

## DETERMINING THE SHORTEST PATH BETWEEN TERMINAL AND AIRPORT IN YOGYAKARTA USING TRANS JOGJA WITH MIN PLUS ALGORITHM

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### ABSTRAK

Pengaturan rute adalah faktor penting untuk dipertimbangkan sehingga daerah-daerah di kota Yogyakarta dapat dijangkau dengan bus Trans Jogja. Salah satu rute yang perlu dipertimbangkan adalah rute yang menghubungkan antara terminal dan bandara di Yogyakarta. Terminal Jombor, terminal Giwangan, terminal Condong Catur, dan terminal Prambanan adalah terminal di Yogyakarta. Dalam tulisan ini, dibahas jalur terpendek antara terminal dan Bandara Adisucipto dengan perkiraan waktu tempuh minimum menggunakan bus Trans Jogja. Penentuan rute ini dicari dengan menggunakan algoritma min plus. Lintasan terpendek yang disajikan adalah lintasan antara terminal Giwangan dan Condong Catur, terminal Condong Catur dan Prambanan, serta Bandara Adisucipto dan terminal Jombor. Artikel ini terbatas pada bagian dari halte Trans Jogja.

**Kata kunci:** Algoritma Min-Plus, lintasan terpendek, Bis Trans Jogja

### ABSTRACT

Route arrangement is an important factor to be considered so that areas in Yogyakarta city can be reached by Trans Jogja bus. One of the routes to consider is the route that connects between the terminal and the airport in Yogyakarta. Jombor terminal, Giwangan terminal, Condong Catur terminal, and Prambanan terminal are terminals in Yogyakarta. In this paper, we discussed the shortest path between the terminal and Adisucipto Airport with the estimated minimum travel time using Trans Jogja bus. Determination of this route is searched by using min plus algorithm. The shortest trajectory presented is the trajectory between Giwangan and Condong Catur terminal, Condong Catur and Prambanan terminal, and Adisucipto Airport and Jombor terminal. This paper is limited to the passage of Trans Jogja bus stop.

**Keywords:** Min-Plus algorithm, shortest path, Trans Jogja Bus

## **INTRODUCTION**

Transportation is a factor of mobility support that has been done by the community. Indirectly, the smoothness of transportation is one of the economic drivers of society. Terminals and airports are transportation facilities frequented by the community. Jombor terminal, Giwangan terminal, CondongCatur terminal, and Prambanan terminal are terminals in Yogyakarta. Adisucipto airport is an airport located in Yogyakarta. The connection between the terminal and the airport is one of the simplest way for community to do something. Trans Jogja route also have discussed by (Januar, Lati, Panduwianita, & Kurnia, 2013), (Susetyo, Suprayogi, & Awaluddi, 2012), (Priyanga & Widartono, 2014), (Kurniawan, 2018), (Retnowati & Mutropin, 2017). Determining the shortest path is the basic factor for community. That problem is similar with some of researches. For example, Andriani describes if the system information of the tourism area is more help full when we can represent the shortest path between tourism area (Andriani, 2014). Jayanti describes if parking area is more effective while the driver knew where park his car in the nearest area (Jayanti, 2014). That research is done by using Floyd-Wharshall Algorithm. Kriswanto dkk describe about determining the shortest path for distribution problem (Kriswanto, Bendi, & Aliyanto, 2014). The other research is done by (Adipranata, Handojo, & Setiawan, 2008). In that research, he usetransitive closure method to determine optimal path.

Research on min-plus algebra has been discussed by (Watanabe & Watanabe, 2014). Research on the shortest route using various algorithms has been discussed by (Pugas, Somantri, & Satoto, 2011) and (Fahim, Subchan, & Subiono, 2013). While determining the shortest route using the min plus algorithm has been discussed by (Suwanti, Bintoto, & Dinullah, 2017) and (Suprayitno, 2017). The people can use private vehicles and public transport to go to the airport and terminal. One type of public transportation that can be used is Trans Jogja bus. Yogyakarta's goverment has provided bus stops from Trans Jogja buses located around the terminal and airport. This resulted, the community can connect with the terminal and airport via Trans Jogja bus. In this paper, we discussed the shortest path between the terminal and airport with the estimated

minimum travel time using Trans Jogja bus. This paper is limited to the passage of Trans Jogja bus stop. In this study, we use algorithm in the journal (Rudhito, 2013) is used. The vertex weight used to obtain the shortest path is travel time. Min plus linear equation system as stated by (Rudhito, 2013) which will later be used to obtain the shortest route of Trans Jogja.

We can make the analogy of min-plus algebra with max-plus algebra. If  $\mathbb{R}_\varepsilon = \mathbb{R} \cup \{\varepsilon\}$  with  $\varepsilon$  is real set and  $\varepsilon = -\infty$ . We can define the operate of  $\mathbb{R}_\varepsilon$  with

$$a \oplus b = \min\{a, b\}$$

$$a \otimes b = a + b$$

for  $a, b \in \mathbb{R}_\varepsilon$ .

The set of  $(\mathbb{R}_\varepsilon, \oplus, \otimes)$  is commutative idempotent semiring with neutral element  $= 0$  and binary element  $\varepsilon = +\infty$ . Later, we called the set of  $(\mathbb{R}_\varepsilon, \oplus, \otimes)$  with min-plus algebra  $\mathbb{R}_{\min}$ . Relation of  $\leq_m$  can be define as  $x \leq_m y \Leftrightarrow x \oplus y = x$ .

A directed graph  $G = (V, E)$  is connected if for  $\forall i, j \in V, i \neq j$  we can find a path from verteks  $i$  to verteks  $j$ . Directed graph  $G$  is a weighted graph if each edge of a graph has an associated numerical value. The weight of a path or distance of a path in weighted graph is the sum of the weight of the traversed edges. The shortest path in directed graph is the minimum distance of path from all possible path.

## **RESEARCH METHOD**

Matrix  $A \in \mathbb{R}_{\min}^{n \times n}$  is semidefinite if all possible path has non positive.

Matrix  $A \in \mathbb{R}_{\min}^{n \times n}$  is defined as

$$A^* = E \oplus A \oplus A^{\otimes 2} \oplus \dots \oplus A^{\otimes n} \oplus A^{\otimes n+1} \oplus \dots$$

The set  $\mathbb{R}_{\min}^n$  is defined as  $\{\mathbf{x} = [x_1, x_2, \dots, x_n]^T \mid x_i \in \mathbb{R}_{\min}, i = 1, 2, \dots, n\}$ .

### **Definition 1**

*A direct path network  $S$  is a strongly acyclic directed weight graph  $S = (V, A)$  with  $V = \{1, 2, \dots, n\}$  following condition : if  $(i, j) \in A$  then  $i < j$ .*

Networks with weights of travel time can be modeled to directed weights graph. This graph can be represented as a matrix over min plus algebra. The shortest path analysis is done by analyzing and modifying forward counting and backwarding techniques on the CPM method on critical path analysis on the project network using the system approach of min plus linear equations.

The existence of singular completion of the system of min plus linear equations as well as the existence of singularity of the system of max plus linear equations (Bacelli). Given  $A \in \mathbb{R}_{\min}^{n \times n}$  and  $\mathbf{b} \in \mathbb{R}_{\min}^n$ . If  $A$  semidefinite, then vector  $x^* = A^* \otimes \mathbf{b}$  is the completion of the system  $\mathbf{x} = A \otimes \mathbf{x} \oplus \mathbf{b}$ .

**Theorem 2**

*Given a direct path network with  $n$  points and  $A$  matrix of the weighted directed graph network. The vector when the earliest start point  $i$  can be passed by  $x^e = (E \oplus A \oplus \dots \oplus A^{\otimes n-1}) \otimes b^e$  with  $\mathbf{b}^e = [0, \varepsilon, \dots, \varepsilon]^T$ . Furthermore,  $x_n^e$  is the minimum time to traverse the network.*

**Theorem 3**

*Given a direct path network with  $n$  points and  $A$  matrix of the weighted directed graph network. The vector at the slowest completion of the point is given by  $\mathbf{x}^l = -((A^T)^* \otimes \mathbf{b}^l)$  with  $\mathbf{b}^l = [\varepsilon, \varepsilon, \dots, -x_n^e]^T$ .*

The two theorems above serve as the basis for the calculation of minimum timing. Minimum time determination is done by first determining star operation on the matrix over the min-plus algebra (Rudhito, 2013). The next step, determining the critical path through CPM, with the min plus algebra approach, the critical path can be searched by requiring  $x_i^l = x_i^e$ .

## **RESULTS AND DISCUSSIONS**

### **A. Computational**

Determination of the shortest path in the network is seen the entry of the vector at the earliest start of the same as the slowest completion vector. We can presented min-plus algebra with MATLAB to determinate of the shortest path. Here is a representation of the min-plus algebra plus with:

The Min Plus algorithm has the following calculation steps:

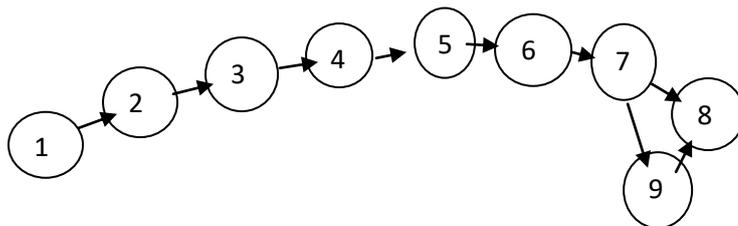
1. Enter the min - plus matrix  $n \times n$ , which is the matrix corresponding to the track graph.
2. Calculating forward:
  - a. Counting  $A^2, A^3, \dots, A^n$  and  $A^+$
  - b. Counting  $E$  and  $A^*$
  - c. Make a matrix  $B$ .
  - d. Calculate vectors when starting at the earliest  $ES_i = A^* \times B$ .
  - e. Make a matrix when starting at the beginning  $MES_i$ .
  - f. Make a matrix when starting at the beginning  $MES_j$ .
  - g. Make a matrix at the fastest completion  $MEC_j$
3. Count down:
  - a. Counting  $A_2$  and  $A_2^+$ .
  - b. Counting  $E_2$  and  $A_2^*$
  - c. Make a matrix  $B_2$
  - d. Calculate the completion vector at the latest  $LC_j = -(A_2^* \times B_2)$ .

### **B. Case Discussion**

Trans Jogja bus route can be described by using graph theory. The graph formed from the bus route is a weighted directed graph. Vertices of graph is represent of bus stops, edge of graph represent of road connecting between bus stops, and the weight of graph is represent of distance between bus stops. Determination of the shortest path is based on directed graphs with paths that do not have a circuit.

In this paper, we discussed the shortest path between the terminals and Adisucipto Airport with the estimated minimum travel time using Trans Jogja bus. The shortest trajectory presented is the trajectory between Giwangan and Condong Catur terminal, Condong Catur and Prambanan terminal, and Adisucipto Airport and Jombor terminal. This paper is limited to the passage of Trans Jogja bus stop.

**1. The shortest path between Prambanan Terminal and Sudirman 1**



**Figure 1.** Route Prambanan Teminal and Sudirman 1

where,

- |          |          |           |
|----------|----------|-----------|
| 1 = PRB  | 4 = SL 1 | 7 = SL 4  |
| 2 = SL 8 | 5 = SL 2 | 8 = LPP   |
| 3 = BAS  | 6 = SL 3 | 9 = SDR 1 |

Figure 1, Route Prambanan Teminal and Sudirman 1 is a graph representation of Prambanan terminal to Sudirman 1. The result from running MATLAB program is:

$$\mathbf{x}^e = \begin{pmatrix} 0 \\ 10 \\ 15 \\ 21 \\ 25 \\ 29 \\ 32 \\ 36 \\ 38 \end{pmatrix} \quad \text{dan} \quad \mathbf{x}^l = \begin{pmatrix} 0 \\ 10 \\ 15 \\ 21 \\ 25 \\ 29 \\ 32 \\ -\varepsilon \\ 38 \end{pmatrix}$$

From this result, the minimum travel time between Prambanan terminal and Sudirman 1 is 38 minute. The shortest path of route is 1-2-3-4-5-6-7-9. In other words, the route from Prambanan terminal to Sudirman 1 is

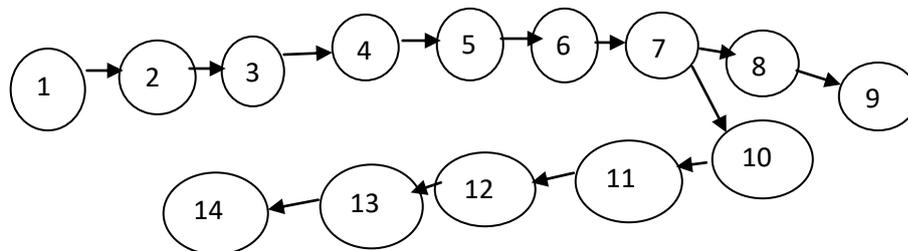
**Determining The Shortest Path Between Terminal and Airport in Yogyakarta Using Trans Jogja With Min Plus Algorithm**

Prambanan – Solo 8 – Airport Adi Sucipto – Solo 1 – Solo 2 – Solo 3 – Solo 4 – Sudirman 1

Figure 1, route between Prambanan Terminal and Sudirman 1 will be continued next halt which direct the different halt. Route between Prambanan Terminal and Sudirman 1 will be continued next halt until Giwangan terminal. The following route is route between Prambanan and Giwangan with the minimum travel time is 90 minute. The route Trans Jogja bus from Prambanan to Giwangan is

Prambanan – Solo 8 – Adi Sucipto Airport – Solo 1 – Solo 2 – Solo 3 – Solo 4 – Sudirman 1 – SMP 5 – YKPN – Solo 11 – UIN 2 – AMPD 2 – SMK 5 – Kusumanegara 4 – Pasar Seni Yogyakarta – UAD – Terminal Giwangan.

**2. The shortest path between Giwangan Terminal and Adi Sucipto Airport**



**Figure 2.** Route Giwangan Terminal and Adi Sucipto Airport

where,

- |           |          |           |
|-----------|----------|-----------|
| 1 = TG    | 6 = SL 6 | 11 = RU 3 |
| 2 = TGD 2 | 7 = SL 7 | 12 = RU 5 |
| 3 = GK 1  | 8 = RU 9 | 13 = RU 6 |
| 4 = GK 3  | 9 = RU 4 | 14 = CC   |
| 5 = SL 5  | 10 = BAS |           |

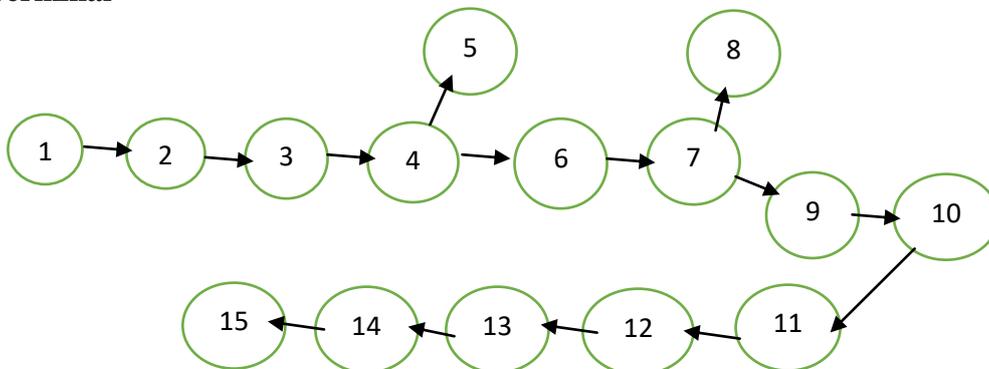
Figure 2, Giwangan Terminal and Adi Sucipto Airport is a graph representation of Giwangan terminal to Condong Catur terminal. The result from running MATLAB program is:

$$\mathbf{x}^e = \begin{pmatrix} 0 \\ 13 \\ 27 \\ 35 \\ 41 \\ 43 \\ 48 \\ \varepsilon \\ \varepsilon \\ 57 \\ 70 \\ 80 \\ 86 \\ 98 \end{pmatrix} \quad \text{dan} \quad \mathbf{x}^l = \begin{pmatrix} 0 \\ 13 \\ 27 \\ 35 \\ 41 \\ 43 \\ 48 \\ -\varepsilon \\ -\varepsilon \\ 57 \\ 70 \\ 80 \\ 86 \\ 98 \end{pmatrix}$$

From this result, the minimum travel time between Giwangan terminal and Condong Catur terminal is 98 minute. The shortest path of route is 1-2-3-4-5-6-7-10-11-12-13-14. In other words, the route from Giwangan terminal to Condong Catur terminal is

Giwangan – Tegal Gendu 2 – Gedong Kuning 1 – Gedong Kuning 3 – Jl. Solo 5 – Jl Solo 6 – Jl Solo 7 – Bandara Adi Sucipto – Ring Road Utara 3 – Ring Road Utara 5 – Ring Road Utara 6 – Condong Catur

**3. The shortest path between Condong Catur Terminal and Prambanan Terminal**



**Figure 3.** Condong Catur Terminal and Prambanan Terminal

*Determining The Shortest Path Between Terminal and Airport in Yogyakarta Using Trans Jogja With Min Plus Algorithm*

where,

1 = CC	6=Solo12	11 = Solo 7
2 = SNV	7=Solo2	12 = BAS
3 = USD	8=Solo 3	13 = Solo 9
4 = Solo 11	9 = Solo5	14 = Solo 10
5 = UIN 2	10=Solo6	15= PRB

Figure 3, Condong Catur Terminal and Prambanan Terminal is a graph representation of Condong Catur Terminal to Prambanan Terminal. The result from running MATLAB program is:

$$\mathbf{x}^e = \begin{pmatrix} 0 \\ 5 \\ 11 \\ 17 \\ 21 \\ 21 \\ 26 \\ 30 \\ 29 \\ 31 \\ 36 \\ 45 \\ 52 \\ 55 \\ 63 \end{pmatrix} \text{ dan } \mathbf{x}^l = \begin{pmatrix} 0 \\ 5 \\ 11 \\ 17 \\ -\varepsilon \\ 21 \\ 26 \\ -\varepsilon \\ 29 \\ 31 \\ 36 \\ 45 \\ 52 \\ 55 \\ 63 \end{pmatrix}$$

From this result, the minimum travel time between Condong Catur Terminal and Prambanan Terminal is 63 minute. The shortest path of route is 1-2-3-4-6-7-9-10-11-12-13-14-15. In other words, the route from Condong Catur Terminal to Prambanan Terminal is

Condong Catur – Suster Novisiat – Universitas Sanata Darma – Jl. Solo 11 – Jl, Solo 12 – Jl Solo 2 – Jl Solo 5 – Jl Solo 6 – Jl Solo 7 – Bandara Adisucipto – Jl Solo 9 – Jl Solo 10 – Prambanan.

4. The shortest path between Adi Sucipto and Jombor Terminal

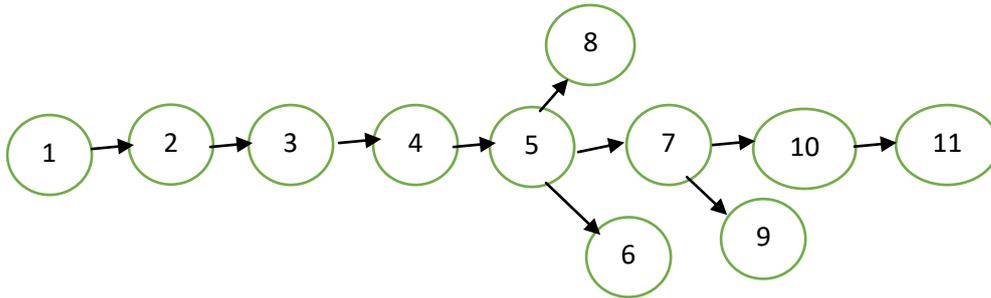


Figure 4. Adi Sucipto and Jombor Terminal

where,

- |           |            |            |
|-----------|------------|------------|
| 1 = BAS   | 5 = CC     | 9 = FK     |
| 2 = RRU 3 | 6 = SNV    | 10 = RRU 2 |
| 3 = RRU 5 | 7 = RRU 7  | 11 = TJ    |
| 4 = RRU 6 | 8 = RRU 10 |            |

Figure 4, Adi Sucipto and Jombor Terminal is a graph representation of Adi Sucipto to Jombor Terminal. The result from running MATLAB program is:

$$\mathbf{x}^e = \begin{pmatrix} 0 \\ 13 \\ 23 \\ 29 \\ 41 \\ 46 \\ 48 \\ 48 \\ 61 \\ 54 \\ 64 \end{pmatrix} \quad \text{dan} \quad \mathbf{x}^l = \begin{pmatrix} 0 \\ 13 \\ 23 \\ 29 \\ 41 \\ -\varepsilon \\ 48 \\ -\varepsilon \\ -\varepsilon \\ 54 \\ 64 \end{pmatrix}$$

From this result, the minimum travel time between Adi Sucipto and Jombor Terminal is 64 minute. The shortest path of route is 1-2-3-4-5-7-10-11. In other words, the route from Adi Sucipto to Jombor Terminal is

Bandara Adi Sucipto – Ring Road Utara 3 – Ring Road Utara 5 – Ring Road Utara 6 – Condong Catur – Ring Road Utara 7 – Ring Road Utara 2 – Jombor.

## CONCLUSION

According computational with use MATLAB, we got:

1. The route for Prambanan to Giwangan is Prambanan – Solo 8 – Adi Sucipto Airport – Solo 1 – Solo 2 – Solo 3 – Solo 4 – Sudirman 1 – SMP 5 – YKPN – Solo 11 – UIN 2 – AMPD 2 – SMK 5 – Kusumanegara 4 – Pasar Seni Yogyakarta – UAD – Terminal Giwangan.
2. The route from Giwangan terminal to Condong Catur terminal is Giwangan – Tegal Gendu 2 – Gedong Kuning 1 – Gedong Kuning 3 – Jl. Solo 5 – Jl Solo 6 – Jl Solo 7 – Bandara Adi Sucipto – Ring Road Utara 3 – Ring Road Utara 5 – Ring Road Utara 6 – Condong Catur.
3. The route from Condong Catur Terminal to Prambanan Terminal is Condong Catur – Suster Novisiat – Universitas Sanata Darma – Jl. Solo 11 – Jl, Solo 12 – Jl Solo 2 – Jl Solo 5 – Jl Solo 6 – Jl Solo 7 – Bandara Adisucipto – Jl Solo 9 – Jl Solo 10 – Prambanan.
4. The route from Adi Sucipto to Jombor Terminal is Bandara Adi Sucipto – Ring Road Utara 3 – Ring Road Utara 5 – Ring Road Utara 6 – Condong Catur – Ring Road Utara 7 – Ring Road Utara 2 – Jombor.

## REFERENCES

- Adipranata, R., Handojo, A., & Setiawan, H. (2008). Aplikasi Pencari Rute Optimum Pada Peta Guna Meningkatkan Efisiensi Waktu Tempuh Pengguna Jalan Dengan Metode A\* Dan Best First Search. *Jurnal Informatika*, 8(2), 100-108.
- Andriani, A. (2014). Rancang Bangun Sistem Infomasi Rute Wisata Terpendek Berbasis Algoritma Floyd Warshall. *Bianglala Informatika*, 98-107.
- Fahim, K., Subchan, & Subiono. (2013). Aplikasi Aljabar Max Plus Pada Pemodelan Dan Penjadwalan Busway Yang Diintegrasikan dengan Kereta Komuter. *Jurnal Teknik Pomits*, 1, 1 -6.
- Januar, M. I., Lati, G. M., Panduwianita, R. R., & Kurnia, R. D. (2013). Implementasi Fasilitas Halte Trans Jogja Berbasis Teknologi Sebagai Upaya Kualitas Pelayanan Transportasi Daerah Yogyakarta. *Khazanah*, VI(1), 41-49.
- Jayanti, N. K. (2014). Penggunaan Algoritma Floyd Warshall dalam Masalah Jalur Terpendek Pada Penentuan Tata Letak Parkir. *Seminar Nasional Informatika*.

- Kriswanto, Y. R., Bendi, R. K., & Aliyanto, A. (2014). Penentuan Jarak Terpendek Rute Transmisi dengan Algoritma Floyd Warshall. *SEMANTIK*, 4(1), 209-216.
- Kurniawan, F. (2018). *Aplikasi Rekomendasi Jalur Bus Trans Jogja Menggunakan Google Maps API dan Google Places API*. Yogyakarta: Universitas Islam Indonesia.
- Priyanga, T. W., & Widartono, B. S. (2014). Peta Skematik Jalur Bus Trans Jogja. *Jurnal Bumi Indonesia*, 3(4), 1-7.
- Pugas, D. O., Somantri, M., & Satoto, K. I. (2011). Pencarian Rute Terpendek Menggunakan Algoritma Dijkstra dan Astar(A\*) pada SIG berbasis Web Untuk Pemetaan Pariwisata kota Sawahlunto. *Transmisi*, 13(1), 27 - 32.
- Retnowati, N. D., & Mutropin, H. A. (2017). Animasi 3D Rute Jalur Bus Trans Jogja Trayek 1 A dan 3A Berbasis Android. *Seminar Nasional Teknologi Informasi dan Kedigantaraan (SENATIK)*.
- Rudhito, A. (2013). Sistem Persamaan Linear Min Plus dan Penerapannya Pada Masalah Lintasan Terpendek. *Universitas Negeri Yogyakarta*. Yogyakarta.
- Suprayitno, H. (2017). Corectness Proof of Min Plus Algebra for Network Shortest Paths Simultaneous Calculation. *Journal of Technology and Social Science (JTSS)*, 1(1), 61 - 69.
- Susetyo, D. B., Suprayogi, A., & Awaluddi, M. (2012). Pembuatan Aplikasi Peta Rute Bus Trans Jogja Berbasis Mobile GIS Menggunakan Smartphone Android. *Jurnal Universitas Diponegoro*, 1(1), 1-10.
- Suwanti, V., Bintoto, P., & Dinullah, R. N. (2017). Penerapan Min Plus Algebra Pada Penentuan Rute Tercepat Distribusi Susu. *Limits*, 14(2), 103 - 112.
- Watanabe, S., & Watanabe, Y. (2014). Min Plus Algebra and Networks. *RIMS Kokyuroku Bessatsu*, 41-54.