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A Car Flow Network Model For Lane-Based Evacuation Routing Problem

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Abstract. The problem of evacuation is very important when a disaster occurs. Evacuation must have systematic planning and good calculation. The planning is related to determining the route and flow of the vehicle. The shortest route problem is a matter of how to travel from one point of source through the paths to the destination with the shortest distance. The shortest path is the minimum trajectory needed to reach a certain point. In addition to the trajectory that has passed the shortest route, it needs to be taken into account about the maximum flow of a network. The maximum flow problem aims to maximize the movement of a number of items or objects through certain paths from the point of source to the end point. In this paper, in the future a model of vehicle movement will be developed to evacuate victims with maximum flow and through the shortest evacuation route by taking into account the paths to be followed in order to implement an effective evacuation process.

1. Introduction
Disasters can occur anytime and anywhere. It can be caused many factors, like human or nature that result in casualties, damage to buildings and affect human psychological conditions. A variety of recent disasters have occurred in Indonesia such as the eruption of Mount in North Sumatra, the earthquake in Lombok and most recently an earthquake accompanied by a tsunami in Palu and Donggala. As a result of these disasters, thousands of people died, tens of thousands of homes and public facilities were destroyed and many people were displaced. Evacuation is an activity to save and keep people from dangerous locations towards safer locations. In an effort to accelerate the evacuation process, a series of plans and strategies for rescuing victims were needed.

The flow network problem is a basic problem from areas of inquiry such as applied mathematics, computer science, operation research, management, and engineering [9]. A network is an arrangement of paths that connects points where in each line there is a shift of one or more objects from one point to another. In its development, it turned out to be a transportation model which is can be described and completed in a network form.

Network problems are part of the discussion about graphs. A graph is a set of sets (V, E), where V is a set of points and E is a set of sides. In planning the implementation of disaster evacuation, we must first arrange the evacuation route or route to be chosen. In the technique of selecting the route or evacuation route, it must first take into account several things, including:
1.1 Determination of the shortest route
In general, the shortest route problem is the problem of how the movement or trip is carried out through the shortest distance or at the cheapest cost. Or in other words, how to optimize distance or cost.

1.2 Calculate the maximum flow of vehicles from each available path.
In the selection of evacuation routes (paths), in addition to choosing the shortest distance must also consider the maximum vehicle flow that can pass on the path.

Evacuation planning must be emphasized because it is very instrumental in saving the victim's activities [7]. Evacuation is often hampered or delays the flow of vehicles when they encounter intersections. One strategy to overcome the delay is by lane-based routing [1]. Line reversal and crossing removal are two strategies that complement each other to increase capacity in certain directions in a network [5]. In this paper, a car flow network modeling is presented to optimize the flow-based evacuation routing.

2. Methodology

2.1. Literature review
In this step, author was looking for papers which related to the discussion about optimization evacuation routing problem. They are sourced from journals or books.

2.2. Determine shortest path
There are a lot of discussions related to shortest path. As in the transportation problems, routing problems, also economic problems. One of problems in network problem is shortest path problems. Even in the other discussion, it was the simplest network flow problem. Generally, the simplest problem related to shortest problem was to find the path between two nodes with the smallest length.

Shortest route problem can be formulated into linear programming formulation, Generically the LP formulation looks like this:

Minimize $Z = \sum_{i=0}^{N} \sum_{j=0}^{N} c_{ij} x_{ij}$
Subject to $\sum_{i=0}^{N} x_{ik} = \sum_{i=0}^{N} x_{kj}$
$\sum_{j=0}^{N} x_{0j} = 1$
$\sum_{i=0}^{N} x_{iN} = 1$
All $x_{ij} \geq 0$
$x_{ij} = \begin{cases} 1, & \text{if the arc } ij^{th} \text{ lies on shortest path} \\ 0, & \text{otherwise} \end{cases}$

2.3. Analyze the network flows
In routing evacuation problem, network flow is complementary model for the shortest path problem. As we have known that in selection of route, distance and vehicle flow two things that cannot to be separated. Maximum flow problems can be formulated like below.

Maximize $P = \sum_{j=1}^{N-1} x_{0j} = \sum_{i=1}^{N} x_{iN}$
Subject to $\sum_{i=0}^{N} x_{ik} = \sum_{j=0}^{N} x_{kj}$
$x_{ik} \leq x_{kj}, \text{ for all arcs}$
All $x_{ij} \geq 0$
Where $x_{ij}$ is the amount travelling on the $ij^{th}$ arc
3. Result and Discussion

An undirected network which is related to two vertices is known as source (s) and sink (t). We assume that for each arc \((i, j) \in A\) is related with length (distance) of two nodes denoted \(l_{ij}\). Let be given \(F(s) = 1\), \(F(t) = -1\), \(F(i) = 0\) for other nodes for the flow limit at each node. The purpose of this problem is to move one unit of flow from starting point (source) to endpoint (sink) throughout the shortest route. In this model’s situation, we want to move streams from start point to endpoint throughout the shortest length from start to end point. In case to get shortest path from source to each other point in the network, then in the minimum cost flow problem we set \(F(s) = (n - 1)\) and \(F(i) = -1\) for all other nodes.

The maximum flow problem is looking for a possible solution that gives the maximum a number of streams from a starting point to the end. Let we represent the maximum stream at path \((i,j)\) with \(m_{ij}\), the maximum stream problem at a path identifies the maximum steady state stream that the network can send from start point to end per unit time.

The main target in this evacuation routing plan is to find vehicle routing toward the nearest evacuation area. The second purpose is to minimize amount of conflict at intersection. In the other word, this model want to erase the intersection crossing-conflicts. The detail as below:

\[\begin{align*}
\text{i} & \quad \text{index of network nodes} \\
i & \rightarrow j \quad \text{directed edge from i to j} \\
F_{i} & \quad \text{flow limit at vertices i} \\
l_{ij} & \quad \text{length i \rightarrow j} \\
C_{ij} & \quad \text{capacity for i \rightarrow j} \\
B & \quad \text{upper bound on the number of merges}
\end{align*}\]

Decision variables:

\[\begin{align*}
x_{ij} & \quad \text{vehicle flow on i \rightarrow j} \\
y_{ij} & \quad \{1, \text{if the flow on arc ij is positive} \} \\
m_{i} & \quad \text{amount of merging traffic flow at node i}
\end{align*}\]

the formula is:

Minimize \[Z = \sum_{i} \sum_{j} l_{ij}x_{ij}\] (1)

Subject to \[\sum_{j} x_{ij} - \sum_{j} x_{ji} = F_{i} \quad \forall i\] (2)

\[x_{ij} \leq C_{ij}y_{ij}, \quad \forall i \rightarrow j \text{ that cross } k \rightarrow l\] (3)

\[x_{kl} \leq C_{kl}(1 - y_{ij}) \quad \forall k \rightarrow l \text{ crossed by } i \rightarrow j\] (4)

\[\sum_{j} y_{ji} \leq m_{i} + 1 \quad \forall i \text{ with a potential merge}\] (5)

\[\sum_{j} m_{i} \leq B\] (6)

\[0 \leq x_{ij} \leq C_{ij} \quad \forall i \rightarrow j\] (7)

The objective

Constraint

(1) Minimize total travel distance.

(2) Basic stream constraint in a network flow problem

(3)\&(4) Avoid conflicts at fork.

(5) note the combine of flows at node i for each vehicle flow more than 1 that end at the node. The binary value at \(y_{i}\) makes \(m_{i}'s\) can be relaxed linear variables, and cause to have integer values.
4. Conclusion
This paper offers a model that is can be use as one of strategies to solve evacuation routing problem. By making a good prepare and panning, the evacuation should be held more efficient. Things to be focused in this paper are make the route to be shortest and having maximal capacities also eliminating the delay at the intersections. This model was be set for the evacuation which is held by government or policy maker, not excluded the self evacuation.

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