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Analysis of the Fastest Cost and Route Using the Graph Theory and Network Analysis

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ABSTRACT

Samarang is one of the subdistricts in the Garut Regency with the most tourism potential. According to 2021 data from Garut Statistics Indonesia, the tourism potential in the Samarang included nature tourism, cultural tourism, special interest tourism, and artificial tourism. Nature tourism had the highest proportion of approximately 49.15% compared to other tourism. Still, there is limited access to these tourist sites due to considerable distance, damaged road conditions, and remoteness from settlements. This research aims to determine the optimal route, cost, and travel time to access the tourist location. Based on this, the methods used were graph theory and network analysis methods. The distance determination was done using Google Maps and quantitative analysis. The results showed that the shortest distance to access tourist sites in the Samarang from the center of Garut city was about 15.55 km, required the cost of IDR132,000, and travel duration of 52 minutes. At the same time, the results of the network analysis method revealed that the normal route was around 21.35 km, which cost IDR158,000 and required a travel time of 66 minutes.

1. Introduction

Samarang is known as one of the favorite tourist destinations in Garut Regency. Based on data from the from Garut Statistics Indonesia, Samarang has the most natural tourism potential with nine tourist destinations: Lake Situ Cibereum, Kamojang Crater, Kamojang Ecopark, Curug Cimanganten, Kamojang Fillage, Kamojang Hill Bridge, Curug Cihaus, Kereta Api Crater, and Madi Kamojang Crater. Given the abundance of natural tourist attractions in Samarang, Samarang has a high potential to attract both domestic or foreign tourists to visit its various tourist sites, either using private vehicles or public transportation. Nevertheless, the accessibility to tourism destinations in Samarang District remains restricted as a result of the considerable distance, damaged road conditions, and remoteness from settlements.

Therefore, there is the need of solutions allowing the determination of the optimal route, cost, and travel time to access the location. The search for the optimal route, cost, and travel time is among the crucial matters as the travel route taken, the costs that must be prepared, and travel time offer convenience to tourists in determining the shortest route to be taken so that travel costs, energy, and time can be more efficient. However, the search for the shortest route is complex, as tourists will be

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looking for tourist attractions that have the optimal route, cost, and travel time of a number of attractions that will select tourists departing from point A.

There are many algorithms used to determine the shortest route, including graph theory and network analysis methods. One of the uses of graphs is to streamline transportation routes [1]. The nature of the construction of effective and efficient transportation routes necessitates the involvement of scientific disciplines such as graph theory [2]. In addition, graphs are used to draw up a travel route and determine the nearest route [3]. In practice, there are many models of network analysis, one of the well-known models used in planning, scheduling, and monitoring is the Program Evaluation and Review Technique (PERT) Program [4]. Network analysis geographic information system is used to determine the fastest route, side road view, roadside obstacle, and optimal route [5]. By utilizing graph theory and network analysis, the shortest route of Samarang district tourist attractions will be determined, thereby assisting tourists in selecting their destination.

This research is inseparable from the previous research' results as they provide material for comparison and study. In addition, the research results that are used as comparisons are inseparable from the topic of this research, namely determining the shortest route using graph theory and network analysis.

The first research has studied the shortest route to Sam Ratulangi Manado airport as the tourists need this information [6]. Referring to previous research, the shortest trajectory was modeled with graph theory using the Dijkstra Algorithm, and the differences in the trajectory of difference with the shortest trajectory could be seen using the Google Maps.

The regulation of road traffic flow can also be described in the form of graphs so that optimal solutions for complex traffic problems are obtained [7]. Nevertheless, at the very least, the visualization of traffic flow through the utilization of graphs can significantly facilitate the determination of solutions. The traffic flow at the Srengseng Kembangan intersection in West Jakarta is very congested due to the fact that it serves as the primary thoroughfare that links the outskirts of Jakarta to Jakarta, as well as West Jakarta to South Jakarta and Central Jakarta. Another study has studied on out how to determine the base and upper dimensions on the zero-divisor graph of the commutative ring [8].

2. Method

This research began with a literature study, namely collecting reference materials from data from the 2022 Garut Statistics Indonesia, journals, lecture notes, and papers on graph theory and network analysis, as well as several other references to support the research objectives.

Furthermore, the method was the case study method, where quantitative data needed for research were collected from the Garut Statistics Indonesia in 2022. The subjects in this study, namely graph theory and network analysis, are utilized to solve the problem in determining the optimal route, cost, and travel time of tourist attractions in Samarang.

The identification of problems seeks to determine the optimal route, cost, and travel time for tourists' trips in Samarang using graph theory and network analysis. Data collection on the names of natural attractions in Samarang was conducted. The source of data needed was obtained from the Garut Statistics Indonesia in 2022. Subsequently, subdistricts with the most natural tourist attractions in Garut per year waere selected. After that, the method used was the analysis of the results of solving the problem using the Floyd Warshall algorithm.

3. Results and Discussion

3.1. Floyd Warshall Graph Theory

The following are the results of the shortest route selected from nine tourist attractions in Semarang District, namely the route to the Tourist Destination Curug Cimanganten. Table I shows detail cost and travel time determination.

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Route description:

A = Garut Institute of Technology
B = Hampor Red Light
C = DPMD of Garut Regency
D = Kurnia Farma Pharmacy
E = SMK Bina Wira Usaha
F = Martabak Cikamiri
G = Curug Cimanganten

Table 1. Cost and Travel Time Determination

Route	Cost (IDR)	Time (Minutes)
A to B	21,000	6
A to C	23,000	7
A to D	22,000	8
B to E	20,000	5
C to E	23,000	8
E to F	46,000	23
D to F	52,000	29
F to G	45,000	18
D to B	25,000	12

Fig. 1 displays a map of the mileage within one kilometer of each predetermined route.

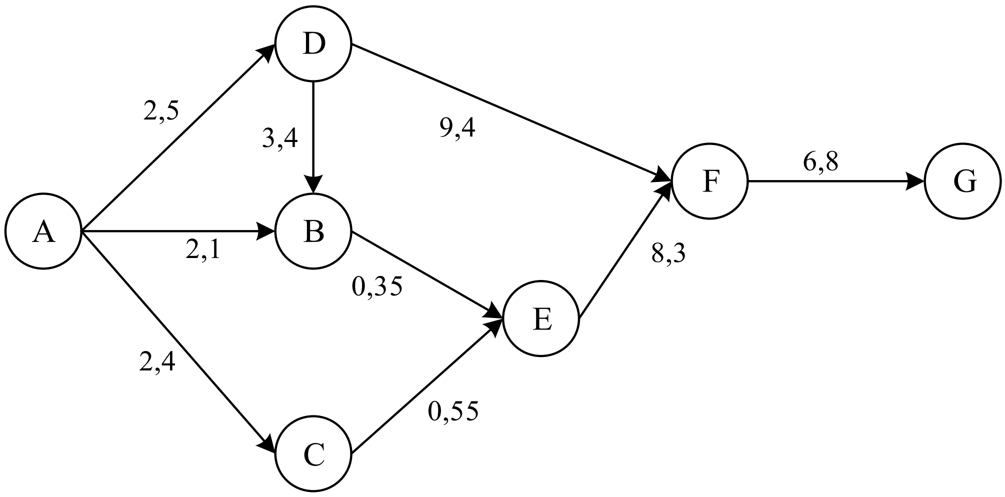

Fig. 1 Route image by Maps.

Based on Fig. 1, the data were changed in the for of iterations. These iterations are presented in the form of a table containing A to G routes. Subsequently, the graph was transformed into a matrix and is presented in Table 2.

Table 2. Transformation of the Graph to Matrix

	A	B	C	D	E	F	G
A	0	2,1	2,4	2,5	∞	∞	∞
B	2,1	0	0,23	3,4	0,35	∞	∞
C	2,4	0,23	0	∞	0,55	∞	∞
D	2,5	3,4	∞	0	4,5	9,4	∞
E	∞	0,35	0,55	4,5	0	8,3	∞
F	∞	∞	∞	9,4	8,3	0	6,8
G	∞	∞	∞	∞	∞	6,8	0

The data used in Table 2 were then used for the next stage with K = 1 iteration from the sample K = G. The results of this data can produce the data in Table 3 in the form of an iterative transformation graph into a matrix and help to determine the shortest travel route which could be searched using the matrix.

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Table 3. Iteration Transform Graph to a Matrix

	A	B	C	D	E	F	G
A	0	2,1	2,4	2,5	2,45	11,9	17,55
B	2,1	0	0,23	3,4	0,45	8,65	15,45
C	2,4	2,5	0	3,63	13	8,85	15,65
D	2,5	13,4	3,63	0	4,5	9,4	16,2
E	2,45	0,35	0,55	4,5	0	8,3	15,1
F	11,9	8,65	8,85	9,4	8,3	0	6,8
G	17,55	15,45	15,65	16,2	15,1	6,8	0

After the distance of each point was found, the shortest travel route can be determined from the matrix. The shortest route was located at the intersection of A and G, with a distance of 17.55 km. To check the correctness of the data, manual calculation of distances is presented below.

A – D – F – G = 2.5 + 9.4 + 6.8 = 18.7 km
A – B – E – F – G = 2.1 + 0.35 + 8.3 + 6.8 = 17.55 km
A – D – B – E – F – G = 2.5 + 3.4 + 0.35 + 8.3 + 6.8 = 21.35 km
A – C – E – F – G = 2.4 + 0.55 + 8.3 + 6.8 = 18.05 km

Based on these calculations, the data were proven to be correct, so that it could determine the cost and time needed, namely as follows.

- Cost (IDR)
  A – B – E – F – G = 21,000 + 20,000 + 46,000 + 45,000 = 132,000
- Time (minutes)
  A – B – E – F – G = 6 + 5 + 23 + 18 = 52 minutes

3.2. Network Analysis PERT Method

Basically, the PERT method is used to schedule a project. However, in this discussion, PERT was utilized to analyze the distance of a tourist trip at normal times as a comparison with graph theory. Preliminary data is shown in Fig. 2.

Caption data = Graph theory (Place, Cost, Time)

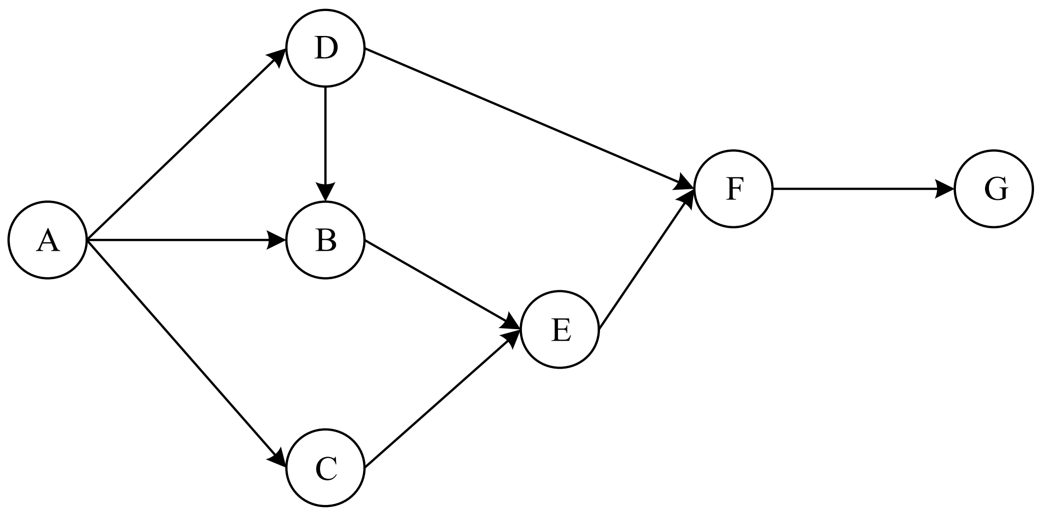

Fig. 2 Preliminary data.

a. Resolving

- Based on the results of previous observations, a network image can be produced which could be seen in Fig. 3 which shows the A until G routes.

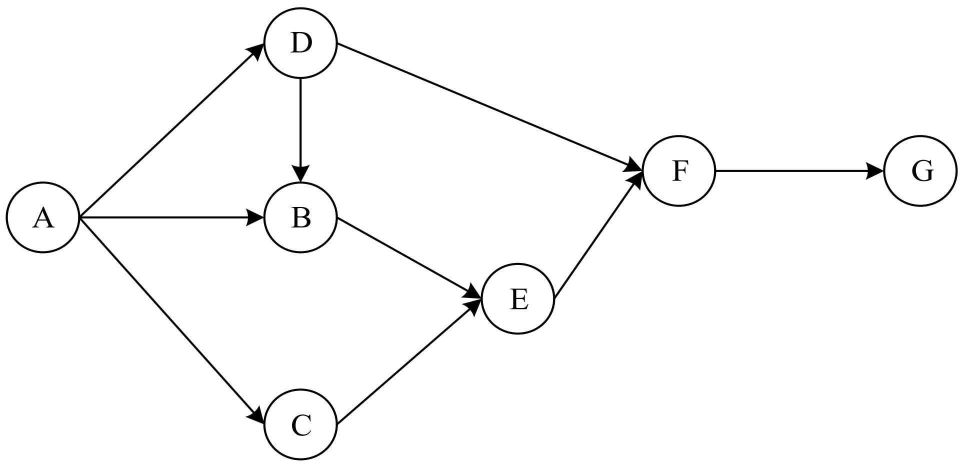

Fig. 3 Network image.

- Create an activity chart, as shown in Fig. 4.

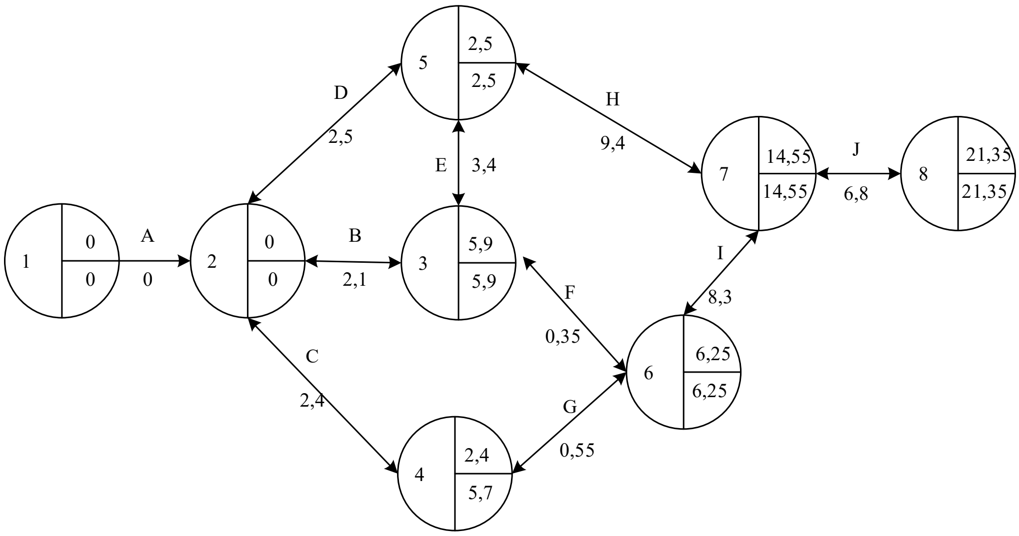

Fig. 4 Activity chart.

The critical path is on A, D, E, F, I, J
with normal distance = 2.5 + 3.4 + 0.35 + 8.3 + 6.8 = 21.35 km
direct costs = 22,000 + 25,000 + 20,000 + 46,000 + 45,000 = IDR.158,000
and travel time = 8 + 12 + 5 + 23 + 18 = 66 minutes

As demonstrated in the previous calculation, the calculation using the graph theory and network analysis yielded the same results. The Kamojang Craters and other natural attractions are explained in the following results.

Kamojang Crater
Distance = A – B – D – E = 25.2 km
Cost = 21,000 + 40,000 + 83,000 = IDR144,000
Time = 6 + 40 + 41 = 87 minutes

Kamojang Ecopark
Distance = A – B – E – F – G = 20.85 km
Cost = 21,000 + 20,000 + 43,000 + 57,000 = IDR141,000
Time = 6 + 5 + 18 + 25 = 54 minutes

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Kamojang Fillage
Distance = A – B – D – E = 20.85 km
Cost = 26,000 + 24,000 + 81,000 = IDR137,000
Time = 6 + 5 + 44 = 55 minutes

Kamojang Hill Bridge
Distance = A – B = 26 km
Cost = IDR126.000
Time = 62 minutes

Curug Cihaus
Distance = A – B – D – E = 19.9 km
Cost = 21,000 + 38,000 + 69,000 = IDR128,000
Time = 8 + 8 + 39 = 55 minutes

Railway Crater
Distance = A – B = 25 km
Cost = IDR135,000
Time = 63 minutes

Curug Madi Kamojang
Distance = A – B – D – E = 25.2 km
Cost = 21,000 + 40,000 + 82,000 = IDR143,000
Time = 6 +18 +37 = 61 minutes

Lake Cibeureum
Distance = A – C – D – F – G = 26.9 km
Cost = 24,000 + 51,000 + 21,000 + 78,000 = IDR174,000
Time = 1 + 27 + 1 + 37 = 66 minutes

b. Statement of Results

Based on the results of the calculation of graph theory using the Floyd Warshall method and network analysis, results of the recapitulation of distance, cost, and time in the form of a graph is discussed in this section.

- Distance Recapitulation

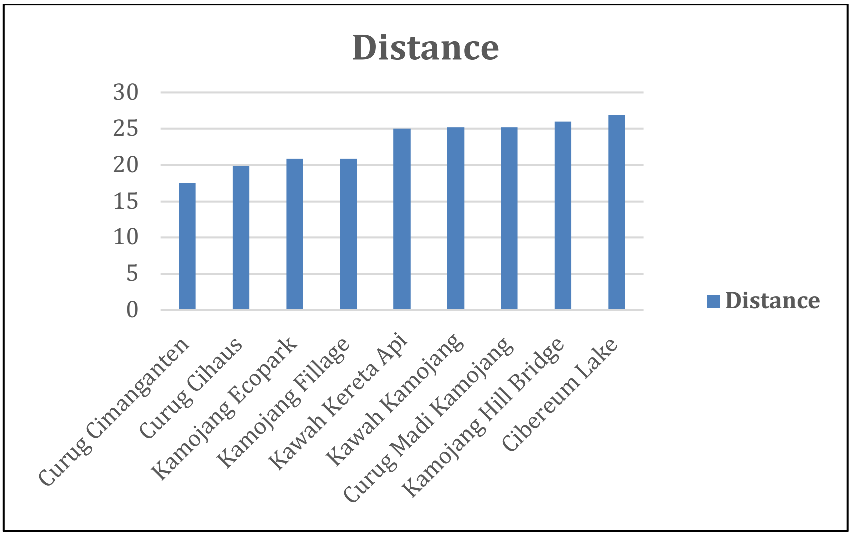

Fig. 5 Distance recapitulation graph.

Based on Fig. 5, tourist destinations with the shortest distance include Curug Cimanganten, with a distance of 17.55 km; Curug Cihaus, with a distance of 19.9 km; Kamojang Ecopark, with a

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distance of 20.85 km; and Kamojang Fillage with a distance of 20.85 km. Meanwhile, the tourist attractions with medium distances are the Kereta Api Crater tour with a distance of 25 km, Kamojang Crater with a distance of 25.2 km, and Madi Kamojang Waterfall with a distance of 25.2 km. The order of tourist destinations with the furthest distance is the Kamojang Hill Bridge, with a distance of 26 km, and Cibereum Lake, with a distance of 26.9 km.

- Time Recapitulation

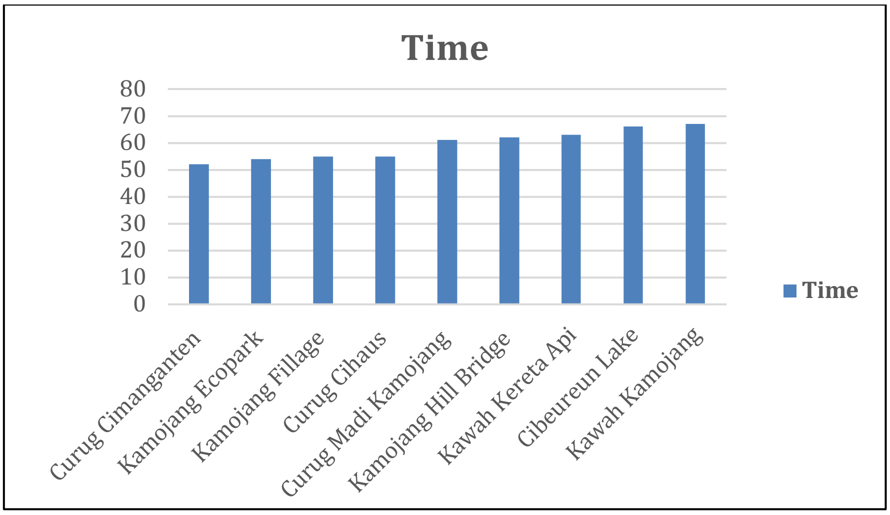

Fig. 6 Time recapitulation.

Based on Fig. 6, tourist destinations with the shortest time includes the Curug Cimanganten tour with 52 minutes, Kamojang Ecopark with 54 minutes, Kamojang Fillage with 55 minutes, and Curug Cihaus with 55 minutes. Meanwhile, the tourist destinations with medium-time travel are the Madi Kamojang Waterfall tour with 61 minutes, the Kamojang Hill Bridge with 62 minutes, and Kereta Api Crater tour with 63 minutes. The order of tourist destinations with the longest time is Cibereum Lake tourism with 66 minutes, and Kamojang Crater with 87 minutes.

- Cost Recapitulation

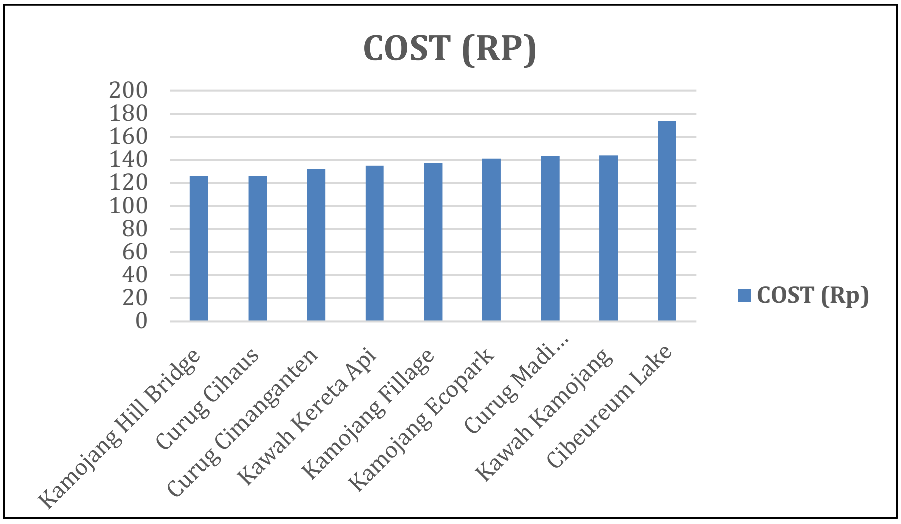

Fig. 7 Cost recapitulation.

Based on Fig. 7, tourist destinations with the highest costs include the Kamojang Hill Bridge tour, which costs IDR126,000; Curug Cihaus, which costs IDR128,000; Curug Cimanganten, which

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costs IDR132,000; and Kereta Api Crater, which costs IDR135,000. Meanwhile, the tourist destinations with medium cost are the Kamojang Fillage tour, which costs IDR137,000; Kamojang Ecopark, which costs IDR141,000; and Madi Kamojang Waterfall, which costs IDR143,000. The order of tourist destinations with the highest cost are the Kamojang Crater, which costs IDR144,000, and Cibereum Lake, which costs IDR174,000.

c. Explanatory Text

The following is the determination of the optimal distance, cost, and travel time based on graph theory using *the* Floyd Warshall method and network analysis using the PERT method.

- Floyd Warshall Method Graph Theory

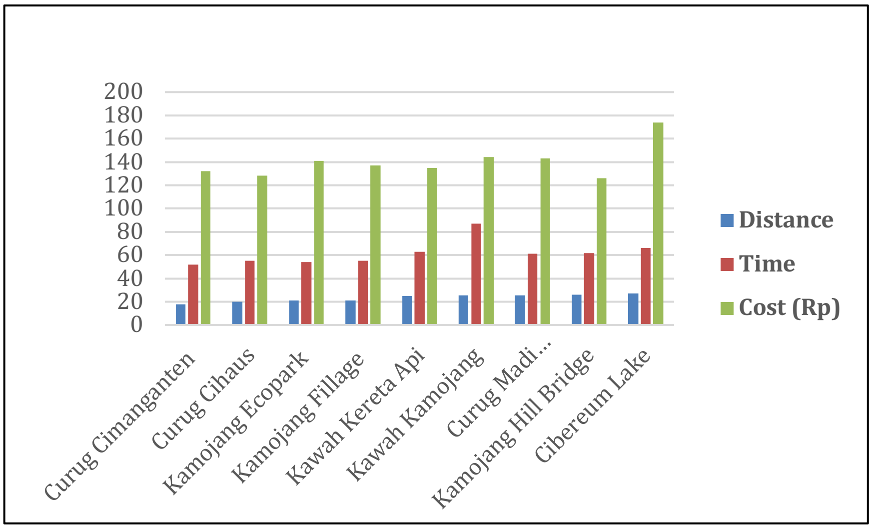

Fig. 8 Recapitulation of graph theory.

Based on Fig 8, which exhibits results from using the graph theory of Floyd Warshall method, natural tourism in Samarang District with the optimal distance, cost, and time travel is the Curug Cimanganten with a distance of 15.55 km, the cost of IDR132,000, and travel time of 52 minutes.

- Network Analysis Using the PERT Method

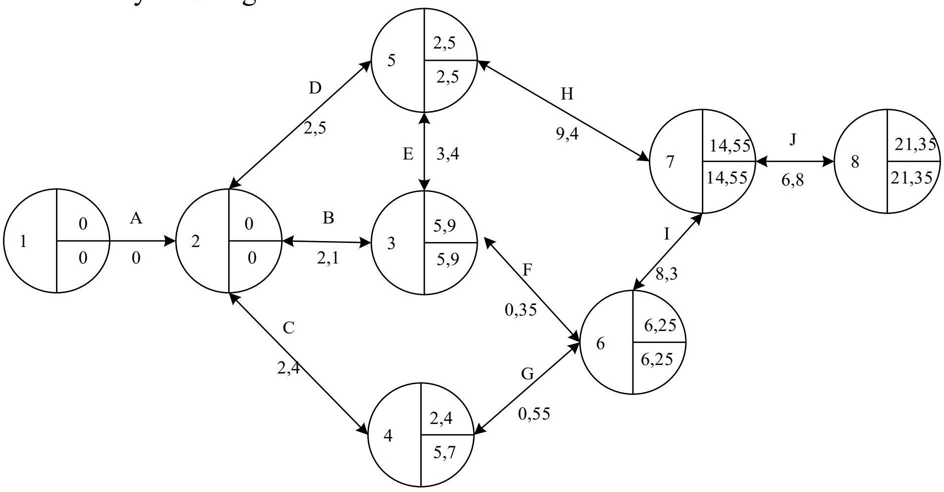

Fig. 9 Analysis of the PERT method.

Fig. 9 presents the analysis of the PERT method. Based on the calculation results using the PERT method. The distance, cost, and normal travel time of the Curug Cimanganten tourism were obtained

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with a normal distance of 21.35 km, a normal cost of IDR158,000, and a normal travel time of 66 minutes.

4. Discussion

The results explicated in the previous discussion has suggested that, when compared to the network analysis using the PERT method, the Floyd Warshall is more effective to determine the tourist destination with the shortest route. The network analysis using the PERT method only resulted in normal routes. In contrast to the findings of the preceding research, this study has refined the application of graph theory, bolstered by the utilization of Google Maps for determining distance and time travel as well as the Grab application for cost determination.

5. Conclusion

The graph theory and network analysis for determining the shortest distance can be deduced from the conducted research. These steps consist of the following: determining the distance, determining the cost, determining the time from the certain location to the direction of natural tourism, changing the specified data in the form of a matrix and summing up the shortest distance, determining the optimal cost and the fastest time. After that, it was compared with network analysis by calculating an activity chart, thereby determining the essential path, direct cost, and optimal time.

From this research, it is possible to develop ways to process data more simply and can be proven to be valid. Therefore, there is no need to conduct a comparison with other methods. However, the conducted research has drawbacks, namely the absence of comparisons with other motor vehicles. Research with the graph method helps determine the shortest route, time efficiency, and the lowest cost. Based on the conducted research, it is recommended that future research consider comparing two vehicles, which are a motorbike and a car.

Acknowledgment

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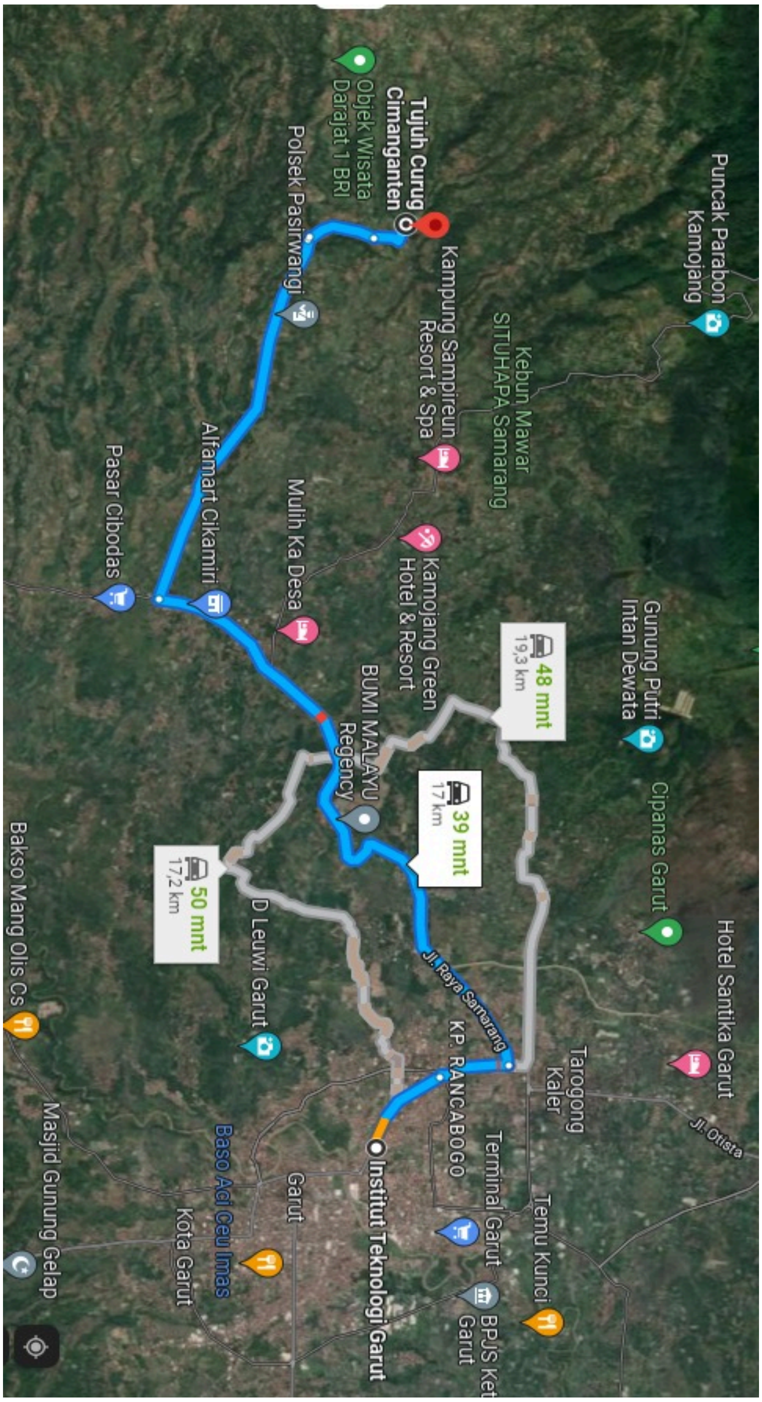
Appendix



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