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**Paper Published Online- IJMET- Volume 9, Issue 8, 2018**

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## INTERNATIONAL JOURNAL OF MECHANICAL ENGINEERING & TECHNOLOGY (IJMET)

Scopus Indexed Journal

www.iaeme.com/ijmet/index.asp

Paper ID: IJMET\_09\_08\_136

Date: 08-Sep-2018

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This is to certify that the research paper entitled “APPLICATION OF THE HAMILTON CIRCUIT ALGORITHM FOR OPTIMAL ROUTE SEARCH IN CITY TRANSPORT ROUTES” authored by “Asep Kosasih, Yuko Dwi Aprianto, Sukardi, Moh Sya'roni, Roby Setiadi” had been reviewed by the Editorial Board and published in “International Journal of Mechanical Engineering & Technology (IJMET), Volume 9, Issue 8, August 2018, pp. 1266–1272; ISSN Print: 0976-6340 and ISSN Online: 0976-6359; Journal Impact Factor (2016): 9.2286 Calculated by GISI (www.jifactor.com); InfoBase Index IBI Factor for the year 2015–16 is 3.46; Thomson Reuters' Researcher ID: B-7384-2016”.



Chief Editor



# APPLICATION OF THE HAMILTON CIRCUIT ALGORITHM FOR OPTIMAL ROUTE SEARCH IN CITY TRANSPORT ROUTES

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## ABSTRACT

*Large cities in Indonesia tend to have the same problems in the field of transportation, namely road congestion. In addition to the large number of private vehicles passing on city streets, large amounts of public transport are also one of the main factors of traffic congestion. It is also exacerbated by the absence of additional road capacity. So that not a few road traffic conditions in urban areas, especially in the city of Bandung, are almost close to saturated status, namely the condition in which the volume of vehicles that cross a road is proportional to the capacity of the road ( $V/C = 1$ ). Traffic engineering is one way that can be done to overcome the congestion problem. In this article, we propose an intelligent agent model based on the Hamilton Circuit Algorithm to carry out public transportation route engineering in the City of Bandung. The approach taken is to change the route of public transportation which has been one path between the departing route and the return route, to a circular path from the point of departure and return to that point. The results obtained, the simulation can reduce the road burden that should be passed by public transportation.*

**Key words:** Hamilton Circuit Algorithm, Transport, Optimal Route.

**Cite this Article:** Asep Kosasih, Yuko Dwi Aprianto, Sukardi, Moh Sya'roni, Roby Setiadi, Application of the Hamilton Circuit Algorithm for Optimal Route Search in City Transport Routes, *International Journal of Mechanical Engineering and Technology* 9(8), 2018, pp. 1266–1272.

<http://www.iaeme.com/IJMET/issues.asp?JType=IJMET&VType=9&IType=8>

## 1. INTRODUCTION

The growth of the number of vehicles in major cities in Indonesia every year continues to grow. According to data obtained from the Republic of Indonesia's Central Bureau of Statistics (BPS), the number of motorized vehicles in Bandung in 2015 was 401,791 four-

wheeled or more motorized vehicles and 1,041,421 motorized two-wheeled vehicles. In addition, generally large cities in Indonesia have urban public transport which is also large in number. In Bandung City, there are approximately 5,521 urban transports with a total of 39 routes or travel routes. So that on average per route there are about 142 urban transports.

Data released by the Department of Transportation in 2006, the criteria for traffic density on a road segment are determined by two factors, namely the volume (V) of vehicles on the road and the capacity (C) of the road that is traversed. If the V/C ratio is worth [0.6, 0.8], then the traffic density of vehicles on the road segment is categorized as normal. But if the ratio  $V/C = 1$ , it means that the traffic on the road is said to be saturated. In this condition, road traffic is congested. Overload conditions occur when the  $V/C$  ratio  $> 1$ . At present, road traffic in major cities in Indonesia, such as Jakarta and Bandung, is nearing saturated conditions ( $V/C = 1$ ). Larger problems will arise in the following years, where the growth in the number of vehicles is predicted to increase. Even so, future congestion efforts can still be pursued.

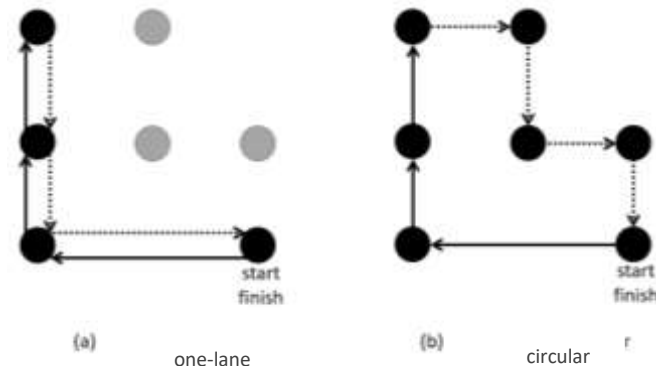
Traffic engineering is one way that can be applied to reduce highway density. In this study, the discussion focused on highway traffic in the city of Bandung with the object of research namely urban public transportation. Bandung is very well known for the large number of city transportation. This is certainly a contributing factor to congestion in the city.

From the aspect of information technology, traffic engineering simulations on the route of urban transport can be done using a computer to get effective city transport route engineering to reduce congestion. Of the many studies that have been carried out, most use graph concepts as a foundation in highway traffic modeling [1-10]. Riedel et.al [1] has long proposed a graph-based model for regulating traffic flow. In particular, graph theory is also used to model and optimize travel routes from public transport in a city, such as traffic modeling in cities in India [2] and analysis of bus routes in cities in Brazil [3]. Even graphs are also implemented to model flight traffic [4].

The use of graphs is very precise in modeling the connection between one point and another so that it forms a model of the highway traffic network. In this study, the Hamilton Circuit algorithm was proposed to model alternative routes for urban transport in the city of Bandung. With this approach, it is possible that the city of Bandung city transportation routes that have been one lane (departing and returning via the same route) can be optimized into a circular route so that the distribution of urban transport lanes can be more evenly distributed and not only focused on one lane. This of course can reduce the degree of saturation ( $V/C$ ) from the road that is commonly traversed by city transportation.

## 2. METHOD

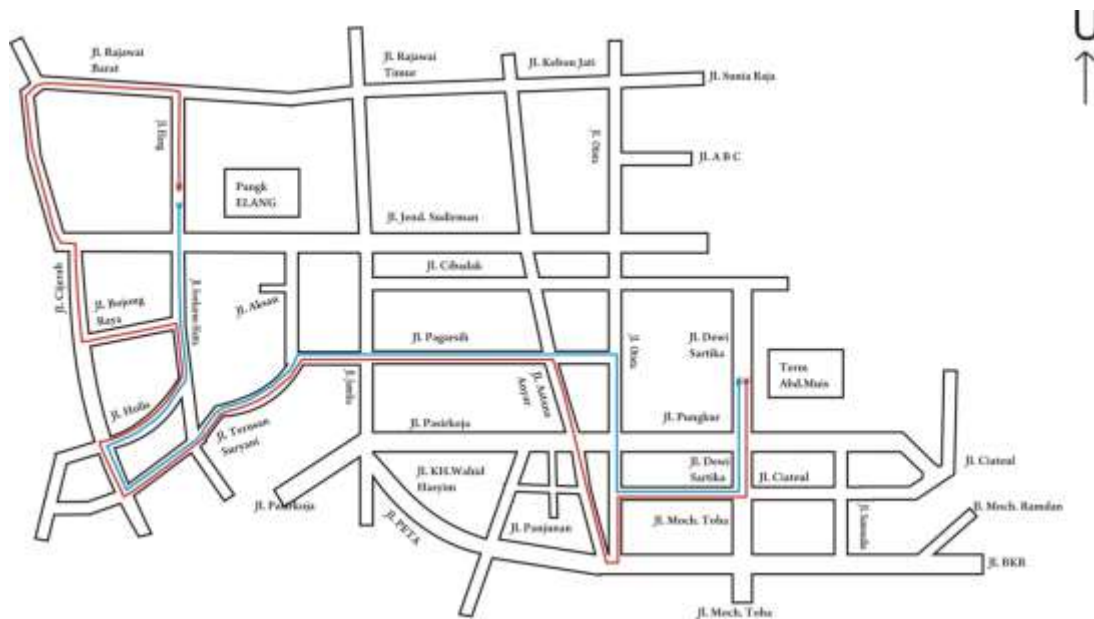
Optimization of the route of urban transportation routes in Bandung City proposed in this study applies a combination of intelligent agent models (intelligent agents) and Hamilton Circuit algorithms. The application of this method aims to find the optimal route of urban transport in the form of a circular path (Figure 1) which can improve the old route which is only one lane.



**Figure 1** Difference between a one-lane route (a) with a circular track route (b)

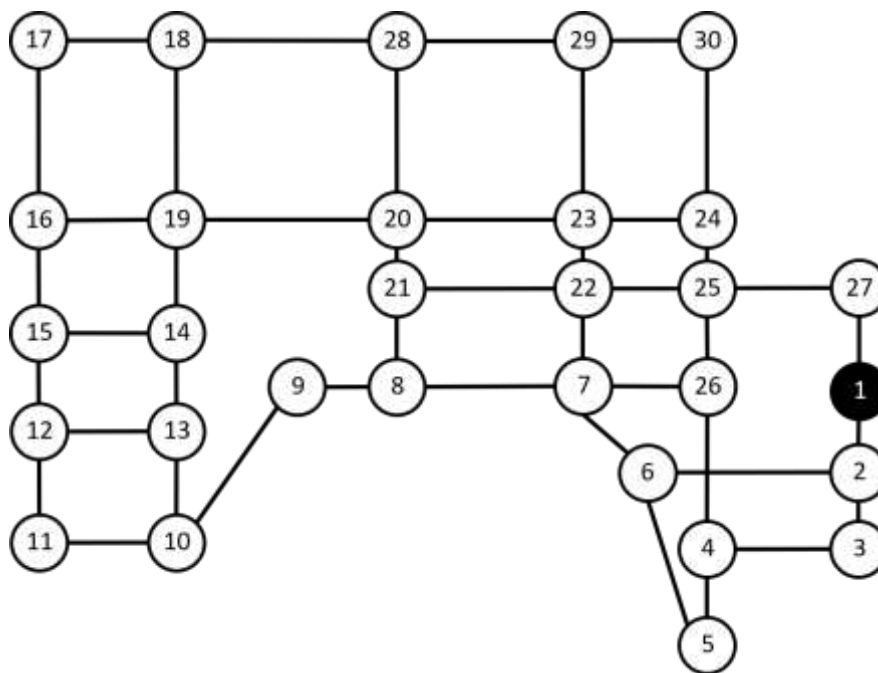
### 2.1. Data

This study uses data released by the Bandung City Transportation Agency, which includes data on street names, city transport route data, distance traveled, travel time, and degree of saturation (V/C). For simulation purposes, researchers used the urban transportation route 'Abdul Muis - Elang' with city transportation code 04. The route consists of 101 urban transports with a distance of about 9.75 km starting from the starting point at Abdul Muis Terminal to Pangkalan Elang, as seen in Figure 2. This means that the round-trip route for the route is 19.5 km. The return route from Pangkalan Elang goes to Abdul Muis Terminal via the same route as departure, except for a few different routes due to one-way routes.



**Figure 2** Route of the city transportation route "Abdul Muis - Elang" as far as 9.75km.

The departure route from Abdul Muis Terminal to Pangkalan Elang passes through 18 road sections, and the opposite route passes through 10 roads. There are several different roads when departing and returning because there is a one-way road.



**Figure 3** Graph model built based on road map in Bandung City. Node No.1 is Abdul Muis Terminal (departure), and node no.19 is Pangkalan Elang (destination).

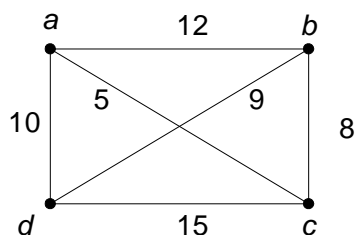
To be able to do the simulation, the road sections in Figure 2 must be converted into a graph by first converting each intersection into a node. After that, each node that is formed is connected by giving a line or vertex to another node connected to it. Figure 3 shows the results of the conversion. Furthermore, each vertex that connects two nodes is weighted according to the value of the saturation ratio (V/C). This weight is a parameter that will guide in making alternative pathways based on the Hamilton Circuit.

### 2.2. Hamilton Circuit

Hamilton Circuit is a path that passes through each node in the graph exactly once. if the path returns to the original node to form a closed path (circuit), then the closed path is called the Hamilton circuit. So, the Hamilton circuit is a circuit that passes each node in the graph exactly once, except the original node (as well as the end node) that is passed twice [11].

The Hamilton Circuit can provide a number of alternative choices of circuit trajectories that can be traversed City transport is based on a certain criterion, with the number of Hamilton circuits that can be calculated using equation (1), where n represents the number of nodes on the graph.

$$N = \frac{1}{2}(n - 1)! \tag{1}$$

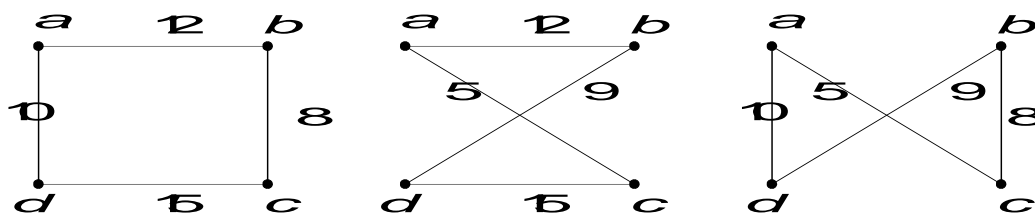


**Figure 4** Graph with 4 points (nodes) and 6 lines (vertices)

As an example, we know 4 nodes (a, b, c, d) with 6 vertices that are weighted: 12, 8, 15, 10, 5, 9. For example, the 4 points represent 4 city corners will be visited (target), while the six lines represent 6 pieces of road that will be passed. If the calculation is done using equation (1), there will be three alternative paths (obtained from  $\frac{1}{2} * (4-1)! = 3$ ) that meet the criteria as the Hamilton Circuit, as can be seen in Table 1. The three alternative pathways it can also be visualized as in Figure 5.

**Table 1** Three alternative pathways that meet the criteria as a Hamilton circuit.

No.	Hamilton Circuit Line	Total Weight
1	(a, b, c, d, a) atau (a, d, c, b, a)	45
2	(a, c, d, b, a) atau (a, b, d, c, a)	41
3	(a, c, b, d, a) atau (a, d, b, c, a)	32



**Figure 5** Three alternative routes that meet the criteria as a Hamilton Circuit.

### 2.3. Backtracking Technique

Backtracking technique is one of the general problem solving techniques. The basis of this technique is a search technique. This search technique is used as an effort to get the possible set of solutions. From this set of possible solutions an optimal or satisfying solution will be obtained. Backtracking techniques have been widely used including: The 8 - Queens Problem, Sum of Subsets, Graph Coloring, Hamilton Cycles, Knapsack Problems, Traveling Salesman Problems. Table 2 displays the general Backtracking algorithm.

**Table 2.** Backtracking algorithm

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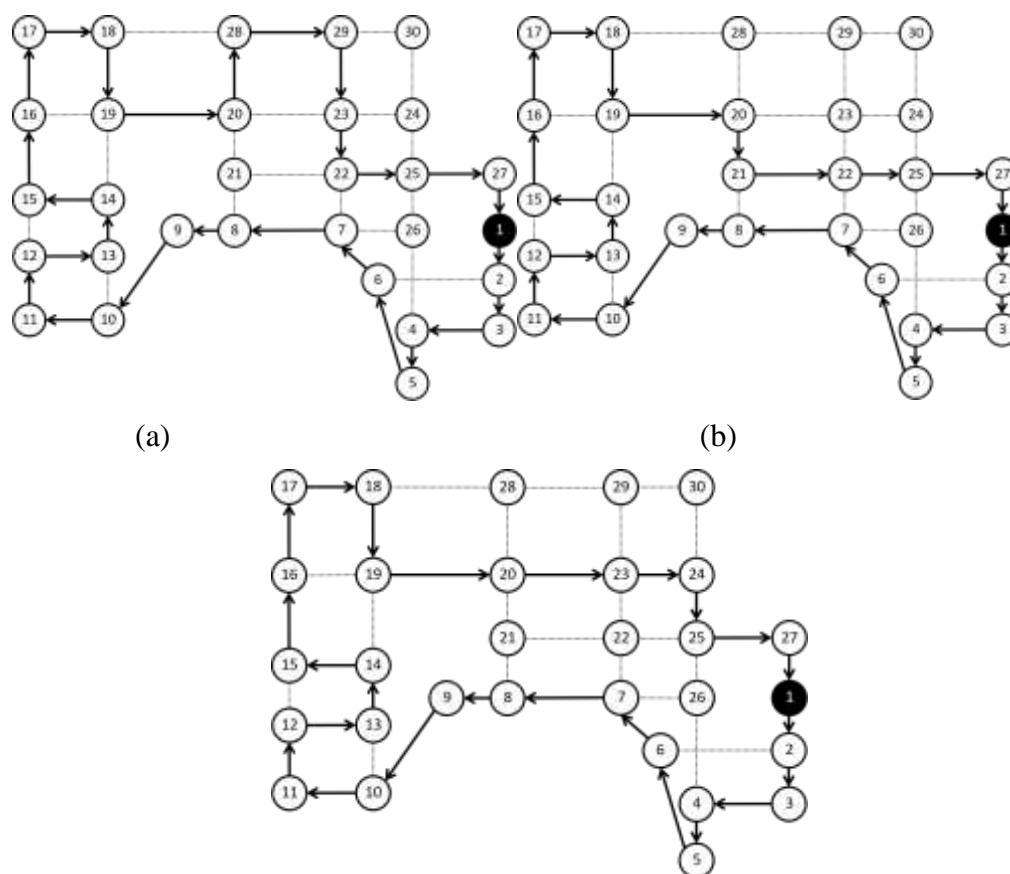
1  procedure backtrack(n)
2  integer k,n; local x(1:n)
3  k = 1
4  while k > 0 do
5      if ada x(k) that has not been tried so that
6          x(k) = t(x(1), ... , x(k-1)) and bk(x(1), ... , x(k)) = true
7          then
8              if (x(1), ... , x(k)) is a path
9              that is a solution
10             then
11                 print (x(1), ... , x(k))
12             endif
13
14             k = k + 1
15         else k = k - 1
16         endif
17 end backtrack
    
```

In this study, the Backtracking technique is useful for finding the optimal Hamilton circuit from the many alternatives available. Searching with this technique is iterative, so it takes some time to produce and display the optimal Hamilton path. The optimal path is defined as a path with the smallest total weight of the V/C ratio.

### 3. RESULTS AND DISCUSSION

Based on the graph model presented in Figure 3, there are approximately  $4 \times 10^{10}$  alternative routes that have Hamilton Circuit criteria. However, in this study, route search was only carried out on the route of return of city transportation to the starting point of departure. That is, the route of departure of city transportation from 1st point (Terminal Abdul Muis) to the 19th point (Pangkalan Elang) still uses the existing route, so the route search is only carried out on the way home from the 19th point to the 1st point. Thus, the total alternative paths are far less than previously mentioned.

From the simulation results using the Hamilton Circuit algorithm and Bactracking technique, three optimal path alternatives were obtained. The three alternative paths can be seen in Figure 6.



**Figure 6** Three alternative optimal routes that meet the criteria of the Hamilton Circuit on the 04 city transportation route (‘Abdul Muis - Elang’) in the city of Bandung.

From Figure 6, it can be seen that the route of urban transport is circular, and it is no longer a path as before. In addition, this route allows for equal distribution of road density, so that the degree of saturation on the road that is commonly traversed by city transportation can decrease.



## 4. CONCLUSIONS

Based on the results of the design and also the experiments that have been carried out, the Hamilton Circuit model combined with the Backtracking technique can be applied to traffic engineering simulations, one of which is the optimal alternative route search for urban public transport. The existence of an alternative route that is circular in nature makes it possible to reduce the degree of saturation on certain road sections, so that the level of road density can be reduced. The results obtained from this study are three alternative pathways on the route of urban transportation 'Abdul Muis - Elang' in the city of Bandung, where each of these results meets the criteria as a Hamilton Circuit.

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