Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 22-23, 2025

Optimal Selection of Evacuation Shelters and Routes Using TOPSIS and a Road Evacuation System in Radiological Disasters

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Keywords: Radiological Disaster, Evacuation Planning, TOPSIS, Road Network, Decision Support System

1. Introduction

Evacuation planning in radiological disasters is crucial for minimizing radiation exposure and ensuring public safety. Traditional plans rely on pre-designated shelters and routes but often fail to assess real-time conditions, leading to congestion, inefficient resource allocation, and increased exposure risks. Given the complexity of radiological emergencies, where radiation levels, accessibility, and road conditions must be considered simultaneously, a more data-driven, multi-criteria decision-making approach is needed.

This study proposes an integrated evacuation framework that combines TOPSIS with a road network-based evacuation system to identify optimal shelters and routes. By ranking shelters using multiple evaluation criteria and integrating dynamic road network optimization, this approach improves evacuation efficiency while minimizing radiation exposure risks.

2. Methods

In radiological evacuation planning, both shelter selection and evacuation routing must be optimized to minimize radiation exposure and ensure a safe evacuation. To achieve this, a road network-based optimization approach is integrated with the TOPSIS-based shelter selection method, considering real-time traffic conditions, road accessibility, and potential hazards

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is an MCDA (Multi-Criteria Decision Analysis) method that ranks alternatives based on their proximity to an ideal solution while maximizing the distance from a negative-ideal solution. It is particularly effective in emergency management, where multiple conflicting factors must be evaluated simultaneously [1].

By combining TOPSIS for shelter ranking with road network optimization, this framework enhances disaster response effectiveness, ensuring evacuees are guided along the safest and most efficient routes. The following sections describe the methodology used to identify the most suitable shelters and evacuation routes in radiological emergencies.

2.1 TOPSIS method for shelter selection

In radiological evacuation planning, TOPSIS helps authorities assess evacuation shelters by considering key criteria such as distance from the nuclear plant, radiation levels, accessibility, and capacity [2]. This approach ensures that the most suitable shelter is selected by identifying the option closest to the best-case scenario while avoiding high-risk alternatives.

To apply the TOPSIS method, we first define evacuation shelters as alternatives and establish evaluation criteria. Each alternative is assessed based on its performance relative to each criterion, which is then structured into a decision matrix (X) containing performance values across multiple criteria. This matrix serves as the foundation for ranking shelters, enabling a systematic and data-driven selection process.

2.2 Route optimization for evacuation

In addition to selecting optimal evacuation shelters using the TOPSIS method, identifying the safest and most efficient evacuation routes is essential. This study integrates a road network-based optimization approach to minimize evacuation time and radiation exposure. The process begins with road network data collection, including road types, traffic conditions, and accessibility constraints. Additional factors such as road width, bridge conditions, and intersections are also considered to ensure accurate route assessment.

GIS (Geographic Information Systems) play a crucial role in analyzing spatial data and optimizing evacuation routes by integrating real-time traffic conditions, road accessibility, and hazard zones [3]. GIS allows for the classification of roads (e.g., highways, urban streets, rural roads) and helps identify restricted or blocked areas near the nuclear plant, enhancing decision-making in evacuation planning. Real-time traffic data further improve feasibility assessments, ensuring that the selected routes remain accessible and efficient.

Pathfinding algorithms determine effective evacuation routes by optimizing travel time, minimizing radiation exposure, and reducing congestion. These algorithms ensure that evacuees are directed to the safest routes even under dynamic emergency conditions. Road evaluations focus on identifying the safest, least congested, and most efficient routes while avoiding high-radiation zones.

Once optimal routes are determined, the evacuation framework integrates TOPSIS-based shelter selection, linking each ranked shelter to its best route, considering real-time conditions. By combining TOPSIS for shelter ranking with road network optimization, this approach ensures evacuees follow the safest and most efficient paths, enhancing disaster response effectiveness.

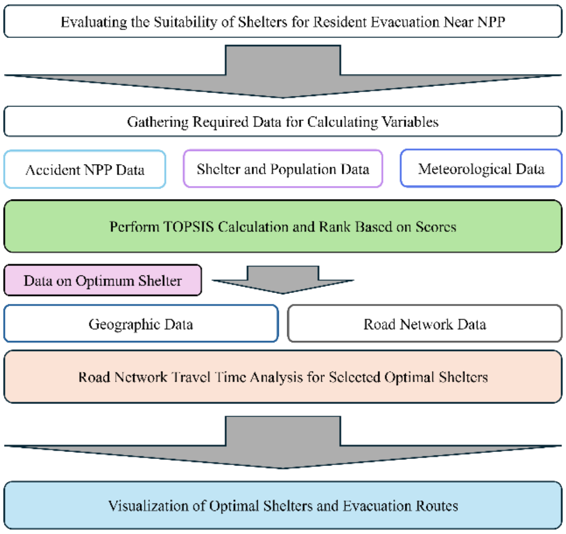

Figure 1. Overview of the research methodology

3. Conclusion

This study presents a systematic methodology for optimizing evacuation shelter selection and route planning in radiological disasters by integrating TOPSIS-based shelter ranking with road network optimization. Unlike conventional static evacuation plans, this approach incorporates multiple decision criteria and real-time road constraints, enabling dynamic and adaptive decision-making. By leveraging real-time data and structured multi-criteria decision analysis, the framework enhances evacuation efficiency and strengthens emergency response planning.

Future research will refine the road network model by integrating real-time traffic conditions, road capacity, and emergency accessibility. Additionally, AHP will be used to optimize TOPSIS criteria and weight values, ensuring a more structured decision-making process. A simulated evacuation scenario near a nuclear power plant will further validate this approach, contributing to a more robust and practical evacuation decision support system, ultimately improving radiological disaster response.

ACKNOWLEDGMENTS

This work was partly supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (Ministry of Science and ICT). (No. 2020M2D2A2062436).

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