

Operational data retrieved from Trans Jatim Corridor I are summarized in TABLE 1 for further analysis.

**TABLE 1.** Supporting Data for Timetable Formulation

| Route | | | | | |
| --- | --- | --- | --- | --- | --- |
| Route | Travel Time (min) | Period | Time | Total Passengers (persons) | Occupancy (persons) |
| Bunder - Porong | 120 | 1 | 05:00 | 246 | 32 |
| 2 | 06:00 | 224 | 32 |
| 3 | 07:00 | 159 | 32 |
| 4 | 08:00 | 136 | 32 |
| 5 | 09:00 | 182 | 34 |
| 6 | 10:00 | 194 | 34 |
| 7 | 11:00 | 139 | 32 |
| 8 | 12:00 | 152 | 32 |
| 9 | 13:00 | 178 | 34 |
| 10 | 14:00 | 216 | 34 |
| 11 | 15:00 | 238 | 32 |
| 12 | 16:00 | 274 | 34 |
| 13 | 17:00 | 206 | 32 |
| 14 | 18:00 | 165 | 32 |
| Porong - Bunder | 120 | 1 | 05:00 | 278 | 32 |
| 2 | 06:00 | 180 | 32 |
| 3 | 07:00 | 125 | 32 |
| 4 | 08:00 | 183 | 34 |
| 5 | 09:00 | 230 | 34 |
| 6 | 10:00 | 220 | 34 |
| 7 | 11:00 | 183 | 34 |
| 8 | 12:00 | 137 | 32 |
| 9 | 13:00 | 160 | 32 |
| 10 | 14:00 | 198 | 34 |
| 11 | 15:00 | 272 | 34 |
| 12 | 16:00 | 176 | 32 |
| 13 | 17:00 | 164 | 32 |
| 14 | 18:00 | 175 | 32 |

## Bus Scheduling Model

The bus scheduling in this study is based on the model developed by Irmeilyana et al. (2020). The minimum number of buses required can be determined using the following expression:

i)

The following binary decision variable indicates the selected departure frequency of the bus, defined as:

where

To evaluate passenger crowding on buses, the following crowding function is defined:

ii)

The main objective of this study is to meet passenger demand optimally by minimizing on-board crowding, thereby enhancing public transport service comfort. This objective is formulated as:

iii)

To ensure the solution reflects real-world operational conditions, only one frequency value may be selected per period for each route. If then for a given period and route , 1 route equal to 1 variable yang nilainya 1, only one decision variable can take the value 1, represented by the constraint:

iv)

Given as the total number of buses available to serve all routes during the operational time horizon , the value of based on equation (i) is constrained by:

v)

The total number of buses allocated to all terminals in the terminal set T must not exceed the total available fleet , formulated as:

vi)

vii)

viii)

TABLE 2 presents the notation used in the formulation of the equations above.

**TABLE 2.** Description of Notations Used in Equations (1) to (8)

|  |  |
| --- | --- |
| Indices | |
|  | Time period index. |
|  | Frequency value or number of departures in time period . |
|  | Route of bus departure (e.g., Terminal Bunder – Terminal Porong). |
|  | Terminal or point of departure (e.g., Terminal Bunder). |
|  | Time within the operational period. |
| Parameters and Variables | |
|  | Operational period when one terminal is in peak hours and the other is in off-peak hours*.* |
|  | Operational period when both terminals are in peak hours*.* |
|  | Set of all terminals . |
|  | Operational period for terminal k, where . |
|  | Set of observed routes []. |
|  | Set of observed time periods [ =1,2,3,...,n]. |
|  | Total number of passengers in time period and route . |
|  | Desired occupancy level (ratio of passengers to bus capacity) in time period and route . |
|  | Minimum allowed frequency in time period . |
|  | Maximum allowed frequency in time period . |
|  | Net departures on route at time . |
|  | Minimum number of buses required to serve the terminal network during the operational period . |
|  | Maximum number of available buses. |
| Decision Variables (Model Outputs) | |
|  | Total passenger crowding level on buses. |
|  | Number of crowded passengers in time period and route when frequency is chosen. |
|  | Binary variable indicating whether frequency is selected in time period and route (1 if selected, 0 otherwise). |
|  | Number of buses required to depart from terminal . |

Based on Equation ii), the value of pa in the first period for the Bungur–Bunder route can be determined. For F=1, then = maximum. For F=2, then = maximum. D Using the same method, the values of , are obtained and summarized in TABLE 3 where they correspond to the binary decision variables .

**TABLE 3.** Decision Variables and Objective Function Coefficients

| Terminal Bunder - Terminal Porong | | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| F | 05:00 | | 06:00 | | 07:00 | | … | | 16:00 | | 17:00 | | 18:00 | |
|  |  |  |  |  |  | … | … |  |  |  |  |  |  |
| 1 | 214 | x1 | 192 | x9 | 127 | x16 | … | … | 240 | x69 | 174 | x78 | 133 | x85 |
| 2 | 182 | x2 | 160 | x10 | 95 | x17 | … | … | 206 | x70 | 142 | x79 | 101 | x86 |
| 3 | 150 | x3 | 128 | x11 | 63 | x18 | … | … | 172 | x71 | 110 | x80 | 69 | x87 |
| 4 | 118 | x4 | 96 | x12 | 31 | x19 | … | … | 138 | x72 | 78 | x81 | 37 | x88 |
| 5 | 86 | x5 | 64 | x13 | 0 | x20 | … | … | 104 | x73 | 46 | x82 | 5 | x89 |
| 6 | 54 | x6 | 32 | x14 |  |  | … | … | 70 | x74 | 14 | x83 | 0 | x90 |
| 7 | 22 | x7 | 0 | x15 |  |  | … | … | 36 | x75 | 0 | x84 |  |  |
| 8 | 0 | x8 |  |  |  |  | … | … | 2 | x76 |  |  |  |  |
| 9 |  |  |  |  |  |  | … | … | 0 | x77 |  |  |  |  |
| … | | | | | | | | | | | | | | |
| Terminal Porong - Terminal Bunder | | | | | | | | | | | | | | |
| F | 05:00 | | 06:00 | | 07:00 | | … | | 16:00 | | 17:00 | | 18:00 | |
|  |  |  |  |  |  | … | … |  |  |  |  |  |  |
| 1 | 246 | x91 | 148 | x100 | 93 | x106 | … | … | 144 | x160 | 132 | x166 | 143 | x172 |
| 2 | 214 | x92 | 116 | x101 | 61 | x107 | … | … | 112 | x161 | 100 | x167 | 111 | x173 |
| 3 | 182 | x93 | 84 | x102 | 29 | x108 | … | … | 80 | x162 | 68 | x168 | 79 | x174 |
| 4 | 150 | x94 | 52 | x103 | 0 | x109 | … | … | 48 | x163 | 36 | x169 | 47 | x175 |
| 5 | 118 | x95 | 20 | x104 |  |  | … | … | 16 | x164 | 4 | x170 | 15 | x176 |
| 6 | 86 | x96 | 0 | x105 |  |  | … | … | 0 | x165 | 0 | x171 | 0 | x177 |
| 7 | 54 | x97 |  |  |  |  | … | … |  |  |  |  |  |  |
| 8 | 22 | x98 |  |  |  |  | … | … |  |  |  |  |  |  |
| 9 | 0 | x99 |  |  |  |  | … | … |  |  |  |  |  |  |

Based on the data obtained from TABLE 3, the decision variables can be defined as follows:

1. the number of buses required for departures from Terminal Bunder to Terminal Porong..
2. the number of buses required for departures from Terminal Porong to Terminal Bunder..

FThe objective function to minimize crowding is based on the passenger density values shown in TABLE 3. Referring to equation iii) and the defined decision variables, the objective function is as follows:

Since for each time period, only one frequency value is selected for the Bunder – Porong and Porong – Bunder routes, the following constraint is applied:

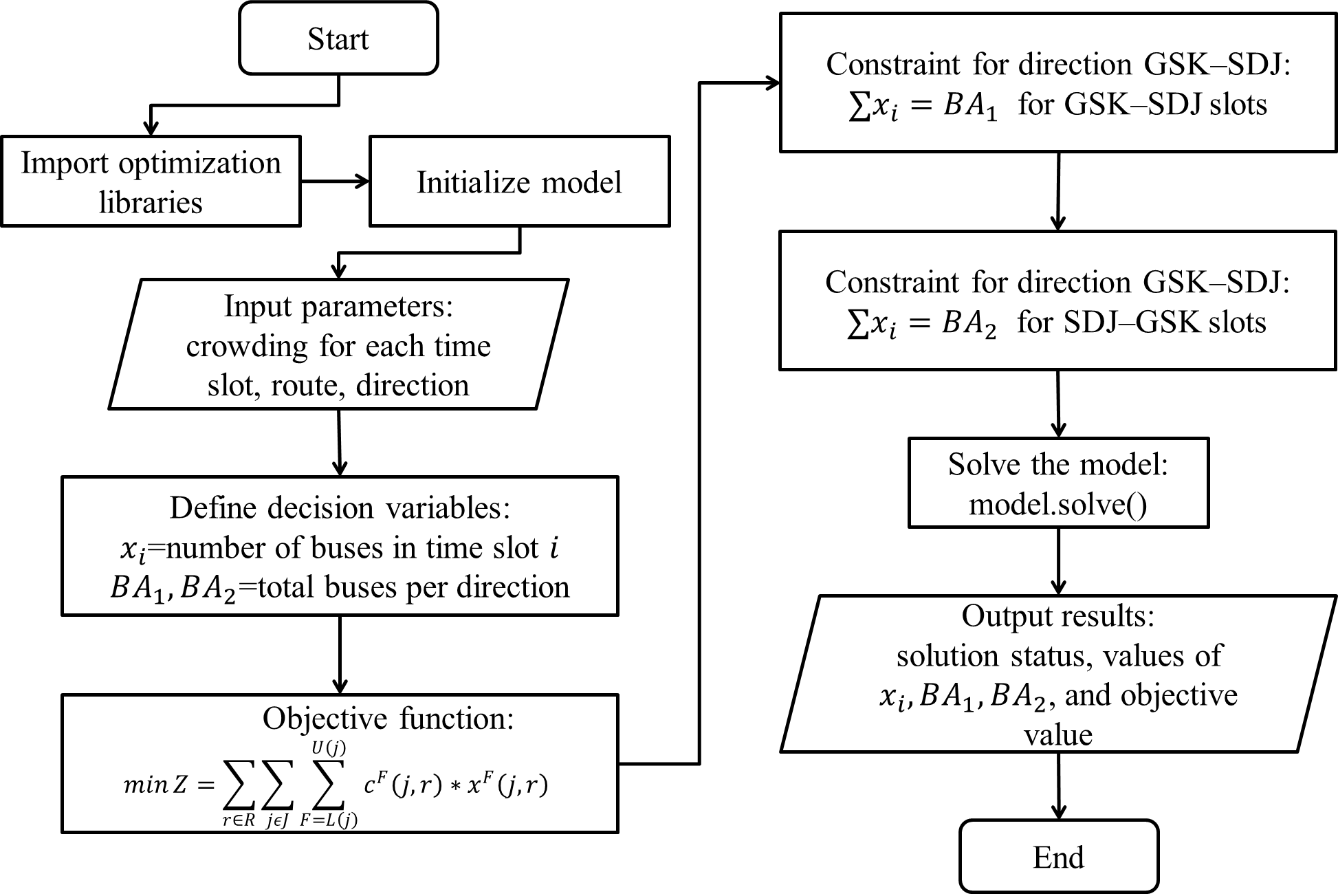
TABLE 3 shows that the maximum value of is . Thus, the minimum headway can be determined based on this maximum frequency, i.e., menit. The total number of buses that depart and arrive at each terminal at intervals less than or equal to 6.6 minutes is then calculated. To simplify the calculations during the operational period, the departure interval is set to every 7 minutes. For every departure, a value of +1 is added; for every arrival, −1 is subtracted. The number of buses departing and arriving at each terminal is calculated for two periods, starting from minute 0 to minute 840. The calculation of vehicle departures on the Bunder – Porong route during period 1 is as follows. At maximum frequency, and assuming: , then:

1. The possible values of at minute 0 are represented by the constraint .
2. The possible values of F at minute 21 are . thus the cumulative constraint becomes .
3. The possible values of F at minute 35 are . leading to the cumulative constraint

Subsequent calculations follow the same method and are automatically computed using Python programming language. These constraints are expressed as inequality constraints. Furthermore, due to limitations in allowable variable values, the following additional constraints are applied:

## Timetable Solution Using the Branch and Bound Method

The branch and bound method applied in this study aims to determine the optimal combination of bus departure frequencies during each operational time period on the Trans Jatim Corridor I route. FIGURE 1 presents a flowchart that systematically illustrates the model-solving procedure, starting from the initialization of crowding parameters, the definition of decision variables, the formulation of the objective function, and continuing to the search for an optimal solution within the feasible solution space that satisfies the constraints. Each step in the flowchart reflects a mathematical approach to formulating the optimization model, including constraints on the maximum number of buses and the minimum departure frequencies for each travel direction. The results of this algorithm serve as the foundation for preparing the daily operational schedule and conducting a comprehensive analysis of the required fleet size.



**FIGURE 1.** Branch and Bound Flowchart

Following the data processing based on FIGURE 1, the optimal solution is determined by the decision variables with a value of 1, which are with the resulting objective function value of 𝑍 = 286.

**TABLE 4.** Headway for Each Route by Time Period

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Period | Time | Active x Variable | Frequency (times) | Active x Variable | Frequency (times) |
| Route | | **Bunder - Porong** | | **Porong - Bunder** | |
| 1 | 05:00 |  | 8 |  | 8 |
| 2 | 06:00 |  | 7 |  | 6 |
| 3 | 07:00 |  | 5 |  | 5 |
| 4 | 08:00 |  | 5 |  | 4 |
| 5 | 09:00 |  | 5 |  | 5 |
| 6 | 10:00 |  | 6 |  | 5 |
| 7 | 11:00 |  | 5 |  | 5 |
| 8 | 12:00 |  | 4 |  | 4 |
| 9 | 13:00 |  | 6 |  | 4 |
| 10 | 14:00 |  | 6 |  | 6 |
| 11 | 15:00 |  | 8 |  | 7 |
| 12 | 16:00 |  | 9 |  | 8 |
| 13 | 17:00 |  | 9 |  | 7 |
| 14 | 18:00 |  | 7 |  | 4 |

TABLE 4 presents information on operational time, active decision variables, and the departure frequencies obtained from the optimization results. On the analyzed day, a total of 41 buses are required, with 26 units allocated from Terminal Bunder and 15 units from Terminal Porong, ensuring smooth service throughout the day. Based on the optimized departure frequencies, a daily operational timetable for Trans Jatim Corridor I buses can be developed. An illustration of the timetable arrangement is shown in TABLE 5.

**TABLE 5.** Sample Timetable Arrangement for Trans Jatim

| **Route** | **Terminal Bunder** | **Terminal Porong** |
| --- | --- | --- |
| **Departure No.** | **Time** | **Time** |
| 1 | 05:00 | 05:00 |
| 2 | 05:08 | 05:08 |
| 3 | 05:16 | 05:16 |
| 4 | 05:24 | 05:24 |
| 5 | 05:32 | 05:32 |
| 6 | 05:40 | 05:40 |
| 7 | 05:48 | 05:48 |
| 8 | 05:56 | 05:56 |

# CONCLUSION

This study successfully developed an optimized daily departure schedule for Trans Jatim Corridor I, covering Monday to Sunday, using the branch and bound method while considering fleet availability and optimal departure frequencies. The resulting timetable is adaptive to fluctuations in passenger demand across different days and time periods, featuring a realistic and evenly distributed headway allocation. Furthermore, the required number of buses for each day is optimally determined based on the frequency distribution generated by the model. For instance, Friday requires 49 buses, whereas Saturday only needs 36 buses, indicating that the model effectively reduces fleet usage without compromising operational efficiency.

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