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# THE SIMPLEX - PREEMPTIVE GOAL PROGRAMMING WITH BRANCH AND BOUND METHOD FOR OPTIMIZING WASTE VEHICLE ROUTES AND TRANSPORTATION

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## ABSTRACT

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*This research discusses the optimization of the assignment of waste vehicle routes and transportation, which are responsible for transporting waste from temporary disposal sites to final disposal sites. The aim is to minimize the remaining waste at temporary disposal sites, thus creating a clean and comfortable environment. The focus of this research is determining the number of trips (rit) for each vehicle (dump trucks and arm roll trucks) on each route. Besides aiming to minimize the remaining waste at temporary disposal sites as the main priority, there are also other priorities, namely minimizing fuel usage and the working time within a day. Therefore, in accordance with the characteristics of the problem, where there are multiple objectives and an integer solution is required, The Simplex-Preemptive Goal Programming with the Branch and Bound method is proposed as the solution method. The optimal solution has been obtained. The result includes the optimal number of trips (rit) for each waste transport vehicles (dump trucks and arm roll trucks) on each routes.*



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## 1. INTRODUCTION

Waste, a solid material that is no longer useful, must be managed to avoid harming the environment. [1]. As the human population grows, it leads to an increase in waste generation, posing a negative impact on the surrounding environment. Poorly managed waste can result in various adverse effects on both the environment and public health. The Environmental Agency (DLH) of Jambi City operates a Waste Management Technical Implementation Unit (UPT) dedicated to addressing Jambi City's waste issues, including the transportation process. This initiative aligns with Jambi Mayor Regulation Number 5 of 2020, which outlines waste management procedures, including waste transportation [2].

The waste transportation process involves moving waste from the Temporary Disposal Site (TPS) route to the Final Disposal Site (TPA) in Talang Gulo, Jambi. TPS serves as a temporary container for waste collected from the community [1]. According to Government Regulation of the Republic of Indonesia Number 27 of 2020, specified waste management in Article 1 Paragraph 18, a Final Disposal Site (TPA) is the ultimate processing location intended for the safe processing and restoration of waste to environmental media, ensuring safety for both humans and the environment [3]. The types of vehicles used are dump trucks and arm roll trucks, capable of handling large-capacity waste, are the types of vehicles utilized. Dump trucks collect waste along the TPS route, while arm roll trucks lift waste containers from the TPS for transportation to the TPA [4]. This vehicle is allotted a fuel allowance of 24 liters per day, with a maximum working period of 11 hours.

The waste transport vehicles move between the landfill and the TPS route, and vice versa. Failure to collect waste left at the TPS may result in sanctions imposed by the Jambi City Environmental Department. Therefore, it's essential to establish the number of trips (rit) for each vehicle on each route to minimize leftover waste at the TPS, while also reducing fuel consumption and the working time per day.

In accordance with the characteristics of the problem, which involve multiple objectives such as minimizing remaining waste in the TPS, reducing fuel consumption, and minimizing working time, Goal Programming modeling is employed to address this issue. Goal programming extends the linear programming model [5] and includes a goal function to minimize deviations in each of the objectives [6]. Furthermore, the Simplex Preemptive Goal Programming method is utilized to establish priority-based decisions [5], along with the Branch and Bound Methods to determine the optimal assignment of vehicles and the number of waste transport routes for each TPS route.

The objective of this research is to optimize the number of trips (rit) for each waste transport vehicle (dump trucks and arm roll trucks) on their respective routes, while minimizing the remaining waste in the TPS, reducing fuel consumption, and minimizing working hours. The research involves six waste transport vehicles, comprising four dump trucks (fleet numbers 10, 19, 27, and 29) and two arm roll trucks (fleet numbers 06 and 08). These six vehicles are selected based on their involvement in transporting the largest amount of waste along TPS routes in Jambi City, as recommended by the Head of Jambi City DLH Waste Management Section. The study specifically focuses on the TPS routes associated with these six selected vehicles.

## 2. RESEARCH METHODS

This research was carried out to optimize the assignment of waste vehicle routes and transportation, which are responsible for transporting waste from temporary disposal sites to final disposal sites to each of the 6 TPS routes. This research uses Goal Programming modeling. Goal Programming is the development of Linear Programming with the same form of assumptions, notation, model formulation, formulation and solution procedures, the difference is that the additional variables in the constraints (slack/surplus) are replaced with deviation variables or deviation variables [7]. The Goal Programming model is formulated to minimize deviations (either upper deviation ($\boldsymbol{DA}$) or lower deviation ($\boldsymbol{DB}$)) at each goal constraint within an objective function [8]. This objective function employs a preemptive type (priority order) [9]. The preemptive method begins by prioritizing goals according to their importance [10]. Each goal is assigned a priority level, ranging from the most important to the least important [11]. Optimal solutions are sought through Simplex

Preemptive Goal Programming utilizing the Branch and Bound method. The general form of the Preemptive Goal Programming model [7] is as follows:

Minimize:

$$Z = \sum_{i=1}^{m} P_k (DB_i + DA_i)\,, \text{for } k = 1,2,\dots,k \tag{1}$$

with targets

$$\begin{gathered} a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n + DB_1 - DA_1 = b_1 \\ a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n + DB_2 - DA_2 = b_2 \\ \vdots \\ a_{m1}x_1 + a_{m2}x_2 + \cdots + a_{mn}x_n + DB_m - DA_m = b_m \end{gathered} \tag{2}$$

with non-negative constraints

$$x_j, DA_i, DB_i \geq 0, \text{ For } i = 1,2,\dots,m; j = 1,2,\dots,n$$

information:

$Z$ : The objective function aims to minimize the deviation of each target constraint variable
$x_j$ : The decision variable to be determined (unit/activity).
$b_i$ : The parameter represents the limited monetary resources/right-hand side constraint.
$a_{ij}$ : The decision-maker parameter/coefficients of the variable $x_j$ in the constraint, for instance, $a_{ij}$represents the quantity of raw material $i$ used to produce one unit of product $j$.
$DA_i$ : The deviation variable above the target against $b_i$.
$DB_i$ : The deviation variable below the target against $b_i$.
$i$ : The number of rows (functional constraints, $a_{ij}, b_i, DB_i,$ and $DA_i$) in the Goal Programming model
$j$ : The number of column (functional constraints, $x_j, a_{ij}$) in the Goal Programming model

The results of this Goal Programming model have 3 possible outcomes that will occur [7] that is:

1. If $DA$ and $DB = 0$, then the target is said to be achieved, formed:

$$\sum_{j=1}^{n} a_{ij} \,.\, x_j = b_i \tag{3}$$

2. If $DB > 0$ and $DA = 0$ , then the value falls below the target. This target constraint will be achieved if the goal is minimized in the objective function, yielding the following results:

$$\sum_{j=1}^{n} a_{ij} \,.\, x_j = b_i - DB_i \tag{4}$$

because the value is below of $b_i$ , then:

$$\sum_{j=1}^{n} a_{ij} \,.\, x_j < b_i \tag{5}$$

3. If $B = 0$ and $DA > 0$ , then a value above the target is obtained. This target constraint will be achieved if the objective is minimized within the objective function, resulting in the following outcomes:

$$\sum_{j=1}^{n} a_{ij} \,.\, x_j = b_i + DA_i \tag{6}$$

because the value is below of $b_i$ , then:

$$\sum_{j=1}^{n} a_{ij} \, . x_j > b_i \tag{7}$$

The conditions $DB$ and $DA > 0$ in the target constraint are unlikely to occur because the two deviation variables will move away from the value area of $b_i$. The variables should be close to the target value. Utilizing a goal programming model offers insights into the possibilities that may arise from the obtained solutions **[12]**. This involves considering which deviation variables need to be minimized to achieve the goal constraint target **[13]**. Subsequently, the completion stage entails finding decision variables and deviation variables using the Simplex Preemptive Goal Programming method **[7]**, as outlined below:

**Table 1. Preemptive Goal Programming Simplex Table Form**

| | $C_j$ | 0 | 0 | … | 0 | $P_1$ | $P_1$ | $P_2$ | $P_2$ | … | $P_m$ | $P_m$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Base coefficient $(CB)$ | Base Variables (B.V.) | $x_1$ | $x_2$ | … | $x_n$ | $DB_1$ | $DA_2$ | $DB_2$ | $DA_2$ | … | $DB_m$ | $DA_m$ | $RHS$ |
| $P_1$ | $DB_1$ | $a_{11}$ | $a_{12}$ | … | $a_{1n}$ | 1 | -1 | 0 | 0 | … | 0 | 0 | $b_1$ |
| $P_2$ | $DB_2$ | $a_{21}$ | $a_{22}$ | … | $a_{2n}$ | 0 | 0 | 1 | -1 | … | 0 | 0 | $b_2$ |
| … | … | … | … | … | … | … | … | | | … | … | … | … |
| $P_m$ | $DB_m$ | $a_{m1}$ | $a_{m2}$ | … | $a_{mn}$ | 0 | 0 | 0 | 0 | … | 1 | -1 | $b_m$ |
| | $Z_j$ | $Z_{x_1}$ | $Z_{x_2}$ | … | $Z_{x_n}$ | $Z_{DB_1}$ | $Z_{DA_2}$ | $Z_{DB_2}$ | $Z_{DA_2}$ | … | $Z_{DB_m}$ | $Z_{DA_m}$ | $Z_{RHS}$ |
| | $Z_j - C_j$ | $Z_{x_1} - C_{x_1}$ | $Z_{x_2} - C_{x_2}$ | … | $Z_{x_n} - C_{x_n}$ | $Z_{DB_1} - C_{DB_1}$ | $Z_{DA_2} - C_{DA_2}$ | $Z_{DB_2} - C_{DB_2}$ | $Z_{DA_2} - C_{DA_2}$ | … | $Z_{DB_m} - C_{DB_m}$ | $Z_{DA_m} - C_{DA_m}$ | |

Method in **Table 1** carried out repeatedly (iteratively) until an optimal solution is obtained **[14]**. What can differentiate Simplex Preemptive Goal Programming from Simplex Linear Programming is the determination values of $\boldsymbol{Z_j - C_j}$, the existence of deviation variables and priority levels **[7]**.

The conditions for getting the optimal solution from the Simplex Preemptive Goal Programming method are if values of $\boldsymbol{Z_j - C_j}$ **[7]**, that is:

1. All priority values are negative, and the deviation variable values in the objective function have been met
2. All top priority values are negative, but the lower priorities remain positive and are are balanced by the negative values of the first priority.

The final stage utilizes the Branch and Bound method. Branch and Bound is a solution method that generates variables with integer values. This involves selecting decision variables with fractional or decimal values and forming upper and lower branches similar to the roots of a tree.**[7]**.

There is a procedure to obtain an optimal solution using the Branch and Bound method **[14]** that is:

1. Determine the optimal solution using the Simplex method.
2. Check if the result is an integer, if not then use the Branch and Bound method.
3. In the Branch and Bound stage, select the variable to be branched, namely the number after the comma that is closest to 0.5.
4. The selected variables $(x_j)$ form new branches, namely and $x_j \leq x_j^*$ and $x_j \geq x_j^* + 1$
5. Determine new solutions from the left and right branches respectively using the Simplex method.
6. Obtain the optimal solution. If the objective is to maximize, then choose the largest positive objective function value, while for minimizing objective, select the smallest positive objective function value.

The Branch and Bound solution is considered feasible if all variables possess integer values and the objective function values are satisfied. If the attained solution satisfies the feasibility criteria but falls short of a more optimal solution, it is deemed inferior/fathomed **[9]** .

The research methodology is presented in the form of a flow diagram, as depicted in **Figure 1**.

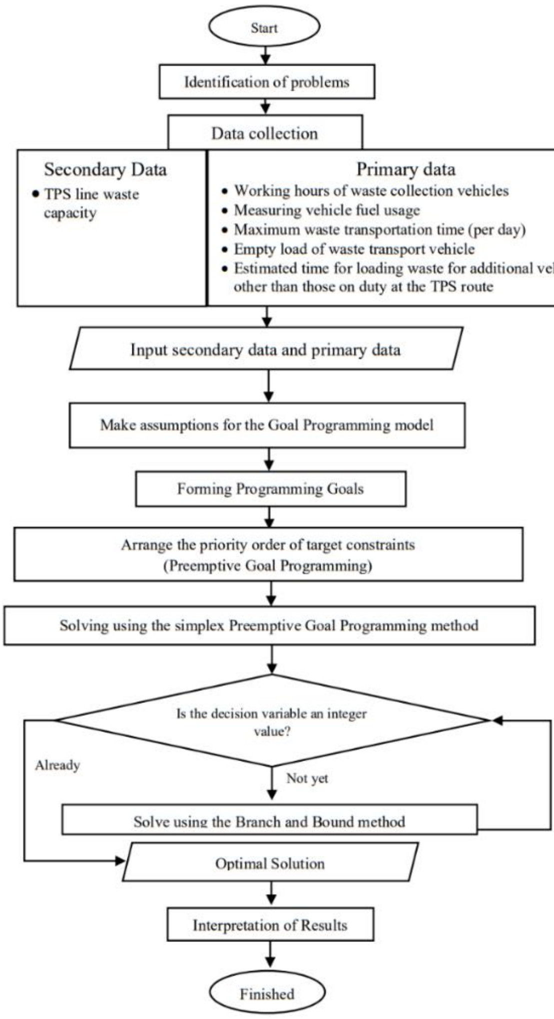



**Figure 1. Research Flow Diagram**

The research data for Goal Programming modeling will be sourced from the Head of the Waste Handling Section of the Jambi City DLH Waste Management UPT, the Talang Gulo Sanitary Landfill TPA, and the dump truck and arm roll truck vehicle drivers from the 6 selected TPS routes as listed in **Table 2**.

**Table 2. Research Data Source**

| No. | Data | Data source | Information |
|---|---|---|---|
| 1. | Working hours of waste collection vehicles | 6 waste Transport Vehicle Drivers | Interview |
| 2. | Estimated waste loading time for additional vehicles other than those on duty at the TPS route | 6 waste Transport Vehicle Drivers | Interview |
| 3. | Measuring vehicle fuel usage | Head of Jambi City DLH Waste Management Section | Interview |
| 4. | Determination of waste transportation route (daily) | Head of Jambi City DLH Waste Management Section | Interview |
| 5. | Empty load of waste transport vehicle | Head of Jambi City DLH Waste Management Section | Interview |
| 6. | TPS routes waste capacity | Talang Gulo Sanitary Landfill | Data retrieval permission |

Knowing the location of the TPS routes assigned to the 6 vehicles that are the object of research uses **Google Earth Pro**.


**(a)** **(b)**

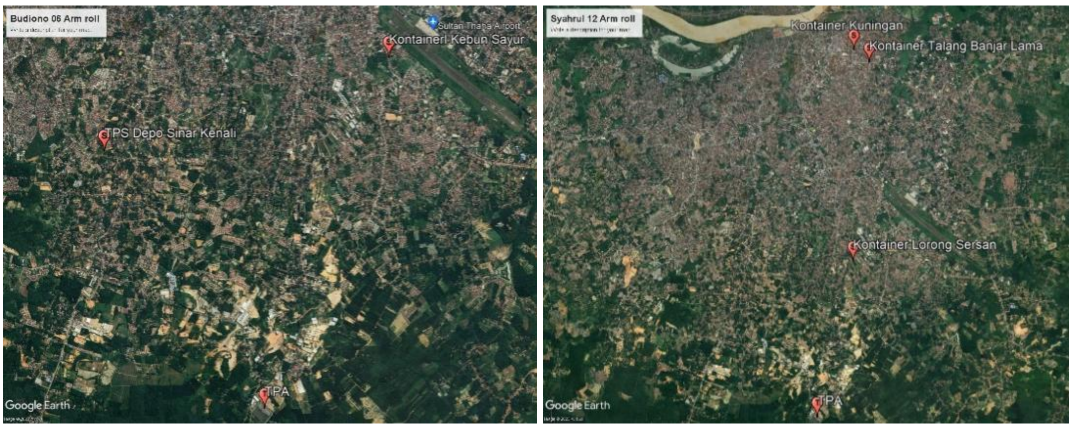
**Figure 2.** **A map of the TPS route traversed by the Dump Truck vehicle is displayed via Google Earth Pro (a) TPS Dump Truck 10 Route; (b) TPS Dump Truck 19 Route.**

**Figure 2 (a)** depicts the route of Dump Truck 10 from TPS, starting at Raja Jamin Bagindo street to Kompol Bastari street in Jambi City. The challenge on this route lies in the high waste capacity at Kuningan TPS, Raja Batu TPS, and Batalion TPS, resulting in increased work time. **Figure 2 (b)** illustrates the route of Dump Truck 19 from TPS along Ir. Juanda Street in Jambi City. The main issue along this route is the presence of numerous TPS due to dense settlements along the road


**(a)** **(b)**

**Figure 3.** **A map of the TPS route traversed by the Dump Truck vehicle is displayed via Google Earth Pro (a) TPS Dump Truck 27 Route; (b) TPS Dump Truck 29 Route.**

**Figure 3 (a)** illustrates the route of Dump Truck 27 from TPS, spanning from Danau Teluk District to Pelayangan District in Jambi City. The challenge lies in the considerable distance between each TPS and the abundance of household garbage cans along the route. 'Titik' in **Figure 3 (a)** marks the roads traversed by Dump Truck 27. **Figure 3 (b)** depicts the route of Dump Truck 29 from TPS, situated along Sumantri Brojonegoro street to Husni Tamrin street in Jambi City. Along this route, there are popular destinations for young people such as culinary establishments and cafes, resulting in a significant amount of waste generation.




**(a)** **(b)**

**Figure 4.** **Map of the TPS route traversed by the Arm Roll Truck vehicle is displayed via Google Earth Pro (a) Arm Roll Truck TPS 06 Route; (b) Arm Roll Truck TPS 08 Route.**

The TPS for the Arm Roll Truck consists of iron containers that can be transported to the TPA by the Arm Roll Truck. In **Figure 4 (a)**, the route of Arm Roll Truck 06 includes TPS locations at Vila Kenali (TPS

Depo Sinar Kenali) and Talang Bakung (Container Kebun Sayur) in Jambi City. These two TPS serve as waste disposal centers for the settlements in this area. Figure 4 (b) displays the route of Arm Roll Truck 08, with TPS locations on Kompol Zainal Abidin Street (Container Kuningan), Talang Banjar Street (Container Talang Banjar Lama), and Lingkar Selatan Street (TPS Lorong Sersan) in Jambi City. The challenge with these three containers is that while they serve as waste disposal centers, Container Kuningan also accommodates waste from the TPS Dump Truck 10 route area.

## 3. RESULTS AND DISCUSSION

The utilization of the Goal Programming model offers the advantage of simultaneously achieving multiple objectives, understanding potential side effects, and meeting target constraints following the attainment of an optimal solution. [9]. In this study, a decision variable was identified as the number of waste transport trips per day for dump trucks ($x_1$) and arm roll trucks ($x_2$). The study incorporates three target constraints (goal constraints), which include the effort to transport waste from the TPS route to the TPA while considering the load capacity of the dump truck or arm roll truck, fuel consumption, and working time.

### 3.1 Goal Programming Model for TPS Dump Truck and Arm Roll Truck Routes

Goal Programming Model for Dump Truck and Arm Roll Truck Routes at TPS, as shown in Table 3.

**Table 3. Formulating a Goal Programming Model for the Dump Truck Route and the Arm Roll Truck Route at TPS in Jambi City.**

| Goal Programming Model TPS Dump Truck Route | Goal Programming Model TPS Arm Roll Truck Route |
|---|---|
| **Minimize** $\boldsymbol{Z = P_1(DB_1) + P_2(DA_2) + P_3(DA_3)}$ | Minimize $Z = P_1(DB_1) + P_2(DA_2) + P_3(DA_3)$ |
| **with constraints:** | with constraints: |
| $\boldsymbol{m_1x_1 + m_2x_2 + DB_1 - DA_1 = MT_d}$ | $m_1x_1 + m_2x_2 + DB_1 - DA_1 = MT_r$ |
| $\boldsymbol{b_1x_1 + b_2x_2 + DB_2 - DA_2 = BB}$ | $b_1x_1 + b_2x_2 + DB_2 - DA_2 = BB$ |
| $\boldsymbol{TD_dx_1 + TA'_dx_2 + DB_3 - DA_3 = WT}$ | $TD'_rx_1 + TA_rx_2 + DB_3 - DA_3 = WT$ |
| $\boldsymbol{x_j \le BR_j}$ | $x_j \le BR_j$ |
| $\boldsymbol{x_j, DB_i, DA_i \ge 0}$ **For** $\boldsymbol{i = 1,2,3; j = 1,2}$ | $x_j, DB_i, DA_i \ge 0$ For $i = 1,2,3; j = 1,2$ |
| $\boldsymbol{x_j \in \mathbb{N} \cup \{0\}\ \ j = 1,2}$ | $x_j \in \mathbb{N} \cup \{0\}\ \ j = 1,2$ |
| $\boldsymbol{d = 1,2,3,4}$ | $r = 1,2$ |

information:

$x_j$ : dump truck or arm roll truck waste transport service (rit/day)
$m_1$ : empty dump truck load to be able to transport waste from TPS route to TPA for one trip (kg/rit)
$m_2$ : empty load of arm roll truck to be able to transport waste from TPS route to TPA for one route (kg/rit)
$b_1$ : the dose of fuel used by a dump truck for one trip (L/rit)
$b_2$ : the amount of fuel used by an arm roll truck for one trip (L/rit)
$TD_d$ : total working time of dump trucks on the $d$ TPS dump truck route during one rit of waste transport route (minutes/rit)
$TA_r$ : total working time of the arm roll truck vehicle on the $r$ TPS arm roll truck route during one rit of waste transport (minutes/rit)
$TD'_r$ : total working time of additional dump truck vehicles for the $r$ TPS arm roll truck route during one transport route waste (minutes/rit)
$TA'_d$ : total working time of additional arm roll truck vehicles for the $d$ TPS dump truck route during one transport route waste (minutes/rit)
$MT_d$ : heaviest $d$ dump truck TPS route waste capacity in one day in the period April 2022-May 2023 (kg/day)
$MT_r$ : the heaviest waste capacity of the $r$ TPS arm roll truck route in one day in the period April 2022-May 2023 (kg/day)
$BB$ : maximum fuel usage for a dump truck or arm roll truck vehicle for one day (L/day)
$WT$ : the working time limit for dump trucks and arm roll trucks is one day (minutes/day)
$DA_1$ : remaining empty load of waste transport vehicle (kg/day)

$DB_1$ : residual waste from TPS routes that is not loaded by waste transport vehicles (kg/day)
$DA_2$ : excess vehicle fuel usage rate over the maximum limit for one day (L/day)
$DB_2$ : remaining unused vehicle fuel for one day (L/day)
$DA_3$ : excess use of vehicle working time over the maximum limit for one day (minutes/day)
$DB_3$ : remaining unused vehicle working time for one day (minutes/day)
$BR_j$ : vehicle waste transport limit for one day (rit/day)

Table 3 is a Preemptive Goal Programming model that has been established for the dump truck TPS Route and arm roll truck TPS Route in Jambi City. Minimizing the objective function according to the priority level, namely minimizing residual waste from the TPS route; minimizing vehicle fuel; and minimize vehicle working time.

### 3.2 Goal Programming Model for 6 Selected TPS Routes

The form of the Goal Programming model for the 6 selected TPS routes is shown in the form Table 4, continued using the Simplex Preemptive Goal Programming method to get a solution.

**Table 4. Goal Programming Model for 6 TPS Routes**

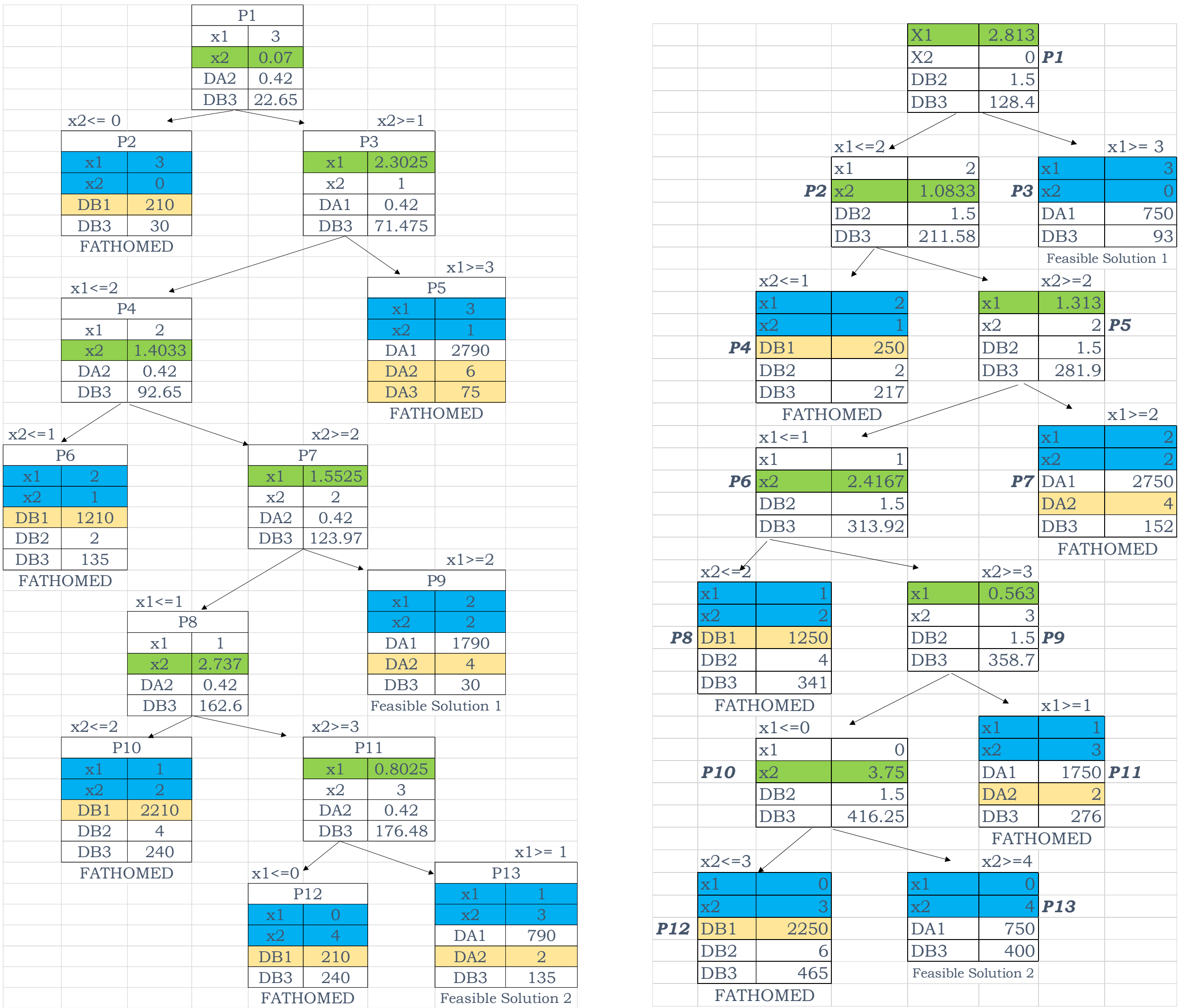
| | | |
|---|---|---|
| 1. | Jl. Raja Jamin Bagindo – Jl. Kompol Bastari<br><br>(Dump Truck 10 Route) | **Minimize** $\boldsymbol{Z = P_1(DB_1) + P_2(DA_2) + P_3(DA_3)}$<br>**with constraints:**<br>$\boldsymbol{4,000x_1 + 3,000x_2 + DB_1 - DA_1 = 12.210}$<br>$\boldsymbol{8x_1 + 6x_2 + DB_2 - DA_2 = 24}$<br>$\boldsymbol{210x_1 + 105x_2 + DB_3 - DA_3 = 660}$<br>$\boldsymbol{x_1 \leq 3}$<br>$\boldsymbol{x_2 \leq 4}$<br>$\boldsymbol{x_j, DB_i, DA_i \geq 0}$ for $\boldsymbol{i = 1,2,3 j = 1,2}$<br>$\boldsymbol{x_j \in \mathbb{N} \cup \{0\} \;\; j = 1,2}$ |
| 2. | Along Jalan Ir. Juanda<br><br>(Dump Truck 19 Route) | Minimize $Z = P_1(DB_1) + P_2(DA_2) + P_3(DA_3)$<br>with constraints:<br>$4,000x_1 + 3,000x_2 + DB_1 - DA_1 = 11,250$<br>$8x_1 + 6x_2 + DB_2 - DA_2 = 24$<br>$189x_1 + 65x_2 + DB_3 - DA_3 = 660$<br>$x_1 \leq 3$<br>$x_2 \leq 4$<br>$x_j, DB_i, DA_i \geq 0$ for $i = 1,2,3 j = 1,2$<br>$x_j \in \mathbb{N} \cup \{0\} \;\; j = 1,2$ |
| 3. | All polling stations in Danau Teluk District and Pelayangan District<br><br>(Dump Truck 27 Route) | Minimize $Z = P_1(DB_1) + P_2(DA_2) + P_3(DA_3)$<br>with constraints:<br>$4,000x_1 + 3,000x_2 + DB_1 - DA_1 = 8,700$<br>$8x_1 + 6x_2 + DB_2 - DA_2 = 24$<br>$205x_1 + 105x_2 + DB_3 - DA_3 = 660$<br>$x_1 \leq 3$<br>$x_2 \leq 4$<br>$x_j, DB_i, DA_i \geq 0$ for $i = 1,2,3 j = 1,2$<br>$x_j \in \mathbb{N} \cup \{0\} \;\; j = 1,2$ |
| 4. | Jl. Sumantri Brojonegoro - Jl. Husni Tamrin<br><br>(Dump Truck 29 Route) | Minimize $Z = P_1(DB_1) + P_2(DA_2) + P_3(DA_3)$<br>with constraints:<br>$4,000x_1 + 3,000x_2 + DB_1 - DA_1 = 10,660$<br>$8x_1 + 6x_2 + DB_2 - DA_2 = 24$<br>$195x_1 + 85x_2 + DB_3 - DA_3 = 660$<br>$x_1 \leq 3$<br>$x_2 \leq 4$<br>$x_j, DB_i, DA_i \geq 0$ for $i = 1,2,3 j = 1,2$<br>$x_j \in \mathbb{N} \cup \{0\} \;\; j = 1,2$ |
| 5. | Kebun Sayur and Sinar Kenali Depo<br><br>(Arm Roll Truck 06 Route) | Minimize $Z = P_1(DB_1) + P_2(DA_2) + P_3(DA_3)$<br>with constraints:<br>$4,000x_1 + 3,000x_2 + DB_1 - DA_1 = 8,380$<br>$8x_1 + 6x_2 + DB_2 - DA_2 = 24$<br>$115x_1 + 55x_2 + DB_3 - DA_3 = 660$<br>$x_1 \leq 3$ |

| | | |
|---|---|---|
| | | $x_2 \leq 4$<br>$x_j, DB_i, DA_i \geq 0$ for $i = 1,2,3 j = 1,2$<br>$x_j \in \mathbb{N} \cup \{0\}\ j = 1,2$ |
| 6. | Kuningan, Sersan Alley, and Talang Banjar Lama Market<br><br>(Arm Roll Truck 08 Route) | Minimize $Z = P_1(DB_1) + P_2(DA_2) + P_3(DA_3)$<br>with constraints:<br>$4{,}000x_1 + 3{,}000x_2 + DB_1 - DA_1 = 7{,}990$<br>$8x_1 + 6x_2 + DB_2 - DA_2 = 24$<br>$130x_1 + 70x_2 + DB_3 - DA_3 = 660$<br>$x_1 \leq 3$<br>$x_2 \leq 4$<br>$x_j, DB_i, DA_i \geq 0$ for $i = 1,2,3 j = 1,2$<br>$x_j \in \mathbb{N} \cup \{0\}\ j = 1,2$ |

The Simplex-Preemptive Goal Programming eliminates $DB_1, DA_2$, and $DA_3$ so that it gets a solution. If the method fails to return an integer, the Branch and Bound method will be employed.

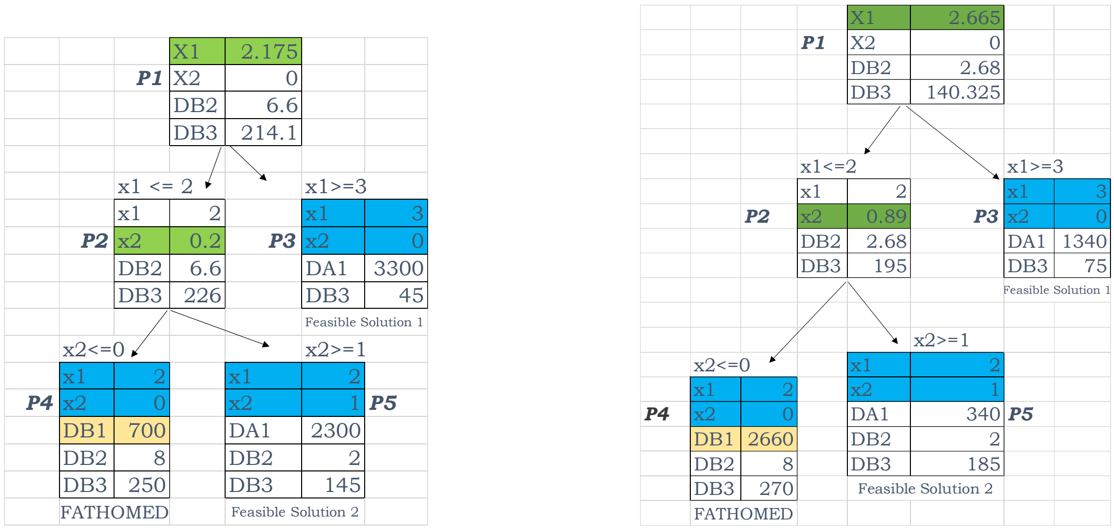
### 3.3 Stage of The Branch and Bound Method

Since the results in Table 4 did not yield integer values, the Branch and Bound method will be applied. Figure 5, Figure 6, and Figure 7 illustrate the solutions for the TPS routes of the 6 selected vehicles obtained using the Branch and Bound method.



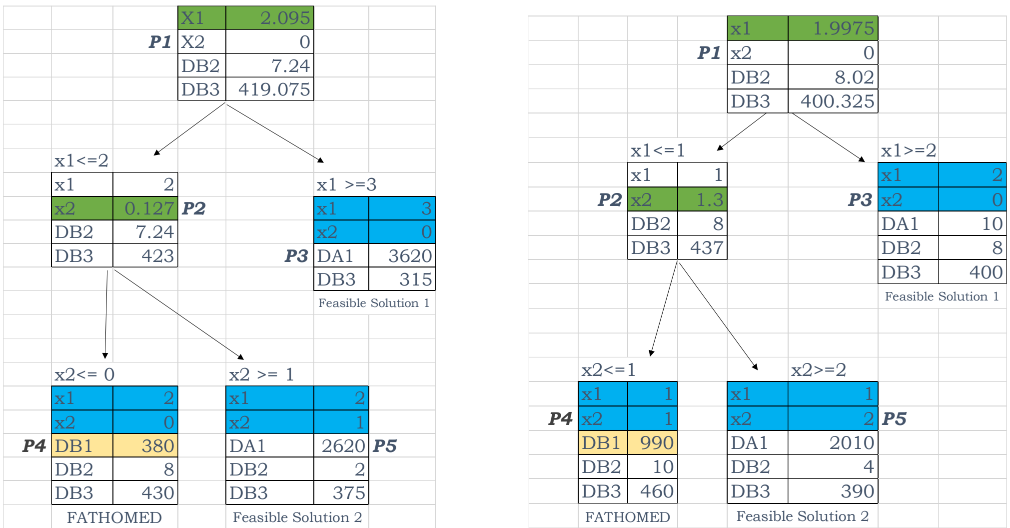

**(a)** **(b)**

**Figure 5. Branch and Bound results obtained 2 feasible solutions for TPS route (a) TPS Dump Truck 10 Route; (b) TPS Dump Truck 19 Route.**




(a) (b)

**Figure 6.** **Branch and Bound results obtained 2 feasible solutions for TPS route (a) TPS Dump Truck 27 Route; (b) TPS Dump Truck 29 Route.**




(a) (b)

**Figure 7.** **Branch and Bound results obtained 2 feasible solutions for TPS route (a) TPS Arm Roll Truck 06 Route; (b) TPS Arm Roll Truck 08 Route.**

The Branch and Bound results of the model of each TPS route from Table 4 are described as follows:

**Table 5.** **Branch and Bound Results of each TPS route**

| | | Information | Feasible Solution 1 | | Feasible Solution 2 | |
|---|---|---|---|---|---|---|
| | | | **Value** | **Goal** | **Value** | **Goal** |
| **TPS Route for Dump Truck 10** | $x_1$ | Waste transport trips for dump truck | 2 rit | - | 1 rit | - |
| | $x_2$ | Waste transport trips for arm roll truck | 2 rit | - | 3 rit | - |
| | $DA_1$ | Remaining empty vehicle load | 1790 kg | achieved | 790 kg | achieved |
| | $DA_2$ | Excess vehicle fuel consumption | 4 L | Not achieved | 2 L | Not achieved |
| | $DB_3$ | Savings in vehicle work time usage | 30 mnt | achieved | 135 mnt | achieved |
| **TPS Route for Dump Truck 19** | $x_1$ | Waste transport trips for dump truck | 3 rit | - | - | - |
| | $x_2$ | Waste transport trips for arm roll truck | - | - | 4 rit | - |

| | | Information | Feasible Solution 1 | | Feasible Solution 2 | |
|---|---|---|---|---|---|---|
| | | | **Value** | **Goal** | **Value** | **Goal** |
| | $DA_1$ | Remaining empty vehicle load | 750 kg | achieved | 750 kg | achieved |
| | $DB_3$ | Savings in vehicle work time usage | 93 mnt | achieved | 400 mnt | achieved |
| **TPS Route for Dump Truck 27** | $x_1$ | Waste transport trips for dump truck | 3 rit | - | 2 rit | - |
| | $x_2$ | Waste transport trips for arm roll truck | - | - | 1 rit | - |
| | $DA_1$ | Remaining empty vehicle load | 3300 kg | achieved | 2300 kg | achieved |
| | $DA_2$ | Excess vehicle fuel consumption | - | achieved | 2 L | achieved |
| | $DB_3$ | Savings in vehicle work time usage | 45 mnt | achieved | 145 mnt | achieved |
| **TPS Route for Dump Truck 29** | $x_1$ | Waste transport trips for dump truck | 3 rit | - | 2 rit | - |
| | $x_2$ | Waste transport trips for arm roll truck | - | - | 1 rit | - |
| | $DA_1$ | Remaining empty vehicle load | 1340 kg | achieved | 340 kg | achieved |
| | $DA_2$ | Excess vehicle fuel consumption | - | achieved | 2 L | achieved |
| | $DB_3$ | Savings in vehicle work time usage | 75 mnt | achieved | 185 mnt | achieved |
| **TPS Route for Arm Roll Truck 06** | $x_1$ | Waste transport trips for dump truck | 3 rit | - | 2 rit | - |
| | $x_2$ | Waste transport trips for arm roll truck | - | - | 1 rit | - |
| | $DA_1$ | Remaining empty vehicle load | 3620 kg | achieved | 2620 kg | achieved |
| | $DA_2$ | Excess vehicle fuel consumption | - | achieved | 2 L | achieved |
| | $DB_3$ | Savings in vehicle work time usage | 315 mnt | achieved | 375 mnt | achieved |
| **TPS Route for Arm Roll Truck 08** | $x_1$ | Waste transport trips for dump truck | 1 rit | - | 2 rit | - |
| | $x_2$ | Waste transport trips for arm roll truck | 2 rit | - | - | - |
| | $DA_1$ | Remaining empty vehicle load | 2010 kg | achieved | 10 kg | achieved |
| | $DA_2$ | Excess vehicle fuel consumption | 4 L | achieved | 8 L | achieved |
| | $DB_3$ | Savings in vehicle work time usage | 390 mnt | achieved | 400 mnt | achieved |

Based on The Simplex-Preemptive Goal Programming with Branch and Bound method and the analysis, two feasible solutions were obtained: Solution 1 and Solution 2 for the 6 TPS routes, as presented in **Table 5**. Based on the priority levels used in the formation of the Preemptive Goal Programming, which are minimizing the remaining waste capacity in the TPS routes, minimize fuel consumption, and reducing vehicle working time. Obtaining results using the branch and bound method will get a more optimal solution and the expected goals are achieved very well **[15]**.

The stage of using the Simplex Preemptive Goal programming and Branch and Bound methods obtained optimal results as follows:

1. Dump Truck 10 Route, namely the assignment of waste transport vehicles with many waste transport routes, is 1 dump truck route and 3 arm roll truck routes.
2. Dump Truck 19 Route, namely the assignment of waste transport vehicles with many waste transport routes, is 4 rit arm roll trucks.
3. Dump Truck 27 Route is the assignment of waste transport vehicles with many waste transport routes, namely 2 dump truck routes and 1 arm roll truck route.
4. Dump Truck 29 Route, namely the assignment of waste transport vehicles with many waste transport routes, namely 2 dump truck routes and 1 arm roll truck route.
5. Arm Roll Truck Route 06, namely the assignment of waste transport vehicles with many waste transport routes, namely 2 dump truck routes and 1 arm roll truck route.
6. Arm Roll Truck 08 Route, namely the assignment of waste transport vehicles with many waste transport routes, namely 2 dump truck routes.

## 4. CONCLUSIONS

The Simplex-Preemptive Goal Programming with Branch and Bound method has proven effective in solving optimization problems related to route and transportation of waste transport vehicles in the city of Jambi. The best feasible solution has been determined through a selection process based on the formulated priorities, as illustrated in this research is as follows:

1. Dump Truck 10 Route has 1 rit dump truck and 3 rit arm roll trucks; Remaining 790 kg empty vehicle load; Excess 2L of fuel consumption; and Savings 135 minutes in working time.
2. Dump Truck 19 Route has 4 rit arm roll trucks; Remaining 750 kg empty vehicle load; and Savings 400 minutes in working time.
3. Dump Truck 27 Route has 2 rit dump trucks and 1 rit arm roll truck; Remaining 2.300 kg empty vehicle load; Excess 2L of fuel consumption; and Savings 145 minutes in working time.
4. Dump Truck 29 Route has 2 rit dump trucks and 1 rit arm roll truck; Remaining 340 kg empty vehicle load; Excess 2L of fuel consumption; and Savings 185 minutes in working time.
5. Arm Roll Truck 06 Route consists of 2 rit dump trucks and 1 rit arm roll truck; Remaining 2620 kg empty vehicle load; Excess 2L of fuel consumption; and Savings 375 minutes in working time.
6. Arm Roll Truck 08 Route with 2 dump trucks; Remaining 10 kg empty vehicle load; Excess 8L of fuel consumption; and Savings 400 minutes in working time.

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