Results in Nonlinear Analysis 6 (2023) No. 2, 172–188
https://doi.org/10.31838/rna/2023.06.02.015
Available online at www.nonlinear-analysis.com

Results in Nonlinear Analysis
ISSN 2636-7556

Peer Reviewed Scientific Journal

Model routing evacuation during disaster

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Abstract

In recent years there are many disasters occur in the whole world and particularly in Indonesia. These disasters could be manmade or natural. Therefore, it is obvious most researchers had put more attention to develop methods disaster management optimally as an effort to mitigate the disasters. Evacuation system can be regarded as a very important factor in disaster management. So far, the existing evacuation system did not involve the potential of emerging technologies. This paper addresses an optimal evacuation system model, such that, could increase safety during evacuation time, to reduce vehicle used accidents as well as congestion. Then we develop a generalized reduced gradient approach for solving the model. We solve an evacuation problem to mitigate a disaster through evacuate people around the disaster area.

Keywords: Disasters, Evacuation system, Modeling, Optimization, Generalized Reduced Gradient

1. Introduction

Evacuation refers to locate and to move rapidly of people and assets from a dangerous place or emergency area to safer locations (UNISDR, 2009; Yazdani et al., 2021). The important thing in evacuation planning is to make sure that the resources (e.g., the transportation network) are well-organized such that there will be no congestion or chaos during the evacuation. Essentially, traffic networks are not designed to handle emergencies such as natural disasters because it is deemed financially impractical. In general, disaster-affected people will try to flee the disaster-affected area as soon as possible, which can cause chaos and disrupt the evacuation process (Zhu et al., 2022).

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Received June 23, 2023; Accepted July 14, 2023; Online October 17, 2023

Normally in creating model for network optimization of evacuation system the main goal is to minimize the total time spending to evacuate people to the safe location or sometimes it is called clearance time in the interconnected system. The optimization model considered is in particular depending on the requirements of evacuation needs. In graph form which can be written as G = (V, E), V is the node represents a hub that represents node-link form, in which each node is can be regarded as point of routing for the vehicles to take people to the safety places. Therefore, accordingly lane reversal, can be considered as an alternative method to reallocate effectively the capacity of evacuation route between two counter traffic directions. This kind of strategy has been extensively studied for building models for solving the as an evacuation planning problem (Islam et al., 2022; Kochilakis et al., 2016). (Tharwat et al., 2019) show the effectiveness of evacuation plan particularly by using lane reversal. This is meant to give more space to the network throughput rate in such a way could reduce traffic delays.

As mentioned before, that the most important strategy in handling to prevent the increasing of the wrath of disasters is the evacuation planning. The plan could include a decision on how to evacuate people from the threatened disaster area to safe places. There are several traffic management strategies have been proposed. Shoulder-Lane, contraflowing traffic, and gradual evacuation are common traffic management strategies for evacuation (Cova & Johnson, 2003; Dhamala & Adhikari, 2018; Purba et al., 2022; Starita et al., 2018). The use of several evacuation methods is recommended in emergency evacuation plans to account for the possibility of traffic delays (Feng & Lin, 2022). They created a model with traffic observation from Hurricane Irma to tackle traffic congestion due to massive evacuations based on a variety of evacuation route.

One solution to tackle the traffic congestion is to build up the road capacity. An economic way to accomplish this idea is to dynamically change the direction of particular lane for specific roads of the traffic evacuation network. In traffic management this kind of strategy is called Contraflow or Lane reversals (Wollenstein-Betech et al., 2021; Xue & Dong, 2000). All In-Bound pathways are turned around and made Out-Bound ones through Contra-Flow, a technique often employed in the emergency evacuation. A route that is going out is called an outbound path, whereas a road coming in is called an inbound path.

During an emergency, the fastest route to get people to safety is on the roads, thus they're the first to be used for evacuations. An efficient traffic management plan is necessary to deal with the dramatic rise in road demand that occurs throughout evacuation and contra-flow techniques. With the use of an ITS Tool, such as the transmission of messages and the presentation of road signs, the contra-flow approach may be implemented (Iliopoulou et al., 2020).

(Stephen, 2007)'s investigation uncovered a number of cases that provide credence to the Contra-Flow tactic, most notably the implementation of In-Bound and Out-Bound Paths. Although it is imperative that the evacuation be carried out as swiftly as possible, the situation would only worsen if many Out-of-Bound ways all point to the same path.

In the event of an emergency, it is essential to construct real-time evacuation models since it is impossible to predict how people would behave based on their past travel habits alone. Understanding the extent of the heavy traffic and re-mapping the evacuation route's capacity are two steps (Sattayhatewa & Ran, 2000) take in their study to find a solution to the issue.

It's important to identify the fastest path while evacuating via a network, and Network Interdiction is one way to do it. It's a strategy for addressing issues based on a kind of BiLevel Programming called Attacker-Defender game models. Finding the quickest route between two nodes within a network with a finite amount of resources is Network Interdiction's major objective. If the origin and destination nodes are identical and all nodes must be traversed, then the Vehicle Routing Problem (VRP) is equivalent to a Traveling Salesman Problem (TSP). The development of VRP has made important contributions to the current state of the art, and there is growing interest in studying VRP. A taxonomic overview of the VRP issue was offered by (Eksioglu et al., 2009). (Laporte, 1992) presented an in-depth examination of VRP strategies, in addition to a comprehensive assessment of the most effective strategies.

When the route finishes at the destination rather than the beginning node, we get what is called as an Open Vehicle Routing Problem (OVRP). Different from VRP's Hamiltonian Cycle, OVRP's solution consists of a collection of linked Hamiltonian Paths to the starting point. Transportation expenses were reduced because to (Soto et al., 2017)'s application of the OVRP approach.

The application of OVRP frequently encounters situations where the delay is frequent, necessitating the use of a robust approach to the uncertain data, which is the Heuristic Open Vehicle Routing Problem with Time Windows (HOVRPTW) approach.

To date, the HOVRPTW method has not been used to studying the evacuation procedure during a Contra-Flow condition. Therefore, this study aims to describe how the Disaster Traffic Management Model may be used in conjunction with HOVRPTW in a Contra-Flow condition to improve traffic flow and safety throughout an evacuation.

The use of vehicle routes during disaster evacuation is crucial for moving people from danger zones to secure places. Urgently needed are both the creation of a strategy for planning evacuation procedures in crisis circumstances and the design and analysis of evacuation procedures within the transportation infrastructure in the case of a natural catastrophe. For dynamic traffic distribution in evacuation planning, (Campos et al., 2012) used an iterative heuristic approach to construct two pathways from the disaster area to each shelter, factoring in journey time and transport network capacity. In order to keep traffic moving smoothly and minimize the risk of accidents, a convenient crossing point is needed on the way to each of the shelters. An alternative formulation of the Open Vehicle Routing Problem (OVRP) may be used to describe the path taken by this evacuation vehicle. All vehicles in the Vehicle Routing Problem (VRP) must first leave from and ultimately arrive back at the same starting point. By contrast, with OVRP the vehicle does not loop back around to the hub. There is a wide variety, or heterogeneity, in the kinds of evacuation vehicles in use. The consequence is a pattern of varying OVRP intensities that we see today. Getting out of there quickly is essential (time windows). Therefore, this need represents the HOVRPTW model pattern in the field of VRP. The delay problem is one of the most common issues, hence the HOVRPTW model was created to get around it by determining when each node will leave the network. The first researcher to use this approach was (Agra et al., 2012).

Contra-Flow, alternatively, can increase numerous of vehicles by switching the In-Bound Lane to the Out-Bound lane. During the evacuation process, it is expected that more and more vehicles will pass through a route in the shortest amount of time possible, despite the possibility of congestion.

Since studies have shown that contraflow is common in all traffic patterns, the resulting model will be an optimization scheme for the transportation planning of emergency evacuations in which contraflow is not present throughout the whole path. In the case of a disaster, this model is intended to provide a novel solution to the OVRP issue of minimizing evacuation time.

2. Disaster Management

The Safe City conference includes a panel discussion on disaster preparedness and management. A catastrophe may be characterized as a major disruption to a society or civilization that results in many casualties, extensive property damage, and economic disruptions. A society or community's capacity to cope with such a high number of deaths usually exceeds that of the society or communities alone.

Many synonyms for "disaster" have been used in the media to convey the same concept. Incident, accident, emergency, and disaster are all synonyms.

Meanwhile, disaster management can be defined as a plan that should be conducted continuously with integrated multi-sectoral. The aim is to mitigate, to prevent casualties, to arrange well preparedness, and to organize recovery.

When a catastrophe strikes, the first priority of any disaster management plan should be to ensure the safety of people's lives and aid in its recovery. Another goal is to ensure security and develop

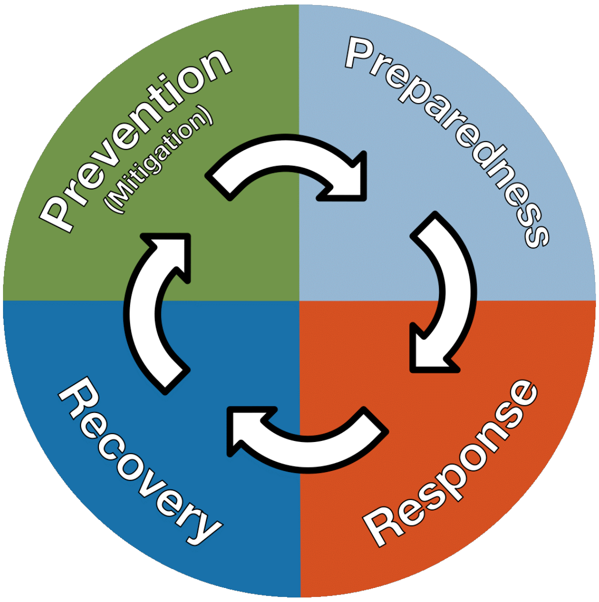

Figure 1. Disaster Management

human habitation in disaster-affected areas. The existing objectives can be expanded into several disaster management targets, as follows:

1. To avoid or mitigate the effects of disasters.
2. To provide victims with immediate assistance.
3. To achieve a quick and effective recovery.

With the help of the disaster management function, the government is able to define its roles and obligations in protecting its population. As an integral part of both the planning and execution of disaster management, the disaster support role must be well thought out and executed. They include critical services needed when a disaster is taking place, and after the occurrence of disaster. The majority of disaster management activities are focused on these functions.

The Disaster Management Function can be seen in the figure below.

The diagram above shows that disaster management encompasses.

3. Traffic Management

When it comes to being prepared for and responding quickly to potential threats or the development of catastrophes, Safe City's Integrated Rescue System, which includes a Disaster Traffic Management System, is a crucial component.

When dealing with traffic during a disaster, there are nine main approaches that are used:

1. Methods to cut down on or eliminate pointless vehicle use
2. Methods for making a vehicle more of a practical transportation option.
3. Methods for transitioning from individual modes of transportation to mass modes of transportation.
4. A traffic-volume-based strategy for improving space distribution.
5. Time distribution strategy based on traffic volume.
6. Strategies for increasing a mode of transportation's supply capacity.
7. Strategies for reducing traffic accidents.
8. Strategies to improve interoperability among modes of transportation.
9. Strategies for minimizing traffic disruption.

Improving space and time allocation according to traffic volume is the primary challenge of catastrophe route optimization. Using a shoulder lane, redirecting traffic, or evacuating slowly are all viable options for distributing traffic and people safely. Other names for Contra-Flow include lane revesals and One-Way-Out. Time allocation may also be optimized with the help of flow scheduling and zone scheduling.

The following is the goal of Disaster Traffic Management.

1. To ensure rapid access and adequate transportation mobility during disasters.
2. Prepare for and plan for emergency situations that may affect transportation.
3. To ensure the availability of a cost-effective transportation system in the event of a disaster.
4. To lessen the environmental impact of disaster transportation.

(Tanaka et al., 2001) stated that in general, there are 5 (five) types of trips that must be considered in Disaster Traffic Management, which are as follows.

1. Evacuation: The process of fleeing to a safe location and relocating to a temporary residence that must be completed within 48 hours of the disaster.
2. Return-to-home: A trip from an affected community that is outside their home to return home to gather with their families before evacuating at the same time.
3. Relief/rescue: Trips made by disaster-affected communities to inspect the condition of their homes.
4. Food and Clothes Acquisition: The type of trip taken to obtain food and clothing for disaster victims.
5. Checking Up on Offices and Schools: This type of trip is taken to inspect the condition of offices and schools.

One of the most important aspects of Disaster Traffic Management is ensuring a smooth evacuation during a disaster. In terms of the evacuation procedure, (Minhans, 2008) has proposed a traffic management framework, as shown in Figure 2.

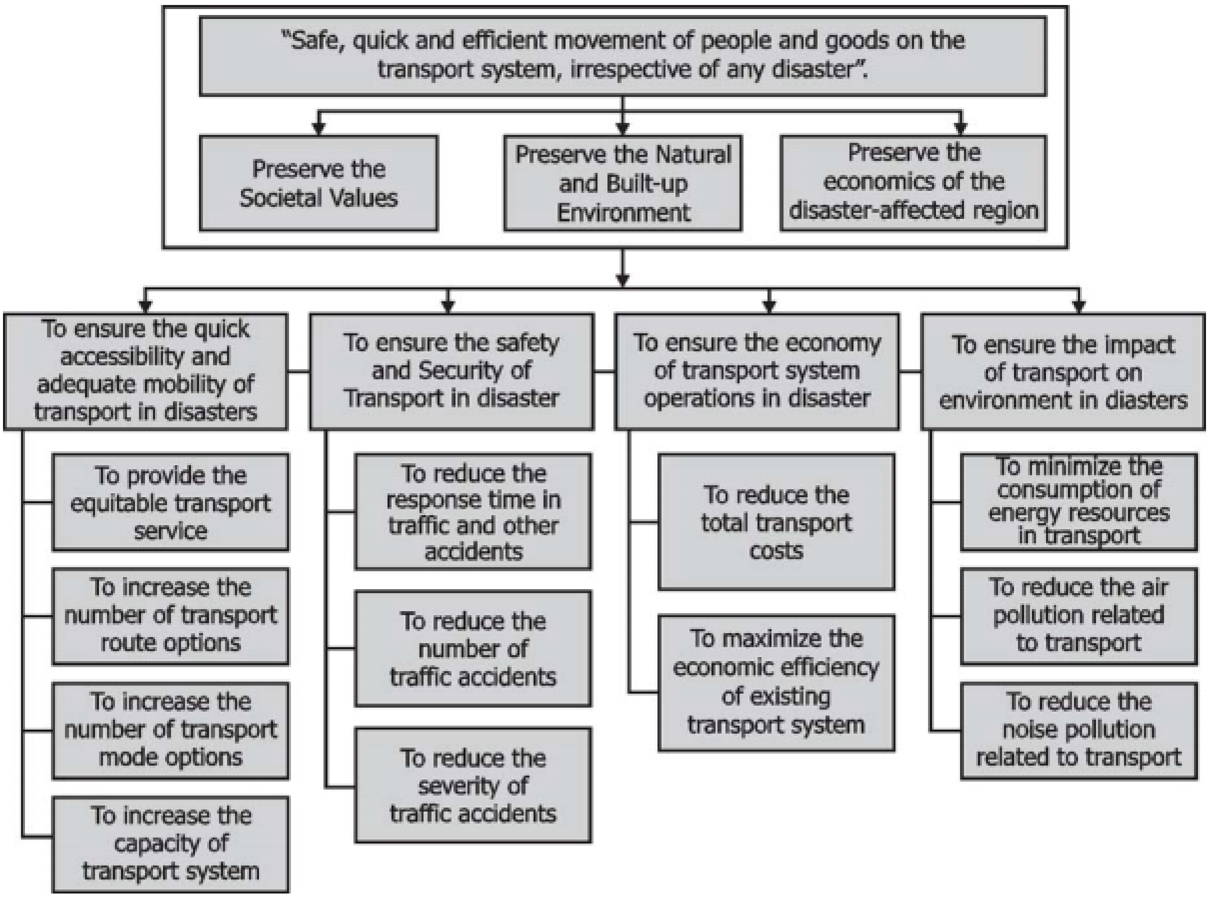

Figure 2. Framework for Traffic Management in a Disaster

Figure 2 shows that in the event of a disaster, several factors must be considered, including the following.

1. Transportation Accessibility, which includes several aspects, along with the following.
   a. Access to equitable transportation services for all.
   b. Get more the number of available transportation routes and options.
   c. Get more the number and variety of modes of transportation available.
   d. Expand the transportation system's capacity.
2. Safety in transportation. There are several aspects of transportation security that must be considered, including the following.
   a. Shorten response time.
   b. Reduce the number of mishaps.
   c. Reducing the severity of the accident.
3. Increasing the capacity of the transportation system of lines. In the event of a disaster, with the available transportation network capacity, the following factors must be considered.
   a. Lower overall transportation costs
   b. Ensure that the available transportation network is used efficiently.
4. Environmental Impact. The transportation process during a disaster must also consider the environmental impact, which is as follows.
   a. Reducing energy consumption during transportation.
   b. Reducing air pollution during transportation.
   c. Minimize noise pollution during transportation.

4. Evacuation Model

During a natural disaster, the flow of vehicle traffic can be represented by a graph directed $G = (V, E)$, where $V = \{v_0, v_1, \ldots, v_n\}$ is the set of evacuation points. The v_0 node is the starting point for evacuation, provided that there are more than one v_0 spot.

The number of vehicle fleets is assumed to be n nodes. The set of vehicle paths is then denoted by $E = \{(v_i, v_j): v_i, v_j \in V; i \neq j; j \neq 0\}$. An alternative formulation of the Open Vehicle Routing Problem may be used to describe the path taken by this evacuation vehicle (OVRP). All cars in the Vehicle Routing Problem (VRP) need to leave and end up back at the same starting point v_0. The vehicle in OVRP, on the other hand, does not circle back to the original node. This is understandable given that the vehicle traffic flow (route) begins at the v_0 evacuation center and ends at the v_n safe area. The graph is depicted in Figure 4.

According to Figure 3, v_0 is the set of N_0 for the disaster's initial location, v_1 is the set of N_1 as the movement flow path of vehicles, and v_n is the set of N_2, which is a disaster safe location.

The generated mathematical formulation will follow the pattern of the OVRP model. The types of vehicles used for evacuation are diverse, or heterogeneous. As a result, the current pattern is heterogeneous OVRP. We need escape windows for a certain length of time. Therefore, the HOVRPTW model pattern is indicated in the context of VRP when this requirement is met.

The intermediate nodes represent the points at which the evacuation flows converge (merge) or crossing. Each arc in E is represented by a path (i, j), which connects nodes i and j. When referring to a network, the term "static" refers to the fact that all of the connections between nodes in the graph are unchanging. For every conceivable combination of route and node, there exists a set of parameters; each node k represents a node in the network with a number of populations of p_k and maximum occupation of q_k. Given the capacity c_{ij} for each path (i, j), in which $(i, j) \in E$. To calculate a path's capacity, simply count how many flows it can handle in a certain amount of time without encountering any delays due to congestion. With a road system divided into lanes, capacity is measured in terms of the average number of vehicles per hour per lane.

Travel time t_{ij} for each section of evacuation route is defined where $(i, j) \in E$. If time t_{ij} is constant and represents the average velocity of vehicle to travel along the (i, j) arc if the track line is free

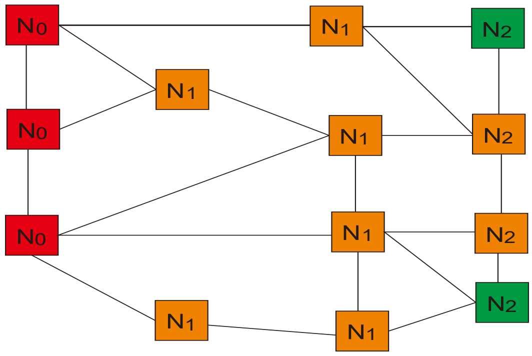

Figure 3. Traffic flow graph

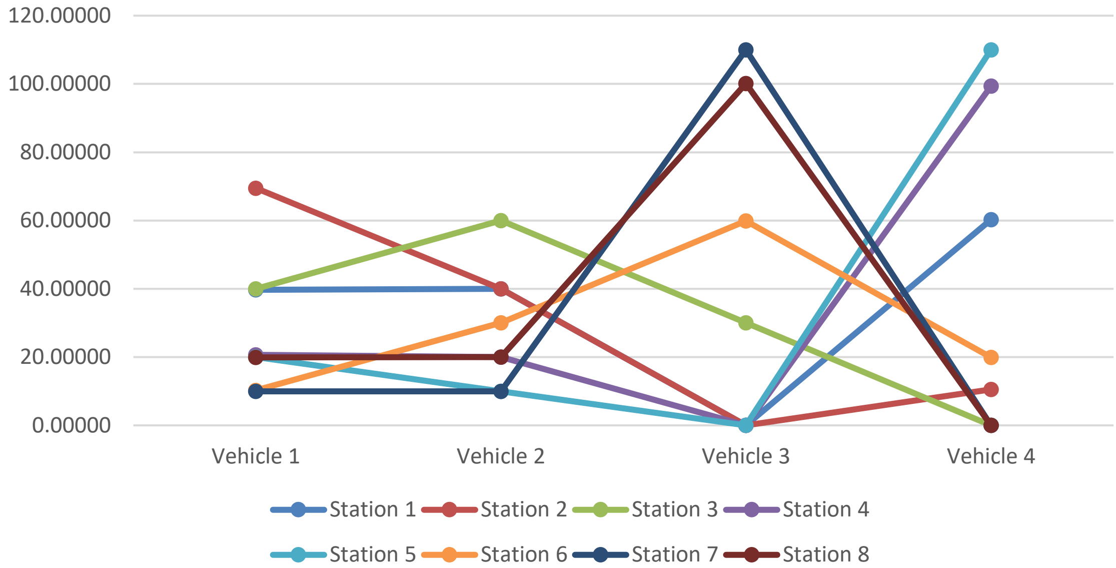

Figure 4. The Values of W Using Optimal Values of L

(empty) from any use of evacuation, this parameter can be referred to as the (i, j) arc's free congestion or free flow rate.

It is expected that the lane service level will be constant throughout the horizon period of the plan, providing an estimate of the amount of evacuation vehicles that will be able to utilize the evacuation lane. In the actual world, lane capacity tends to fluctuate over time. In actuality, the amount of objects available in each particular arc determines the path's capacity. Adding flow-dependent capacity makes this network flow issue a network flow issue with new limitations.

The ultimate goal of the optimization model of evacuation plan is to minimize the time needed to travel of vehicles along the arc (i,j) carrying people from the point (or node) in which a disaster occur to a safe location (node)

With a note that:

Notation used

Sets

N = Defines nodes
K = Vehicles
N_0 = Defines initial evacuation nodes,
N_1 = Defines transfer nodes
N_2 = For final nodes (safe destination),
T = Travel times

Parameter

Q_k = Vehicle can carry $k \in K$

t_{ij} = Traverse time from node $i \in N_0$ to node $j \in N_1$

$[a_i.b_i]$ = First and last time at node $i \in N_1$

c_{ij} = Path capacity move from node $i \in N_0 \cup N_1$ to node $j \in N_1 \cup N_2$

st_i = Service time at node $i \in N_0 \cup N_1$

td_i = Slowest time of arrival at node $i \in N_1$

Decision variables are made up of binary variables and continuous variables.

x_{ij}^k equal to 1 if there is an evacuation flow with one path from node $i \in N_0$ to node $j \in N_1 \cup N_2$ with $k \in K$ vehicles. Otherwise, equals 0.

y_{ij}^k equal to 1 if there is an evacuation flow with one path from node $i \in N_1$ to node $j \in N_1 \cup N_2$ with $k \in K$ vechicles. Otherwise, equal to 0.

z_{ij}^{kl} equal to 1 if there is a contraflow evacuation current from node $i \in N_0$ to node $j \in N_1 \cup N_2$ with $k \in K$ vehicles. Otherwise, equal to 0.

w_{ij} denotes the number of vehicle flows from node $i \in N_0$ to node N1.

l_i^k arrival time of vehicle $k \in K$ at node $i \in N_1 \cup N_2$ (continuous variable)

4.1 Evacuation Plan Modeling

The main objective of this model is to reduce the travel time from the disaster's original positions to the safe destination.

$$Minimum \;\; A = \sum_{i \in N_0} \sum_{j \in N_1} t_{ij} \sum_{k \in K} x_{ij}^k + \sum_{i \in N_1} \sum_{j \in N_2, i \neq j} t_{ij} \sum_{k \in K} x_{ij}^k + \sum_{i \in N_0} \sum_{j \in N_1} t_{ij} \sum_{k \in K} z_{ij}^{kl} + \sum_{i \in N_1} \sum_{j \in N_2, i \neq j} t_{ij} \sum_{k \in K} z_{ij}^{kl} \tag{1}$$

When there are constraints or requirements that must be met:

$$\sum_{k \in K} \sum_{i \in N_0} x_{ij}^k = d, \qquad \forall j \in N_1 \cup N_2 \tag{2}$$

Using this formula, we can be guaranteed that each respective vehicle will leave from the disaster's starting point l to the next node j on the path E.

$$\sum_{d \in N_0} \sum_{k \in K} y_{di}^k + \sum_{j \in N_1; i \neq j} \sum_{k \in K} x_{ji}^k = 1 \qquad \forall i \in N_1 \tag{3}$$

Given this restriction, it is impossible to take a route that does not first begin at one of the initial places affected by the catastrophe.

$$\sum_{j \in N_1} x_{ij}^{tk} = \sum_{j \in N_2} x_{ij}^{tk}, \qquad \forall k \in K, \forall i \in N_0, \forall t \in T \tag{4}$$

Using this model causes the vehicle to come to a halt, permanently altering the route's duration t.

$$\sum_{i \in N_0} x_{ij+1}^{tk} \leq 1, \qquad \forall j \in N_1 \cup N_2, \forall k \in K, \forall t \in T \tag{5}$$

There are artificial nodes:

$$\sum_{k \in K} \sum_{i \in N_0} x_{(j+1)i}^{tk} = 0, \qquad \forall j \in N_1, \forall t \in T \tag{6}$$

It is not permitted to begin service with artificial nodes.

$$\sum_{k\in K}\sum_{j\in N_1\cup N_2} x_{ij}^{tk} = 0, \qquad \forall i \in N_0, \forall t \in T \tag{7}$$

It is forbidden for vehicles that have already left the catastrophe site to return to it.

$$\sum_{(i,j)\in N, i\neq j} x_{ij}^{tk} \leq ST - 1, \qquad \forall k \in K, \forall t \in T \tag{8}$$

Sub-tour elimination procedure (ST):

$$\sum_{k\in K}\sum_{i\in N_0} x_{ii}^{k} = 0 \tag{9}$$

To keep loops from happening.

$$y_{ij} \leq c_{ij} x_{ij}^{k} \qquad \forall i \in N_0, \forall j \in N_1 \cup N_2, i \neq j, \forall k \in K \tag{10}$$

To check that the total route currents do not surpass the maximum allowed, we use the following equation:

$$l_i^k \leq a_i \sum_{j\in N_1} x_{ij}^k, \qquad \forall i \in N_o, \forall k \in K \tag{11}$$

$$a_i \sum_{j\in N_1} x_{ij}^k \leq l_i^k + t_{ij} \leq b_i \sum_{j\in N_1} x_{ij}^k, \quad \forall i \in N_0, \forall k \in K \tag{12}$$

The time of arrival and departure from a node should be recorded.

Consider two α_{ij} connectedness indicators, the intersection of nodes

$$\forall_i \in N_0 \cup N_1 \text{ and } \forall_j \in N_1 \cup N_2 \tag{13}$$

Then there are the paths between β_{js} nodes

$$j \in N_0 \cup N_1 \text{ and } \forall_s \in N_1 \cup N_2 \tag{14}$$

If $\alpha_{ij} = 1$, the condition states that positive flow is permitted in the crossing path, whereas $\alpha_{ij} = 0$ indicates that (i, j) flow is closed and, as a result, $w_{ij} = 0$. This condition indicates that at least one path along the node (j,s) is used if $\beta_{js} = 1$ (such as $n_{js} \geq 1$). If $\beta_{js} = 0$ (or $n_{js} = 0$), the flow along the node (j,s) has been lost in the evacuation route network (in other words the paths normally designed for this direction of traffic flow are all diverted to contraflow). n_{js} is a decision variable that represents the number of paths connecting nodes j and s.

With this connected condition, there are several obstacles to the evacuation flow network, namely the capacity of the number of lanes.

$$n_{js} = n_{sr} = n_{jr} \text{ denotes the type of connection } \beta_{ij} \text{ and}$$

$$n_{pq} = n_{qv} = n_{pv} \text{ denotes the type of connection } \beta_{ij} \text{ and}$$

$$n_{jr} + n_{pv} = n_{jp,rv} \text{ denotes the type of connection } \beta_{ij} \tag{15}$$

For a given number of lanes in each direction, say $n_{jp,rv}$, the result is the total number of lanes.

Crossing Elimination

$$\alpha_{oj} + \alpha_{ab} \leq 1 \tag{16}$$

$$\alpha_{ij} + \alpha_{rv} + \alpha_{ab} \le 1 \tag{17}$$

Crossing conflicts between pathways α_{oj} and α_{ab}, as well as between α_{ij}, α_{rv}, and α_{ab}, should be avoided in the evaluation design.

Conditions' constraints If $\beta_{js} = 1$, $n_{js} \ge 1$, and if $\beta_{js} = 0$, $n_{js} = 0$.

$$\beta_{js} \le n_{js} \tag{18}$$

$$\beta_{js} M \le n_{js} \tag{19}$$

Where M is a Fairly Large Constant.

Constraints for declaring the presence of contraflow currents.
According to the previous description, contraflow occurs when $\beta_{js} = 0$ (or $n_{js} = 0$). This statement can be expressed mathematically as:

$$1 - z_{js}^{kl} \le \beta_{js} \qquad \forall j \in N_0 \cup N_1; \forall s \in N_1 \cup N_2; j \ne s \tag{20}$$

and

$$x_{js}^{k} \le \beta_{js} \qquad \forall j \in N_0 \cup N_1; \forall s \in N_1 \cup N_2; j \ne s \tag{21}$$

An optimization model of disaster evacuation transportation management is shown in Equations (1) to (21). This model's main assumption is that the safe area has been determined. This assumption is met in a realistic way. Contraflow does not have to occur in every section of the path, as it has been reported in previous journals.

5. Developing Method to be Used

It is assumed that *f*(*x*) is sufficiently smooth. then it could be broadened in a Taylor's series at some point between x to $x + p$ up to second order:

$$f(x+\mathrm{p}) = f(x) + g(x)^T \mathrm{p} + \frac{1}{2}\Delta x^T G(x+\gamma \mathrm{p})\Delta x \tag{5}$$

where, the matrix of second partial derivatives or Hessian matrix is denoted by $\gamma \in [0,1]$ and $G(\boldsymbol{x} + \gamma\mathrm{p})$. Due to the fact that *f*(*x*) is quadratic, then G is a constant matrix, in which p is equal to Δx

It is assumed that matrix A can be segmented into matrix basis (B), matrix non-basis (NB) and matrix superbasis (S). Correspondingly $\Delta\boldsymbol{x}$ and $\boldsymbol{g}(\boldsymbol{x})$ are partitioned to the partitioning of A, to be basic, non-basic and superbasic.

The following two results can be derived if *f*(*x*) were quadratic

Result 1.

$$\begin{bmatrix} B & S & N \\ 0 & 0 & I \end{bmatrix} \begin{bmatrix} \Delta\boldsymbol{x}_B \\ \Delta\boldsymbol{x}_S \\ \Delta\boldsymbol{x}_N \end{bmatrix} = 0 \tag{6}$$

The Equation (6) means that the step Δx stays on the surface prone of the convergence of the active constraints.

Result 2.

$$\begin{bmatrix} g_B \\ g_S \\ g_N \end{bmatrix} + G \begin{bmatrix} \Delta \boldsymbol{x}_B \\ \Delta \boldsymbol{x}_S \\ \Delta \boldsymbol{x}_N \end{bmatrix} = \begin{bmatrix} B^T & 0 \\ S^T & 0 \\ N^T & I \end{bmatrix} \begin{bmatrix} \mu \\ \lambda \end{bmatrix} \tag{7}$$

Because of the structure of Equation (7), we may claim that the gradient at at $\boldsymbol{x} + \Delta\boldsymbol{x}$ (supplied by the left hand side) satisfied to a geometric property of a feasible solution and can thus be expressed as a vector obtained by taking a weighted sum of the vectors which are perpendicular to the active constraints.

Algorithm Outline

Step 1. Do a convergence test while in the in the solution space that satisfies all the given constraints Check whether $||\boldsymbol{h}|| >$ TOLRG, if yes move to step 3.

Step 2. Compute λ a multiplier (a variable belongs to superbasic set to be added).

- (a) Select $\lambda_{q_1} < -$TOLDJ ($\lambda_{q_2} > +$TOLDJ),. If empty, STOP; the optimal necessary conditions are satisfied (Kuhn-Tucker).
- (b) If not,
  - (i) Find $q = q^1$ or $q = q^2$ in according to $|\lambda_q| = \max(|\lambda_{q_1}|, |\lambda_{q_2}|)$;
  - (ii) take a^q as a new column of S;
  - (iii) get λq as a new element of h;
  - (iv) find a suitable new column to $\boldsymbol{R}$.
- (c) Elevating s by 1.

Step 3. (Find vector $\boldsymbol{p} = Z\boldsymbol{p}_s$ as vector of search).

- (a) Compute $R^T R p_s = -h$.
- (b) Compute $\mathrm{LU}p_B = -Sp_s$.
- (c) Get $\boldsymbol{p} = \begin{bmatrix} \boldsymbol{p}_B \\ \boldsymbol{p}_S \\ 0 \end{bmatrix}$

Step 4.

- (a) Determine $\alpha_{\max} \geq 0$, the maximum value of α such that $x + \alpha p$ is feasible.
- (b) If $\alpha_{\max} = 0$ do step 7.

Step 5.

- (a) Determine α, a close value to α^*, in which

$$F(\boldsymbol{x} + \alpha^* \boldsymbol{p}) = \min_{0<\theta\leq\alpha_{\max}} f(\boldsymbol{x} + \theta \boldsymbol{p})$$

- (b) Replace $\boldsymbol{x}$ with $\boldsymbol{x} + \alpha\boldsymbol{p}$ and make f and $\boldsymbol{g}$ at the new $\boldsymbol{x}$.

Step 6. (Work out a search gradient, $\bar{\boldsymbol{h}} = Z^T\boldsymbol{g}$).

- (a) Get $U^T L^T \pi = g_B$.
- (b) Determine the new search gradient, $\bar{\boldsymbol{h}} = g_s - S^T\pi$.
- (c) Get new R corresponding to some function to change dynamically during the recursive process on $R^T R$, using α, p_s and the replace them in reduced gradient, $\bar{\boldsymbol{h}} - h$.
- (d) Take $h = \bar{\boldsymbol{h}}$.
- (e) If $\alpha < \alpha_{\max}$ go to 1. Only former constraint was involved therefore stick in the current subspace.

Step 7. (Move a basis from the set of basic variables; discard one superbasic). In this case $\alpha < \alpha_{max}$ and for the case p ($0 < p \leq m + s$) then a variable belongs to the p-th column of [B S] has struck one of its bounds.

(a) If a variable equals to its bound ($0 < p \leq m$),

(i) exchange the columns of p and q from

$$\begin{bmatrix} \boldsymbol{B} \\ \boldsymbol{x}_B^T \end{bmatrix} \text{and} \begin{bmatrix} S \\ \boldsymbol{x}_S^T \end{bmatrix}$$

orderly, considering that q is chosen to keep B solvable (it is necessary for a vector π_p to satisfy $U^T L^T \pi_p = e_p$);

(ii) get new L, U, R and π to represent this modification in B;

(iii) find $h = g_s - S^T\pi$ as a recent gradient

(iv) go to (c).

(b) If not, a variable (SB) strikes its border ($m < p \leq m + s$). Let $q = p - m$.

(c) Set the q-th variable in S nonbasic at the right bound, thus:

(i) discard the q-th columns of

$$\begin{bmatrix} \boldsymbol{S} \\ \boldsymbol{x}_S^T \end{bmatrix} \text{and} \begin{bmatrix} R \\ \boldsymbol{h}^T \end{bmatrix}$$

(ii) bring back R to triangular form.

(d) Decline s by 1 and back to 1.

5. Data and Result with MPS

5.1. Data collection

The data collection categories are as follows:

a. Numerical data

Numerical data in the form of a matrix that aids in the quantification process of modeling and provides mathematical clarity of the system's objective function. The data is drawn from the bare minimum of function matrices, as shown in the Table 1.

Travel time of the evacuation flow to the track in minutes. According to the table above, the vehicle travels from IJ to track J to the initial track, j = 2 in the trail of travel stains, and j = 3 to a safe location under the following conditions: The evacuation flow from the disaster site to Xij's initial path takes 100 minutes. The evacuation flow journey from the track node to the safe lane took 150 minutes with Xij, and the evacuation flow journey in the contraflow node took 200 minutes with Xij.

The numerical data presented above will be used in simulations involving MPS applications (Mathematic Programming System)

Computational Result

EXIT -- OPTIMAL SOLUTION FOUND.
NO. OF ITERATIONS 494 OBJECTIVE VALUE 4.2181818181818E+02
NORM OF X 1.100E+02 NORM OF PI 1.360E+02
1
PROBLEM NAME VRP-EVAC OBJECTIVE VALUE 4.2181818182E+02
STATUS OPTIMAL SOLN ITERATION 494

Table 5 presents the optimal route to travel for each n = 4 vehicles. For example, for vehicle 1, from the origin of the disaster point moves to destination 1. Then, from station 1 the vehicle moves to station 2, from station 2 proceeds to station 4.

Table 1. Matrix of Evacuation Flow Data from the Disaster Site to the Trajectory

X	J = 1	J = 2	J = 3
I = 01	100	150	200
I = 02	100	150	200
I = 03	100	150	200
I = 04	100	150	200
I = 05	100	150	200

Table 2. Data from the Evacuation Flow Matrix from Tracks to Safe Locations

1	0	5	7	5	6
2	5	0	6	7	4
3	7	6	0	5	7
4	5	7	5	0	5
5	6	4	7	5	0

Table 3. Data Matrix Contra Flow from Disaster Location to Trajectory

X	12	22	32	42	52
1	0	8	5	7	6
2	8	0	9	8	5
3	5	9	0	7	4
4	7	8	7	0	6
5	6	5	4	6	0

Table 4. Data Matrix Contra Flow from Track to Safe Location

X	13	23	33	43	53
1	0	7	10	9	8
2	7	0	8	6	7
3	10	8	0	10	9
4	9	6	10	0	10
5	8	7	9	10	0

Table 6 shows the optimal number of vehicles i = 1,2,3,4 to be used from each stations j = 1,2,…,8. For example, At station 1, there are 40 vehicles of vehicle 1 to be used, there are 40 vehicles of vehicle 2 to be used, but none of vehicle 3, then 60 vehicles of vehicle 1 to be used.

Conclusion

This paper creates an optimization model for evacuation route planning. It is well understood from the consequence that may occur the evacuation process requires proper planning for a number of conditions. The main condition that we consider in this paper is the need to pay attention to the capacity of the number of vehicles that can pass a path in a contra flow situation. In this paper we develop an integer programming model that could adjust the capacity of the vehicle that can pass through a time based on the time setting to clear an evacuation route and the time to go through a node on a transportation network needs to be done in a contra flow situation.

Table 5. The Result of Binary Variable X

X		0	1	2	3	4	5	6	7	8
1	0		1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	1	0.00000		1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	2	0.00000	0.00000		0.00000	1.00000	0.00000	0.00000	0.00000	0.00000
	3	1.00000	0.00000	0.00000		0.00000	0.00000	0.00000	0.00000	0.00000
	4	0.00000	0.00000	0.00000	1.00000		0.00000	0.00000	0.00000	0.00000
	5	0.00000	0.00000	0.00000	0.00000	0.00000		1.00000	0.00000	0.00000
	6	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000		0.00000	1.00000
	7	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000		0.00000
	8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	
2	0		0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000
	1	0.00000		1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	2	0.00000	0.00000		0.00000	1.00000	0.00000	0.00000	0.00000	0.00000
	3	1.00000	0.00000	0.00000		0.00000	0.00000	0.00000	0.00000	0.00000
	4	0.00000	1.00000	0.00000	0.00000		0.00000	0.00000	0.00000	0.00000
	5	0.00000	0.00000	0.00000	0.00000	0.00000		0.00000	1.00000	0.00000
	6	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000		0.00000	0.00000
	7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000		1.00000
	8	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	
3	0		0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000
	1	0.00000		0.00000	0.00000	1.00000	0.00000	0.00000	0.00000	0.00000
	2	0.00000	0.00000		0.00000	0.00000	1.00000	0.00000	0.00000	0.00000
	3	0.00000	0.00000	0.00000		0.00000	0.00000	0.00000	1.00000	0.00000
	4	0.00000	1.00000	0.00000	0.00000		0.00000	0.00000	0.00000	0.00000
	5	0.00000	0.00000	0.00000	0.00000	0.00000		0.00000	0.00000	1.00000
	6	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000		0.00000	0.00000
	7	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000		0.00000
	8	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	
4	0		1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	1	0.00000		1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	2	0.00000	0.00000		0.00000	1.00000	0.00000	0.00000	0.00000	0.00000
	3	0.00000	0.00000	0.00000		0.00000	0.00000	0.00000	1.00000	0.00000
	4	0.00000	0.00000	0.00000	1.00000		0.00000	0.00000	0.00000	0.00000
	5	0.00000	0.00000	0.00000	0.00000	0.00000		0.00000	0.00000	1.00000
	6	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000		0.00000	0.00000
	7	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000		0.00000
	8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	

Table 6. The Result of Variable W

W				
	1	2	3	4
1	39.74026	40.00000	0.00000	60.25974
2	69.48052	40.00000	0.00000	10.51948
3	40.00000	60.00000	10.12987	19.87013
4	20.64935	20.00000	0.00000	99.35065
5	20.00000	10.00000	0.00000	110.00000
6	10.25974	30.00000	79.74026	0.00000
7	19.74026	10.00000	100.25974	0.00000
8	10.12987	20.00000	109.87013	0.00000

Table 7. The Result of Variable L.

L		
	1	2
1	9.50649	0.00000
2	39.80519	12.00000
3	10.00000	12.00000
4	10.02597	10.00000
5	10.02597	10.00000
6	12.00000	10.00000
7	9.01299	10.00000
8	10.02597	10.00000

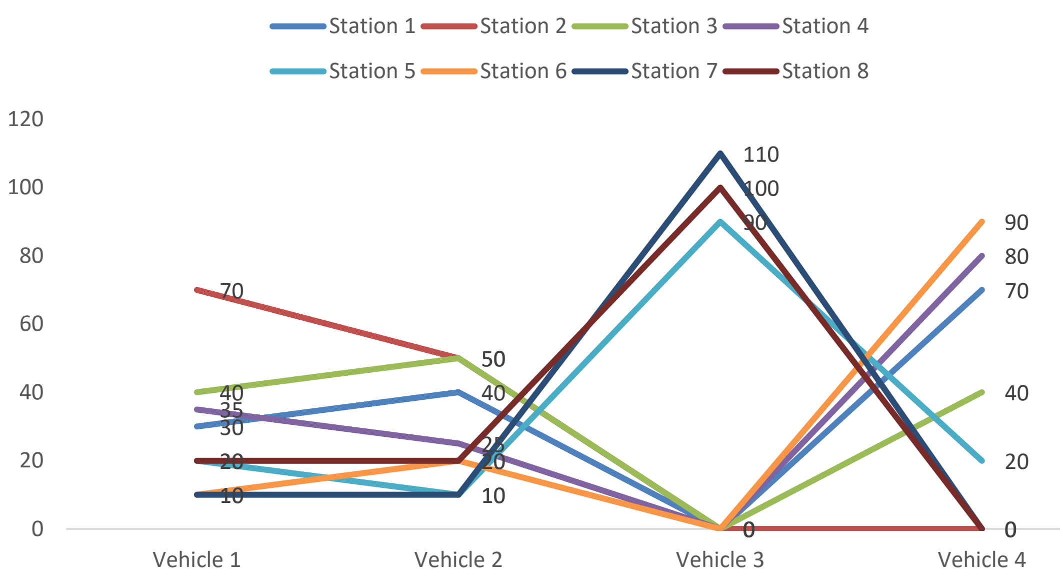

Figure 5. The Values of W with L Values are Fixed

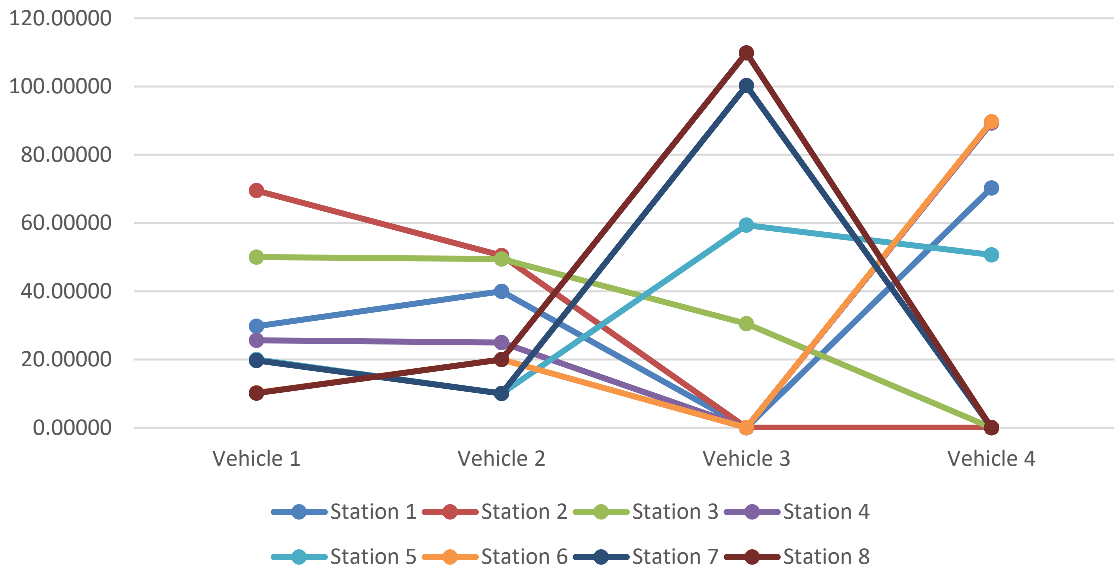

Figure 6. The Values of W Using Smaller L Values

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