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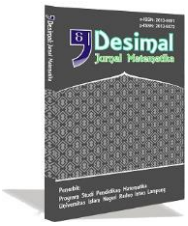

Bellman-ford and greedy algorithms to optimize the shortest route of PT. TIKI Jalur Nugraha Ekakurir (JNE)

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ABSTRACT

The purpose of this research is to find a comparison of Bellman-Ford and Greedy algorithms to optimize the shortest route of PT Tiki Jalur Nugraha Ekakurir (JNE). Bellman-Ford and Greedy algorithms are two algorithms that are often used in finding the shortest distance or optimal solution on a weighted graph. This research will be carried out at the JNE Medan Representative Office located on Jl. SM Raja Km 10.5 Amplas Trade Center Complex Blok F-10, while the type of research that will be used in this paper is applied research. The results of the study indicated the selection of the Bellman-Ford method because the Bellman-Ford method provides a more optimal route in terms of distance. Where the total initial distance used by PT Tiki Jalur Nugraha Ekakurir (JNE) is 20.5 km through routes including A→C → D → E → G→ H → J→ K→ L → N → O → P → R. While the total distance from the results of the new route sequence using the Bellman-Ford algorithm is 17.3 km by going through routes including A→B→D→E→F→H→I→K→L→M→O→Q→R And the total distance of the new sequence results using the Greedy algorithm is 17.5 km by going through routes A→B → D → E → F→ H → J→ K→ L → N → O → Q → R. This shows an efficiency of 15% in comparing existing routes with routes resulting from data analysis using Bellman-Ford.

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INTRODUCTION

The rapid development of technology in this era, apart from the rapid dissemination of information, also requires an acceleration in various other fields, including human movement and the delivery of goods and services (Alfioza & Sahputra, 2022). People who are increasingly busy with their personal lives are trying to find efficient ways to achieve their goals in order to save time and energy, such as sending documents and buying and selling transactions. In this series of technological developments, online systems have become a solution that facilitates the performance of various activities by all parties (S. Liu et al., 2018).

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This is the basis for creating efficient goods delivery services. In general, goods delivery services or expedition services are very important because they are really needed, especially in Indonesia, which consists of many islands. One of the things that must be considered in supporting the smooth distribution of the flow of goods and services are goods delivery transactions, recording goods transactions, shipping, cost information, and checking receipts (Drakakis & Kotropoulos, 2024).

Delivery of goods is one branch of various companies operating in the service sector. Expedition services are services related to receiving, transporting, combining, storing, delivering, logistics, and distributing goods, as well as additional services and consulting services (Iskandar & Riti, 2022). The high public demand for goods delivery services has transformed the travel business into a business opportunity (Berggren et al., 2022). This business is starting to attract the attention of many merchants because the number of goods sent to online stores is increasing (Wayahdi et al., 2021). This goods delivery service also brings profits to the company, so the need for this goods delivery service plays an important role in supporting the smooth running of the Indonesian economy (Wang et al., 2020).

JNE focuses on goods delivery services between regions and provinces, prioritizing delivery speed. To increase delivery efficiency, the choice of delivery route must be fast and according to the delivery schedule (Tiara Pratiwi et al., 2021). Currently, JNE delivery in Medan still depends on the nearest area, then the furthest area, and even then, it still depends on the shipping costs paid by the customer (Melliana et al., 2023). The problems that arise arise from the large number and types of deliveries, making timing a major obstacle (Quiaro & Sacchi, 2024). The next problem in the delivery process carried out by courier employees is that they have different delivery areas when making deliveries, so each courier has a different delivery target. Plus, the problem is that the address given does not match the destination address, so delays often occur in delivery (Saktia Purnama et al., 2024). JNE is one of the delivery service providers in Indonesia, and the number and location of deliveries vary every day. Delivery delays affect company efficiency, in addition to the problem of determining routes that are less than optimal and high fuel costs due to inefficient routes (Hadibrata & Maudin, 2020).

Determining the shortest route from city A to city B is not only determined by distance. However, consider actual traffic conditions so that it is not only about the shortest route but also about alternatives to avoid traffic jams (Yusuf et al., 2023).

One effort that can be made to solve this problem is to determine the shortest route. In the process of determining the shortest route, all roads have connections between one road and another and form a graph (Puja Kekal et al., 2021). A graph is a set of points connected by a weighted line. It can be said that a graph is a set of vertices connected by edges. In general, there are a number of methods to find the shortest route, including the Djiktra algorithm, Ant or Ant Colony algorithm, Floyd Warshall algorithm, Bellman-Ford algorithm, Distance Vector algorithm, Ford-Fulkerson algorithm, Greedy algorithm, and others (Tiara Pratiwi et al., 2021). These algorithms were created to find the most efficient route. In this research, the shortest route uses the Bellman-Ford and Greedy algorithms (Fitriani et al., 2022). The Bellman-Ford and Greedy algorithms are two algorithms that are often used to search for the shortest distance or optimal solution in weighted graphs (P. Liu & Huang, 2022). The Bellman-Ford algorithm is an algorithmic system used to find the shortest route in a trajectory (Zhao et al., 2022).

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The Greedy algorithm is an algorithm that can gradually solve optimization problems through a flow that is always developing until the problem solution can be resolved (Fitriani et al., 2022). The Greedy algorithm can choose a route that is taken first to provide a local alternative in order to produce a comprehensive optimal alternative so that the fastest route is obtained (Jukna & Schnitger, 2016). By applying these two algorithms, we can compare the optimal solution to the shortest route (Chou et al., 2020). Previous research was conducted by Sri Basriani, Elfira Safitri, She Arssy Yesti, and Nilwan Andiraja in 2021 with the title "Implementation of the Bellman-Ford Algorithm in Determining the Shortest Path of Garbage Disposal Trucks". This research aims to find the shortest path (Basriati et al., 2022). The results of this research show the shortest route for a garbage truck in the city of Taluk Kuantan, namely, there is one route with the minimum distance to reach the Sentajo final disposal site more quickly. The number of iterations obtained to achieve the final result was seven, with a minimum distance of 17.2 km (Bhat et al., 2024).

Previous research was also conducted by Elia Resita Ningrum, Ardhi Sanwidi, and Rachmadania Akbarita in 2023, entitled "Optimization of LPG Gas Distribution Routes Using the Floyd Warshall Algorithm and the Greedy Algorithm". This research was conducted to find the shortest route for the distribution of LPG gas. The calculation results of this study with the Floyd Warshall algorithm and the Greedy algorithm obtained the Floyd Warshall algorithm with a distance of 14.57 km and the Greedy algorithm with a distance of 13.13 km. So the more optimal algorithm to use in solving the problem of the shortest route for LPG gas distribution at PT Petro Jaya Gas is to use the Greedy algorithm because it has a shorter distance (Ningrum et al., 2023).

Based on this problem, I researched optimizing the shortest route so that an algorithm was needed to find the shortest route well and in a planned manner so that it could be used as a guide by JNE specifically for couriers who deliver packages in Medan Kota District.

METHOD

In this research, researchers used the Bellman-Ford algorithm and the greedy algorithm to search for the shortest route in package delivery by JNE couriers.

A. Bellman-Ford Algorithm

General form of mathematical notation of the Bellman-Ford algorithm (Azdy & Darnis, 2019).

$$M[i,v] = \min\big(M[i-1,v], (M[i-1,n] + Cvn)\big) \quad (1)$$

Where:

M : The sign to be iterated
i : The iteration performed
v : The point to be tested
n : Connected points
C : Distance between nodes

Using equation (1), several stages are carried out to find the shortest route using Bellman-Ford (Pratama & Dermawan, 2022):

1. Converts a map to a directed and weighted graph
2. Determine the start point and end point, and describe all points and edges
3. Gives a value to the origin = 0 and other points to infinity.
4. Starting iteration with all existing points, starting with the origin point, which spreads information to points that are directly related to the origin point according to the path weight value. All points that already have value will spread information to points that are directly related. If a point is filled with more than one value, then the value that will be taken is the smallest

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5. Perform iterations repeatedly until a value is obtained at each point that has been explored
6. Obtain the final results of the iterations that have been carried out.

B. Greedy Algorithm

$$\text{Route (R)} = \sum_{i=A}^{R} L(i) \qquad (2)$$

Where:
Route (R): Quantity distance traveled courier
R : A lot passing point
i : A, B, C, ..., R.
$L\ (i)$: Route traveled

To find the shortest path, it can be formulated as follows (Santi & Budianti, 2023):

1. Check all edges directly adjacent to the node, select the edge with the smallest weight. This edge first becomes the shortest path, let's call it $L(\ i\ )$.
2. Calculate the shortest path with the node next in the following way:
   a) Calculate: $d\ (\ i\ )$ = length $L(\ i\ )$ + weight of the node last $L(\ i\ )$ to the vertex i others.
   b) Choose the smallest $d\ (\ i)$. Compare $d\ (\ i\ )$ with edge weight $(\ a, i\ )$. If the weight edge $(\ a, i\ )$ is less than $d\ (i)$, then $\mathrm{L}(i) = \mathrm{L}(a) \cup \mathrm{d}(a, i)$ edge of the final node $L\ (\ i\ )$ at the node $(\ i\ )$.

Similarly, repeat step 2 to determine the next shortest path.

RESULTS AND DISCUSSION

The data used in this study show on Table 1.

Table 1. Package Delivery Point Data of Medan Kota Sub-district.

No.	Symbol	Type	Location
1	A	JNE Amplas Trade Center	Timbang Deli, Medan Amplas, Medan City, North Sumatra
2	B	Road Intersection	Jl. Selambo
3	C	Delivery 1	Jl. SM Raja
4	D	Delivery 2	Jl. Tanjung Bunga
5	E	Delivery 3	Jl. Jaya II
6	F	Road Intersection	Jl. Bahagia
7	G	Delivery 4	Stadion Teladan
8	H	Delivery 5	Jl. HM Joni
9	I	Road Intersection	Jl. Laksana
10	J	Delivery 6	Jl. Ismailiyah
11	K	Delivery 7	Jl. Amaliun
12	L	Delivery 8	Jl. Ansari
13	M	Road Insersection	Jl. Yoserizal
14	N	Delivery 9	Sun Yat Sen Street
15	O	Delivery 10	Jl. Pemuda Baru
16	P	Delivery 11	Jl. Riau
17	Q	Road Intersection	Jl. M.T. Haryono
18	R	Delivery 12	Jl. Bulan

The data in Table 1 are data points that form the package delivery network in Medan Kota Sub-district. The points consist of the starting location, namely JNE Amplas Trade Center, Delivery Location, and Road intersection. Based on table 1, it can be seen that the points that form the package delivery network in Medan Kota Subdistrict are 18 points consisting of the departure place, namely JNE Amplas Trade Center, 12 Delivery Locations, and 5 Road Intersections.

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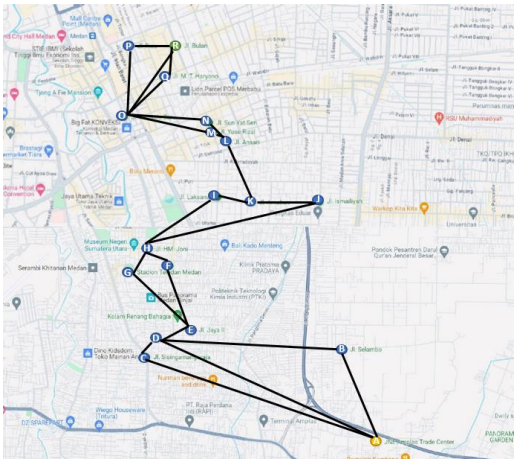

Figure 1. Route Overview using Bellman-Ford and Greedy

Based on Figure 1, the initial stage that must be made in the shortest route search process is to create a table containing related points. Table 2 shows the related points regarding the distance of several points.

A. Application of the Bellman-Ford Algorithm

1. Converting a Map to a Directed and Weighted Graph
2. Determine Starting Point, Destination Point as well Elaborate Entire Points and Sides
3. Assign 0 marks to Starting Point and Point Other With ∞
4. Start iterating over all existing points, starting with the origin point, spreading information to points directly connected to the origin point according to their path weight values.

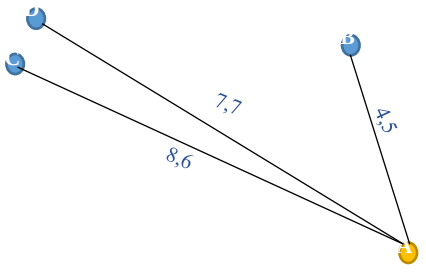

Figure 2. First Iteration Graph

Table 2. Connected Points

No.	Connected Point	Distance (km)
1	A-B	4.5
2	A-C	8.6
3	A-D	7.7
4	B-C	3.2
5	C-D	1.3
6	D-E	0.7
7	E-F	1.7
8	E-G	2.3
9	F-H	0.8
10	G-H	0.7
11	H-I	1.5
12	H-J	1.2
13	I-K	0.6
14	J-K	1
15	K-L	1.5
16	L-M	0.5
17	L-N	0.3
18	M-O	0.9
19	N-O	1.2
20	O-P	0.9
21	O-Q	0.6
22	O-R	1.7
23	P-R	0.8
24	Q-R	0.8

$$M(1,B) = \min\left(M[0,B], (M[0,A] + 4.5)\right)$$
$$= \min(\infty, [0 + 4.5])$$
$$= \min(\infty, 4.5) = 4.$$
$$M(1,C) = \min\left(M[0,C], (M[0,A] + 8.6)\right)$$
$$= \min(\infty, [0 + 8{,}6])$$
$$= \min(\infty, 8.6) = 8.6$$
$$M(1,D) = \min\left(M[0,D], (M[0,A] + 7.7)\right)$$
$$= \min(\infty, [0 + 7.7])$$
$$= \min(\infty, 7.7) = 7.7$$

It can be seen that from the results of the first iteration, point B has a value of 4.5 km, point C has a value of 8.6 km, and point D already has a value of 8.4 km, while the values of the other points are still ∞. Next, the next iteration will be carried out which can be seen in Table 3.

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Table 3. Calculation of the Eleventh Iteration of Bellman-Ford Algorithm

	Start	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	Finish
0	0	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
1	0	4.5	8.6	7.7	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
2	0	4.5	8.6	7.7	8.4	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
3	0	4.5	8.6	7.7	8.4	10.1	10.7	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
4	0	4.5	8.6	7.7	8.4	10.1	10.7	10.9	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
5	0	4.5	8.6	7.7	8.4	10.1	10.7	10.9	12.4	12.1	∞	∞	∞	∞	∞	∞	∞	∞
6	0	4.5	8.6	7.7	8.4	10.1	10.7	10.9	12.4	12.1	13	∞	∞	∞	∞	∞	∞	∞
7	0	4.5	8.6	7.7	8.4	10.1	10.7	10.9	12.4	12.1	13	14.5	∞	∞	∞	∞	∞	∞
8	0	4.5	8.6	7.7	8.4	10.1	10.7	10.9	12.4	12.1	13	14.5	15	14.8	∞	∞	∞	∞
9	0	4.5	8.6	7.7	8.4	10.1	10.7	10.9	12.4	12.1	13	14.5	15	14.8	15.9	∞	∞	∞
10	0	4.5	8.6	7.7	8.4	10.1	10.7	10.9	12.4	12.1	13	14.5	15	14.8	15.9	16.8	16.5	17.6
11	0	4.5	8.6	7.7	8.4	10.1	10.7	10.9	12.4	12.1	13	14.5	15	14.8	15.9	16.8	16.5	17.3

In Table 3, it can be seen that to reach point R (Jalan Bulan) or finish, eleven iterations were carried out to have a value, and from the results of the calculation, the smallest value was obtained, namely 17.3. Which means that the shortest route that will be taken by the PT. Tiki Nugraha Ekakurir (JNE) package delivery courier can be determined via the route A→B→D→E→F→H→I→K→L→M→O→Q→ R point.

B. Application of the Greedy Algorithm

The following is a way to solve the shortest route problem using the Greedy algorithm, which is assisted by Python software as proof.

1. Calculation process iteration 1

Point: {A} JNE Amplas Trade Center

Set candidate: JNE Amplas Trade Center {A} to Jl. Selambo {B}

Set solution: {A→B}

Function selection: A→B

Function appropriateness: A→B

Function objective: A→B, the total distance is 0 + 4.5 = 4.5 km

Based on the iterations that have been carried out, there is 1 route that the package courier will take to get to the final delivery point, namely Jalan Bulan, passing through 13 points or nodes that are 17.5 km away by passing the points A→B → D → E → F→ H → J→ K→ L → N → O → Q → R.

C. Comparison of the Bellman-Ford Algorithm and the Greedy Algorithm

To see a comparison of routes at PT. Nugraha Lane Tiki Ekakurir (JNE), which is displayed by applying the two algorithms, see Table 4.

Table 4. Comparison of the Bellman-Ford Algorithm and Greedy Algorithm

Bellman-Ford	Greedy
$A \rightarrow B \rightarrow D \rightarrow E \rightarrow F \rightarrow H \rightarrow I \rightarrow K \rightarrow L \rightarrow M \rightarrow O \rightarrow Q \rightarrow R$	$A \rightarrow B \rightarrow D \rightarrow E \rightarrow F \rightarrow H \rightarrow J \rightarrow K \rightarrow L \rightarrow N \rightarrow O \rightarrow Q \rightarrow R$

Iteration 1

Figure 3. Route with Bellman-Ford Algorithm

Figure 4. Route with Greedy Algorithm

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Iteration 2

Figure 5. Route with Bellman-Ford Algorithm

Figure 6. Route with Greedy Algorithm

Iteration 12

Figure 7. Route with Bellman-Ford Algorithm

Figure 8. Route with Greedy Algorithm

In this research, it can be seen that using the Bellman-Ford algorithm to find the shortest route is more optimal than using the Greedy algorithm, and what differentiates this research from previous research is the research subject and the distance used based on the Here We Go software. Apart from that, this research uses two algorithms that are rarely compared, so by comparing the two algorithms, we can see the optimal results between the two methods in finding the shortest route at JNE.

CONCLUSIONS AND SUGGESTIONS

The conclusion of this study is that to get the shortest package delivery route after research and analysis by comparing the Bellman-Ford algorithm and the Greedy algorithm, the Bellman-Ford method was chosen because the Bellman-Ford method provides a more optimal route in terms of distance. The initial total distance used by PT Tiki Jalur Nugraha Ekakurir (JNE) was 20.5 km through routes including A→C→D→E→G→H→J→K→L→N→O→P→R. While the total distance from the results of the new route sequence using the Bellman-Ford algorithm is 17.3 km by going through routes including A→B→D→E→F→H→I→K→L→M→O→Q→R. And the total distance of the new sequence results using the Greedy algorithm is 17.5 km by going through routes including A→B→D→E→F→H→J→K→L→N→O→Q→R. This shows an efficiency of 15% in comparing existing routes with routes resulting from data analysis using Bellman-Ford.

Suggestions for future researchers are to expand the sampling area for the problems studied. So that in the future it is hoped that the research results will be maximized. And for future researchers, this research can be assisted with software such as Python. and also suggestions for PT. Tiki Jalan Nugraha Ekakurir (JNE) Medan City District is expected to consider implementing the Bellman-Ford algorithm in optimizing package delivery routes.

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