mdm26-evacuationplanner

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November 2025

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Abstract

1 Introduction

2 Related Work

The field of evacuation routing under hazardous environmental conditions spans many different research areas, including atmospheric dispersion modeling,exposure and dose estimation,geo-spatial routing and multi-hazard evacuation systems.

Prior work has approach the problem from different angles depending on the hazard type(chemical releases,radioactive leakage,wildfires,flooding) and the available spatial information(predefined road networks,indoor layouts,or uncharted terrain).This section reviews the most relevant contributors across these themes and highlights how the proposed system integrates concepts from multiple research domains.

2.1 Atmospheric Dispersion Modeling

2.1.1 Dose Model

2.1.2 Air Pollution Aware Routing

2.2 Evacuation Route Planning

2.2.1 General evacuation route planning on road networks

2.2.2 Wildfire and wildland evacuation and routing

Atmospheric dispersion modeling plays a central role in predicting the transport and deposition of hazardous airborne materials. A variety of models have been employed in the literature,

3 System Model & Problem Formulation

In this section we present the system model, problem formulation, and baseline approaches.

3.1 System Model

The proposed system consists of three principal components: (1) an atmospheric dispersion simulation module based on the HYSPLIT model, (2) a web-based interface for simulation configuration and visualization, and (3) an escape-route planning module that operates on the processed dispersion output.

HYSPLIT Simulation Component: HYSPLIT is an established atmospheric dispersion model widely used for modeling the transport and diffusion of hazardous airborne materials. It requires as input the source location,release height, release duration, and meteorological data corresponding to the simulation period. Because HYSPLIT only accepts meteorological data in the ARL (Air Resources Laboratory) format, publicly available GFS (Global Forecast System) data must first be preprocessed using the official conversion utilities. After preprocessing, the model is executed within a Dockercontainer hosted on a dedicated server. The model produces a sequence of hourly output files,each containing concentration values at discrete geographic coordinates.

Data Processing Component: Upon completion of the simulation, the generated output files are parsed and the concentration values, coordinates, and timestamps are extracted. These data are then stored on the server in a structured format for subsequent use by the route-planning module and for visualization.

Web Interface Component: A web application allows users to configure the simulation parameters (e.g., source location, release characteristics, meteorological dataset) and initiate model runs. The interface also provides interactive visualization of the dispersion results on a map, enabling users to explore the spatial and temporal evolution of the hazardous plume.

Escape Route Planner Component: The escape-route planning module operates on the processed pollutant concentration data and the underlying road network stored in a spatial database. It prepares the required exposure and cost information for subsequent route computation, enabling analysis of evacuation paths under different scenarios.

3.2 Problem Formulation

The evacuation routing problem is defined on a directed road network $G = (V, E)$, where V denotes the set of intersections and E denotes the set of road segments.In practise G denotes the *subgraph* of the road network induced in the area of interest, i.e, the portiom of the network that lies withing the HYSPLIT simulation domain or within a user-defined area. Each edge $e \in E$ is associated with a length $l(e)$ and a time-dependent pollutant concentration function $c(e, t)$, which represents the estimated concentration of hazardous material in that segment at time t.

Given a source node $s \in V$ and a destination node $d \in V$, the objective is to compute a path $P = (e_1, e_2, \ldots, e_k)$ that **minimizes cumulative exposure to hazardous material**. In its general form, the optimization problem can be expressed as:

$$\min \sum_{e \in P} w(e, t), \tag{1}$$

where edge cost $w(e, t)$ is a composite function that can incorporate multiple factors relevant to evacuation routing. In the current system, the cost function includes the following:

- **Exposure cost:** The concentration of pollutant $c(e, t)$ associated with the edge $e$at time t.
- **Travel distance:** The physical length $l(e)$ of the road segment.
- **Travel time:** A function of distance and expected speed on edge e.

The framework is designed to be extensible, allowing additional parameters to be incorporated into the cost function when required. Examples of such parameters include:

- **Traffic congestion:** Dynamic congestion levels that affect travel time or road usability.
- **Road accessibility constraints:** Temporary closures, capacity limits, or restricted zones.
- **Safety or risk modifiers:** Penalties for proximity to the release location or hazardous areas.

Table 1: Cost function Used in Evacuation Routing

Parameter	**Description**
Exposure Cost	Pollutant concentration $c(e,t)$ on edge e at time t
Travel Distance	Physical length $l(e)$ of road segment e
Travel Time	Estimated travel time on edge e based on distance and speed
Traffic Congestion	Dynamic congestion levels affecting travel time

Although the mathematical objective remains constant — *minimizing exposure along a feasible path from s to d*— the specific scenario defined by the user determines the constraints under which the route must be computed. In practice, this system supports multiple scenario types, including:

- **Scenario of the user-specified destination:** The user specifies a particular destination d. The route is calculated based on the estimated travel time from s to d and the exposure along the path.
- **Time-constrained scenario:** The user specifies a maximum allowable travel time T_{max}. The route is calculated to minimize exposure while ensuring that the total travel time does not exceed T_{max}.
- **User-prioritized trade-off scenario:** The user assigns a weight between exposure minimization and travel distance/time,modifying the edge cost function.
- **Worst-case scenario (safety-first): the** route is computed under the maximum concentration observed for each edge within the simulation window.
- **Escape route scenario:** The route was computed with no specific destination in mind, but rather to lead the user away from the hazardous area as quickly as possible.
- **Multi-destination scenario:** The user specifies multiple potential destinations, and the system computes routes to each, allowing the user to choose based on exposure and travel time.

- **Predefined safe zones scenario:** The user can select the option of safe zones, and the system computes routes to the nearest safe zone (Government-designated shelters) while minimizing exposure.

Regardless of the chosen scenario, the underlying goal of the system is to compute a path that satisfies the user's constraints while minimizing the expected exposure to the hazardous material.

3.3 Baseline Approaches

4 System Requirements

5 System Arcitecture

6 Data Model