The utilization of graph applications in the making of Angkot B2 lines (Minggu of market – Black River) Bengkulu city

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Abstract. This study discusses how the application of graph theory is used to assist in the construction of the B2 angkot route in Bengkulu City so that it is more regular and can reduce congestion. With a neat and orderly route, it can help make it easier for people to determine which angkot they will use to get to their chosen destination. This research will use the literary method (the problem of the Chinese postman). The results showed that the trajectory made by the literary method (the problem of the Chinese postman) can solve traffic jams.

1. Introduction
Angkot is one type of public transportation that is widely used today, especially by those who do not have a private vehicle, the time it takes for an angkot to arrive at its destination is not much different from the time it takes to arrive at their destination using a private vehicle, except for the angkot that we take first, it will take longer.

One of the angkots that the writer studies is angkot B2 majoring in Pasar Minggu - the black river terminal. The writer noticed that the angkot with the direction of B2 often tapped, causing congestion. To overcome this, graph theory was used. In the euler concept, we can use it to assist in making the route of the B2 public transportation route to the Pasar Minggu-Hitam Hitam so that it is more regular and can reduce congestion.

Unlike the angkots from other routes that pass the same route, other angkots rarely do ngetem. The author sees that the number of public transportation in Pasar Minggu - the Sungai Hitam terminal is said to be very large when compared to other public transportation that passes this route, so the competition for these angkot drivers is quite tight to get passengers.

From the problems that occur above, this study discusses the use of graph applications in the making of the B2 Angkot in Bengkulu City so that it is more regular and can reduce congestion.

2. Methods
The method used in making this paper is the Chinese postman problem method [4]. This method is arguably quite well-known in the discussion of graph theory. [5] The problem faced is how the Chinese postman can deliver mail to an address along the road in an area without passing the same route twice and returning to the place of departure.

For tracks and circuits, the authors use eulerian trajectories and circuits. This is because the problem of the Chinese postman is to determine the euler circuit in the graph. [5] If the map of the
street worker where the postman delivers the letter is an eular graph, then the circular circle is easy to find. But if the graph is not euler, then some edges in the graph must be passed more than once or by using more than one postman.

3. Basic Theory

3.1 Graph

Graph is an old subject but has applications in everyday life. [6] Graph is used to represent discrete objects and the relationship between them.

3.2 Graph definitions

Graph can be defined as a non-empty set between pairs of vertices and edges connecting a pair of vertices [6]. The set of vertices cannot be empty, while the set of sides can be empty [3]. So a point can also be called a graph. A graph that consists of only one vertex without any edges is called a trivial graph.

3.3 Graph Types

Based on the presence or absence of rings or double edges on a graph, a graph can be classified into two types [6]:

a. Simple Graph

A simple graph is a graph that does not contain rings or doubles. An example of a simple graph represented by a computer network. In a simple graph the sides are unsorted pairs. So side \((u, v)\) is the same as \((v, u)\).

b. Non-Simple Graph

A non-simple graph is a graph that contains double sides or rings. Simple graphs are divided into two types, namely double graphs and pseudo graphs. A double graph is a graph that contains double edges. Meanwhile, pseudo graph is a graph containing rings. The edges of a pseudo graph can be connected to itself.

Based on the directional orientation on the side, a graph can be divided into two types:

a. Undirected Graph

Undirected graph is a graph whose sides have no directional orientation. The order of the pair of vertices on a directed graph is not considered, so the edges \((u, v)\) are equal to \((v, u)\). An example of an undirected graph in everyday life is a network on a two-way channel.

b. Directed graph

Directed graph is a graph where each side is given a directional orientation. This directed side is usually called an arc. In a directed graph, the edges \((u, v)\) are not the same as \((v, u)\). For arcs \((u, v)\), vertex \(u\) is the terminal vertex. In everyday life, a directed graph is often used to describe the flow of a process.

4. Concepts Discussed

In this article, the researcher will use several methods commonly used in graph problems, namely the Euler path and circuit and the Chinese postman problem.

4.1 Euler’s track and circuit

Eulerian path is a path that passes through each side in the graph exactly once (Figure 1) [1]. When the path returns to the original vertex, forming a closed path (circuit), the closed path is called the Eulerian circuit (Figure 2).

Thus, the Eleur circuit is a circuit that passes through each side exactly once [1]. If a graph has an Eulerian circuit, it is called an Eulerian graph. Meanwhile, a graph that has an Eulerian path is called a semi-Euler graph.
Figure 1. Euler’s trajectory path that passes through each side in the graph exactly once

Figure 2. Example of the Euler Circuit

When the path returns to the original vertex, forming a closed path (circuit), the closed path is called the Eulerian circuit. There are some sufficient and necessary conditions to determine whether a graph is an Eulerian path or circuit \(^6\).

1. If and only if every vertex in the graph is even degree then it is an Eulerian graph (having Eulerian circuit).
2. If and only if there are exactly two vertices with odd degree in the graph then it is a semi-Eulerian graph (having Eulerian trajectory).
3. If and only if the graph \(G\) is connected and each vertex has the same degree of entry and degree of exit then it is a directed connected graph which has Eulerian circuit.
4. If and only if the graph \(G\) is connected and each vertex has the same degree of entry and degree of exit except for two vertices, the first one has the degree of exit one greater the degree of entry, and the second has the degree of entry one greater than the degree of exit then the connected graph directed which has Euler’s trajectory.

4.2 The Chinese Postman Problem

The problem of the Chinese postman was first raised by Mei Ko Kwan, a Chinese mathematician, in 1962 \(^2\). This problem is a problem faced by many postmen, namely about how a postman will deliver the letters he brings to the address along the road in an area. He must plan his travel route so that he only plans his route so that he only passes each road section exactly once and returns to the place of departure.

In solving the problem behind this post, graph theory is very useful. In a graph there is a vertex and there is a side. In the case of post trade, each existing road segment is represented by a side, while each intersection is represented by a node. In addition, solving the problem of the Chinese postman will inevitably also use the Euler method, namely in determining whether the road the postman has to pass is the Euler route, the Euler Circuit, or neither.

5. Discussion of Problems

The construction of city transportation routes is not much different from the problem of the Chinese postman. The problem with the Chinese postman is how to deliver the letters brought to addresses along the road, while the problem with public transport routes is how the driver of the public transportation can deliver the passengers faster, whose addresses are scattered along the road.

Another problem, the postman has to plan a route so that he only passes every road section exactly, as well as the member driver. He also had to pass every road section precisely so as not to waste gasoline and so that passengers could arrive at their destination more quickly. But there is a slight difference between the problem of urban transportation routes and the problem with the Chinese postman. In the case of the Chinese postman, the postman has to return to his original place when he has finished delivering all his letters so that it will form an Euler circuit.
Meanwhile, in the construction of a city transportation route, the angkot driver does not return to his place of origin, but instead heads to another terminal or stop so that it will form an Euler line. Actually, there are no definite rules regarding this matter so that a city transportation route can be made like a postman route, namely a route that turns around and returns to its place of origin (a circuit).

This chapter will discuss four problems that are most likely to be encountered in the construction of urban transportation routes, namely if the road is an eulerian route, an eulerian circuit, or an eulerian route and route.

5.1 The road is the Euler trajectory
The first problem that will be discussed is if the road to be passed by city transportation is in the form of an euler line. Roads in the form of euler trajectories are easy roads for city transportation routes to be made. This road is used by public transportation, namely from one terminal to another. An example of a road in the form of an euler trajectory can be seen in Figure 3.

![Figure 3. Example of a road in the form of the Euler trajectory. This road is used by public transportation, namely from one terminal to another](image)

In the example of the road above, it is like a crossroads that has an even number of branches, except for two intersections that have an odd number of branches. This is in accordance with sufficient conditions and it is necessary that a graph be called a semi-Eulerian graph, that is, if and only if every vertex in the graph is even degree, except for two vertices having odd degree. This is because the starting node is not the same as the ending node. The line making on the Euler line is the same as the city transportation route in general, where the driver starts to depart from one terminal to another, as shown in Figure 4.

![Figure 4. Example of an angkot route that can be made](image)
The line making on the Euler line is the same as the city transportation route in general, where the driver starts to depart from one terminal to another. The road with the Euler border only requires one type of city transportation to pass each existing road. Meanwhile, the required amount of city transportation depends on the route that is passed. If the route is long, it will require a large number of city transportation. This is done so that passengers do not wait too long for city transportation. If the route that is passed is not too long, it does not require too much city transportation. If the road route is not too long, many city agkutan are operated, then the city transport drivers will experience difficult competition for passengers, so that all means will be legalized, especially ngetem.

5.2 The path is the Euler circuit
The next problem is if the road to be passed by city transportation is the Euler circuit. The road in the form of the Euler circuit is also easy for city transportation routes to be made because the route making is almost the same as the road in the form of the Euler line. The difference lies in the final destination of the city transportation. If on a road in the form of an Euler line the final destination is another terminal, then on a road in the form of the Euler circuit the final destination is the terminal where he departs. An example of a road in the form of an Euler circuit can be seen in Figure 5.

![Figure 5](image)

**Figure 5.** An example of a road in the form of an Euler circuit. Euler line the final destination is another terminal, then on a road in the form of the Euler circuit the final destination is the terminal where he departs.

In the example of the road above, each intersection has the same number of branches, which has four branches. This is in accordance with sufficient conditions and it is necessary that a graph be called a eular graph, that is, if and only if every vertex in the graph is even degree. Making a path on the Eulerian circuit is almost the same as making a line on the Eulerian border, but the final destination is the terminal where the city transportation departs, as shown in Figure 6.

![Figure 6](image)

**Figure 6.** Example of an *angkot* line can be made.
Making a path on the Eulerian circuit is almost the same as making a line on the Eulerian border, but the final destination is the terminal where the city transportation departs. The road with the Euler circuit also only requires one type of city transportation to pass through each existing road segment. The amount of city transportation needed also depends on the route that is passed. If the route is long, it will require a large number of city transportation. The reason is the same as making routes on the Euler line, namely so that passengers do not wait too long for city transportation. If the route that is passed is not too long, it does not require too much city transportation. The reason is also the same as making a route on the Euler line.

5.3 The road is the Euler track and circuit
Next is if the road to be passed is a combination of Euler's track and circuit. Making the angkot net is not as easy as the two problems above. On a road like this, it must be seen first which route the Euler track or circuit can be made of. When one path has been made, then we just need to make another path that does not go through the first path. An example of a road in the form of Euler's track and circuit can be seen in Figure 7.

![Figure 7](image)

**Figure 7.** An example of a path in the form of Euler's track and circuit.

When one path has been made, then we just need to make another path that does not go through the first path. Sometimes it is impossible to make another route without going through the first. To solve this problem, inevitably we have to use more than one type of angkot on several roads. One of the angkot (angkot that is on the Euler circuit) will return to its place of origin / departure terminal and the other angkot (angkot that is on the Euler line) will go to another place / terminal. Making public transportation lines can be seen in Figure 8.

![Figure 8](image)

**Figure 8.** an example of an angkot line that can be made

One of the angkot (angkot that is on the Euler circuit) will return to its place of origin / departure terminal and the other angkot (angkot that is on the Euler line) will go to another place / terminal. In
the example above, it is not possible to use only one type of angkot to pass all roads, at least two types of angkot will be required. Angkot 1 in the figure passes through the line which is the Euler circuit, so the angkot from terminal one will return to one terminal one. Meanwhile, angkot 2 passes the line which is the Euler line, so that the angkot from terminal one will go to terminal two.

The existence of two types of angkot on one road can sometimes confuse passengers in deciding which angkot they will use. In order to minimize the problems that will occur, the two angkots are also on the road. The two roads were chosen because they are the shortest roads passed by the two angkots.

6. Relevant Researches
There are several studies that are relevant to this research as follows: Julaeha et al [6] supposed G is a Eulerian directed graph with an edge labeling. In this paper will discuss the literature studies an algorithm to construct Euler trail that starts at a node r with the lexicographic minimum label among all Euler trail that starts node r is.

The Chinese Postman Problem is how a postman will deliver mail to addresses along the road in an area and how he plans his route so that he passes each way exactly once and returns to the starting place of departure with the minimum distance / time / cost. The tracks and circuits used in this study are the Eulerian trajectory and circuit. In this study, the Greedy algorithm is compared with the Dynamic Program to solve the Chinese Postman problem by using the Kedaton Bandar Lampung area map as an example. The results showed that the Dynamic Program method produced better scores [7].

7. Conclusion
By making city transportation routes neat and orderly, the problem of transportation can be reduced. Angkot drivers will reduce their ngetem frequency because there are only one or two types of angkot that travel on the same road. The congestion that usually occurs will also decrease because the number of angkot drivers who usually ngetem will decrease. City transport users will also find it easier to determine which angkot they will take because there are only one or two types of angkot and also because their angkot routes are clear. The city transportation route will be easier to make if the road to be passed is the Euler circuit or the Euler line, but not both. If the road is in the form of the Euler circuit and the Euler line, it will be more difficult to determine the city transportation route because one route has to be made first and then another route. Another difficulty is in determining which road segments should be used together, the shortest road should be chosen so as not to be too detrimental to angkot drivers.

Furthermore, regarding the number of public transportation operated on one route. It is recommended that the number of angkot operated according to the length of the angkot route from the place of origin to the destination. If the angkot route is far, the number of angkot that is operated must be large enough so that the passengers who are going to take the angkot don't wait too long. On the other hand, if the angkot route is not too far away, the number of angkot operated does not need to be too much. This is also done for the convenience of angkot drivers. They will think twice about ngetem their chances of getting passengers will decrease.

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