Emergency Service Search using Ant Colony Optimization Algorithm and AHP-TOPSIS Method

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Abstract. Ant Colony Optimization (ACO) algorithm has a good ability in route search, ACO's ability to leave traces on routes that have been traced and find the nearest route to reach the destination location, but now the nearest distance search is not only about distance problems but many things must be considered, like travel time and others, especially in emergency conditions require the fastest route to provide help when an accident, disaster, etc. AHP-TOPSIS method is used to support the ACO in finding the best route based on the criteria. The purpose of this research is to implement the ACO algorithm supported with AHP-TOPSIS to find the quickest path on the search for emergency services. ACO supported with Google Maps will provide a route from the emergency service location to the user location, that the value will be put to TOPSIS as a value to increase the decision based on the ranking. AHP is used as the basis of the priority values of each attribute such as time, distance, health facilities, and the nearest ambulance. This value will be inserted into TOPSIS as a priority value. TOPSIS provides emergency services by condition and provides the fastest emergency service route recommendations.

1. Introduction

Ant Colony Optimization (ACO) Algorithm has a strong endurance in route searching by leaving traces on traced routes, good adaptability, easy to combine with another algorithm [1]. ACO Algorithm has successfully implemented to solve various optimization problems, for example, vehicle route problem (VRP) so that the dynamic optimization problem is challenging because the purpose of an algorithm is not only to discover the optimum of the problem immediately but also to efficiently trace the optimum moves when changes occur [2]. ACO can provide a solution in managing train traffic in real-time and offer alternative tracks to lessen even resolve the traffic so that vehicles can come without delay [3].

AHP-TOPSIS has been used widely, and it is effective for various purposes in location selection, measuring service quality, etc. The two-stage, multi-criteria decision-making approach that combined the Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), this method is very effective to measure and determine the rank of service quality of bus transit route compared with other methodology [4].
The problem of finding the best route can be resolved by the ACO Algorithm, however, in current condition the best finding is not only finding the shortest track but finding the best route also have to pay attention to traffic, distance, traveling time, etc. so that it needs approach from the AHP-TOPSIS method in resolving the problem of multi-criteria decision [5].

ACO Algorithm and AHP-TOPSIS method to look for the nearest emergency services by providing the best route become the basis of the problems studied. The approach of the ACO Algorithm supported by Google maps will provide the location of emergency service based on distance and time after which the value will be entered into TOPSIS as a value to improve decision based on ranking. The two-stage, multi-criteria decision-making, that combined AHP and TOPSIS to give rank based on the condition. AHP method to determine the priority of every attribute such as traffic, distance, health facility, and nearest ambulance, this value will be entered into TOPSIS as a weighted value in TOPSIS then the next process is adopting TOPSIS to give information of the nearest emergency service.

2. Methods

2.1. Analytical Hierarchy Process (AHP)

In this study, AHP method is used to do weighted value on every criteria of emergency service selection so as to get the basis of priority scores on each criterion. This value will be used in TOPSIS to determine the recommendation of emergency service [4]. Firstly, sum up the value in every column of the matrix pairs with the following formula:

\[ c_{ij} = \sum_{i=1}^{n} c_{ij} \]  

(1)

Secondly, divide every element in the matrix with the column in which the total yields a normalized matrix with the following formula:

\[ x_{ij} = \frac{c_{ij}}{\sum_{i=1}^{n} c_{ij}} \begin{bmatrix} x_{11} & x_{12} & x_{13} \\ x_{21} & x_{22} & x_{23} \\ x_{31} & x_{32} & x_{33} \end{bmatrix} \]  

(2)

Third, divide the number of normalized matrix column with the number of criteria used to yield weighted matrix \((n)\) with the following formula:

\[ W_{ij} = \frac{\sum_{j=1}^{n} x_{ij} W_{ij}}{n} \begin{bmatrix} W_{11} \\ W_{12} \\ W_{13} \end{bmatrix} \]  

(3)

Fourth, multiply the pairing comparison matrixes with criterion weight to obtain weight vector value with formula as follows:

\[ Vek_i = a_{i,j} \cdot W_i \]  

(4)

Fifth, calculate the \(\lambda_{max}\) by dividing each element in the Total Weight Vector with each element in the Priority Weight with the formula:

\[ \lambda_{max} = \frac{1}{n} \sum_{i=1}^{n} \frac{Vek_i}{W_1} \]  

(5)
Sixth, the determination of preference value between elements must be consistently logic that can be measured by calculating CI (Consistency Index) and CR (Consistency Ratio). Actually, the study uses Eigen value as the basis for priority value, however in AHP we have to look at the obtained value of CR to see whether the criteria granted are correct or not. If CR value ≤ 0.1, the calculation deemed correct with the formula:

\[
CI = \frac{\lambda - n}{n - 1}
\]

\[
CR = \frac{CI}{RI}
\]

2.2. Ant Colony Optimization (ACO)
Ant Colony Algorithm is used after the value of AHP and Haversine Algorithm is done. Haversine Algorithm is used to choose 6 nearest emergency service, after getting the 6 nearest emergency service locations, researchers use ACO Algorithm to determine the route, distance, and time. Firstly, looking for the nearest distance location using Haversine (\(d_r\)), with the formula:

\[
h'_{aversion}(d_r) = h'_{aversion}(\phi_2 + \phi_1) + \cos(\phi_1).\cos(\phi_2).Haversine(\lambda_2 + \lambda_1)
\]

Second, calculate the visibility (\(\eta\)), which is the inverse from the starting point of the vehicle (r) and the point of intended location (s). The calculation of distance and visibility with the formula:

\[
\eta_{(r,s)} = \frac{1}{d_{(r,s)}}
\]

Third, calculate the probability (\(P_{rs}^k\)) from ant (k) on the starting point (r) to choose the route to the intended location point (s) using the formula:

\[
P_{rs}^k = \left(\frac{\tau_{(r,s)}}{\sum_{\forall r,s} \tau_{(r,s)}}\right)^\beta
\]

Fourth, after the route is established, every ant will modify the pheromone that exists at every point it passes that called local pheromone update (\(\tau_{(r,s)}\)) by using the formula:

\[
\tau_{(r,s)} = (1 - \rho)\cdot \tau_{(r,s)} + \rho \cdot \Delta \tau_{(r,s)}
\]

\[
\Delta \tau_{(r,s)} = \frac{1}{L_{(r,s)}}
\]

Fifth, when all the vehicles end their journey, a pheromone located in the intended point will be modified again into a global pheromone, with the formula:

\[
\tau_{(r,s)} = (1 - \alpha)\cdot \tau_{(r,s)} + \alpha \cdot \Delta \tau_{(r,s)}
\]

\[
\Delta \tau_{(r,s)} = \frac{1}{L_{(r,s)}}
\]

2.3. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)
The TOPSIS method has become the ranking method in this system. The value that taken from the AHP will be used as the basis of the priority criteria value in TOPSIS, while the value from ACO is in the form of collected values such as distance and time, so ACO values will be entered in the criteria in TOPSIS and
ACO weighted value based on the obtained AHP value [4]. First, determine the normalized decision matrix with the formula:

\[
    r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}
\]  

Second, calculate the weighted normalized decision matrix with the formula:

\[
    y_{ij} = W_{ij} \cdot r_{ij}
\]

Third, calculate the positive ideal solution matrix and the negative ideal solution matrix with the formula:

\[
    A^+ = (y^+_1, y^+_2, ..., y^+_n) \\
    A^- = (y^-_1, y^-_2, ..., y^-_n)
\]

Fourth, calculate the distance between the value of every alternative and the positive ideal solution matrix and the negative ideal solution matrix with the formula:

\[
    D^+_i = \sqrt{\sum_{j=1}^{n} (y^+_i - y_{ij})^2} \\
    D^-_i = \sqrt{\sum_{j=1}^{n} (y^-_i - y_{ij})^2}
\]

Fifth, calculate the preference value for every alternative with the formula:

\[
    V_i = \frac{D^-_i}{D^-_i + D^+_i}
\]

3. Implementation
The first step in this study is by determining the priority value based on the expert (doctors). The assessment from the doctors will be calculated in the AHP method. There are 5 criteria in this study based on the doctors in finding the nearest emergency service and can be seen in Table 1.

| Code | Criteria                 | Weight Value          |
|------|--------------------------|-----------------------|
| C1   | Distance                 | Very Near, Near, Far  |
| C2   | Time                     | Very Near, Near, Far  |
| C3   | Doctor Availability      | Lots, Enough, Less    |
| C4   | Room Capacity            | Lots, Enough, Less    |
| C5   | Nurse Availability       | Lots, Enough, Less    |

The result of the above criteria will be used to create an equation comparison matrix that can yield Eigen value \(W_{ij}\) that useful to be used in the TOPSIS method as the basis of priority value in giving the rank of emergency service. The result can be seen in Table 2.
Table 2. Equation Comparison Matrix

| Code | C1  | C2  | C3  | C4  | C5  |
|------|-----|-----|-----|-----|-----|
| C1   | 0,00| 0,33| 6,00| 6,00| 7,00|
| C2   | 3,00| 0,00| 6,00| 6,00| 7,00|
| C3   | 0,17| 0,17| 0,00| 5,00| 6,00|
| C4   | 0,17| 0,17| 0,20| 0,00| 6,00|
| C5   | 0,14| 0,14| 0,17| 0,17| 0,00|

The next step is to determine every intersection point in the City of S. This study uses 144 points of intersection in City of S. The obtained intersection points are calculated using Haversine to determine 6 locations with the nearest distance and then determine the route selection based on the time and distance with ACO method. In this study, the parameter in the ACO method can be seen in Table 3.

Table 3. Parameter of ACO

| Parameter | Value |
|-----------|-------|
| Q         | 1     |
| 𝜏(𝑟,𝑢)   | 0,01  |
| α         | 0,1   |
| β         | 1     |
| ρ         | 0,1   |
| m         | 3     |
| NCmax     | 1     |

The third step is to determine the rank for every emergency service based on the priority value from AHP, the value of ACO, and the data on emergency service. The value of those three will be calculated using the TOPSIS method to obtain the recommendation of the best intended emergency service. The TOPSIS value can be seen in Table 4.

Table 4. TOPSIS Criteria Value

| Code | Very Near | Near | Far | Lots | Enough | Less |
|------|-----------|------|-----|------|--------|------|
| C1   | 5         | 3    | 1   | -    | -      | -    |
| C2   | 5         | 3    | 1   | -    | -      | -    |
| C3   | -         | -    | -   | 5    | 3      | 1    |
| C4   | -         | -    | -   | 5    | 3      | 1    |
| C5   | -         | -    | -   | 5    | 3      | 1    |

4. Result and Discussion

4.1. Result
The value in Table 2 will be inserted as a basis value in AHP method to determine the priority value. The calculation result from the value in Table 2 using AHP method can be seen in Table 5. The AHP calculation value can be used since the CR value gives a result of 0.1.
Table 5. Calculation Result of AHP Method

| Criteria | \(x_{ij}\) | \(W_{ij}\) | \(V_{ek_j}\) | \(\lambda_{max}\) | CI | CR |
|----------|----------|----------|-----------|-------------|----|----|
| C1       | 1,52     | 0,30     | 2,00      |             |    |    |
| C2       | 1,97     | 0,39     | 2,78      |             |    |    |
| C3       | 0,78     | 0,16     | 0,91      | 5,36        | 0,09| 0,1|
| C4       | 0,50     | 0,10     | 0,44      |             |    |    |
| C5       | 0,24     | 0,05     | 0,14      |             |    |    |

The result of Haversine calculation from the data obtained can be seen in Table 6. This value will be used as the value to determine the location of emergency service that will be calculated in the ACO method.

Table 6. Calculation Result of Haversine

| Location | Latitude | Longitude | Haversine (km) |
|----------|----------|-----------|----------------|
| Location of User (LU) | -0,47448 | 117,16313 | 2,16           |
| RS 4     | -0,47896 | 117,144253| 2,34           |
| RS 1     | -0,49583 | 117,14719 | 2,34           |
| RS 7     | -0,474025| 117,142115| 2,34           |
| RS 10    | -0,492783| 117,150655| 2,34           |
| RS 5     | -0,4948  | 117,148818| 2,34           |
| RS 2     | -0,50103 | 117,14214 | 2,34           |
| RS 6     | -0,49841 | 117,1368  | 2,34           |
| RS 8     | -0,472784| 117,124610| 2,34           |
| RS 9     | -0,507047| 117,109218| 2,34           |
| RS 3     | -0,558654| 117,110398| 2,34           |

The calculation result in Table 6 will be selected by the nearest 6, and the ACO will be calculated. This value will be used as the value to rank in TOPSIS. The ACO value gives the value of distance and time from every route. The result of the ACO value can be seen in Table 7.

Table 7. Calculation Result of ACO

| Route | Distance (km) | Time (Minutes) |
|-------|---------------|----------------|
| RS 4  | 3,026         | 7              |
| RS 1  | 3,575         | 7              |
| RS 7  | 2,729         | 7              |
| RS 10 | 3,018         | 8              |
| RS 5  | 3,878         | 8              |
| RS 2  | 4,702         | 9              |

In the table above, there are distance and time value that has been obtained using ACO calculation, after that the value obtained from ACO calculation and data from local health service will be entered in TOPSIS calculation to give a recommendation of nearest emergency service. The value of the TOPSIS calculation can be seen in Table 8 and Table 9.
Table 8. TOPSIS Weighted Normalization Calculation Result
(Normalization Matrix of ACO Value, Health Service Data and Eigen AHP Eigen Value)

|     | C1     | C2     | C3     | C4     | C5     |
|-----|--------|--------|--------|--------|--------|
| RS 4| 0,181  | 0,235  | 0,028  | 0,036  | 0,014  |
| RS 1| 0,036  | 0,047  | 0,085  | 0,036  | 0,014  |
| RS 7| 0,109  | 0,141  | 0,085  | 0,036  | 0,024  |
| RS 10| 0,036 | 0,047  | 0,085  | 0,060  | 0,014  |
| RS 5| 0,109  | 0,141  | 0,028  | 0,036  | 0,024  |
| RS 2| 0,181  | 0,235  | 0,028  | 0,036  | 0,024  |

Table 9. Calculation Result of TOPSIS

| Stage 1 | Stage 2 | Stage 3 |
|---------|---------|---------|
| $A^+$   | $A^-$   | $D_i^+$ | $D_i^-$ | $V_i$  |
| C1      | 0,181   | 0,036   | RS 4    | 0,062  | 0,237  | 0,521  |
| C2      | 0,235   | 0,047   | RS 1    | 0,239  | 0,057  | 0,470  |
| C3      | 0,085   | 0,028   | RS 7    | 0,121  | 0,132  | 0,794  |
| C4      | 0,060   | 0,036   | RS 10   | 0,238  | 0,062  | 0,794  |
| C5      | 0,024   | 0,014   | RS 5    | 0,134  | 0,119  | 0,206  |
| RS 2    | 0,062   | 0,238   |         |         |        | 0,192  |

The calculation result from Table 9 shows the recommendation of the nearest emergency service with a health facility, namely the RS 7 and RS 10, with the highest value of 0.794. RS 7 has a mileage of 2.729 km and 7 minutes of traveling time, and RS 10 has a mileage of 3.018 km and 7 minutes of traveling time. In this study, the researcher compared Google maps where the distance of RS 7 is 2.792 km with 8 minutes of traveling time, and the distance of RS 10 is 3.030 km with 9 minutes of traveling time. This result proves that the implementation of ACO and AHP-TOPSIS methods can provide the recommendation of the nearest emergency service.

5. Conclusion

Based on this study, the methods of ACO and AHP-TOPSIS can be used to find the nearest route and emergency service from the user location in the City of S. The feature of road info and algorithm parameter built by applying Ant Colony Optimization algorithm can produce the shortest route so it can create efficiency of time and distance in looking for emergency service.

References

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