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Assessing terrain passability for effective crisis management

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Abstract:

Crisis management encompasses activities focused on preventing, preparing for, responding to, and recovering from crisis situations, with particular attention to their spatial dimensions. Access to detailed spatial information is crucial for determining optimal access routes to danger zones, especially in remote areas without established transportation infrastructure. This research tackles the challenge of planning emergency routes in such off-road areas and presents findings that offer practical solutions.

The influence of terrain on risk assessment and crisis management has been widely studied. Ahola et al. (2007) explored spatiotemporal models to enhance risk assessment and decision-making in rescue operations, while Rehak et al. (2019) focused on the dynamic modelling of critical road infrastructure failures. Hošková-Mayerová (2015) emphasized the importance of spatial data quality for accurate crisis management decisions. Additionally, Cai (2005) introduced a GIS architecture for crisis management, with applications also highlighted in works on forest fire and earthquake management. Rybanský (2009, 2020) contributed significantly to the understanding of terrain passability, analysing the impact of terrain relief and vegetation on vehicle movement in off-road crisis situations.

Specifically, the study demonstrates the potential use of a previously developed methodology, introduced by Dawid et al. (2022), for identifying access routes to hard-to-reach locations outside the regular transport network . By integrating the existing road network with terrain passability maps, high-resolution digital terrain models, and vehicle traction parameters, the approach enables a detailed analysis of microrelief, ensuring that inaccessible areas are effectively excluded from potential routes. This comprehensive method enhances the ability to navigate challenging terrains during crisis situations, thereby improving the overall effectiveness of crisis management efforts.

A key factor in crisis situations is the speed of reaching the destination. Challenges arise when the destination lies outside the established road network, requiring rescue vehicles to traverse difficult terrain. In this study, the process of generating access routes is divided into two stages. First, the route is determined using the existing paved road network. The second stage involves determining the route from the nearest paved road to the destination, using passability maps developed with an automated passability map generation system, as detailed in Pokonieczny (2017).

The methodology operates as follows: first, a passability map is created based on land cover data. In this study the authors utilized OpenStreetMap data. Next, the starting and ending points for the route are identified. If the destination is situated away from the road network, an additional point is selected on a paved road, positioned as close as possible to the destination. With all essential points determined, the algorithm calculates the most efficient route between the starting point and the additional point on the paved road. The final stage involves mapping out a cross-country route using a graph with traversal costs derived from the terrain passability map, while excluding impassable areas based on detailed microrelief analysis. The whole workflow of the algorithm is presented in Figure 1.

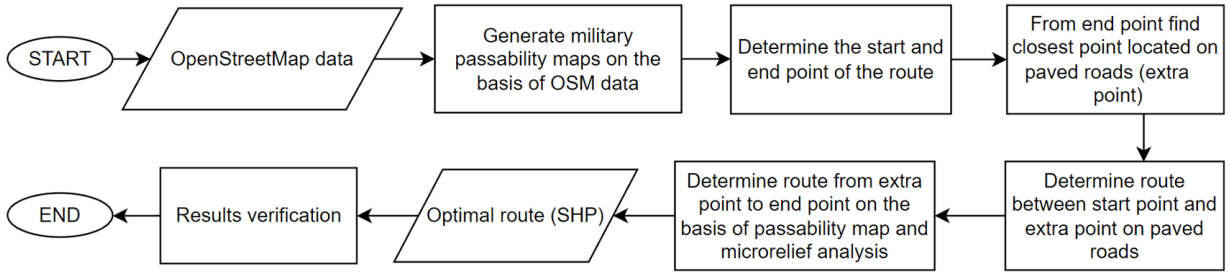

Figure 1. Workflow of the route determination process.

The methodology was applied in a case study conducted in Warsaw-West County, Poland. It focused on two single-family homes situated far from paved roads, complicating access for rescue operations. It modelled a fire emergency scenario requiring intervention by a fire truck from the local County Fire Station (MAN TGM 15.290 BL vehicle), highlighting the challenges of reaching these remote locations. The results were further validated through terrain verification. The study area, as well as the determined routes using the described methodology, are presented in Figure 2.

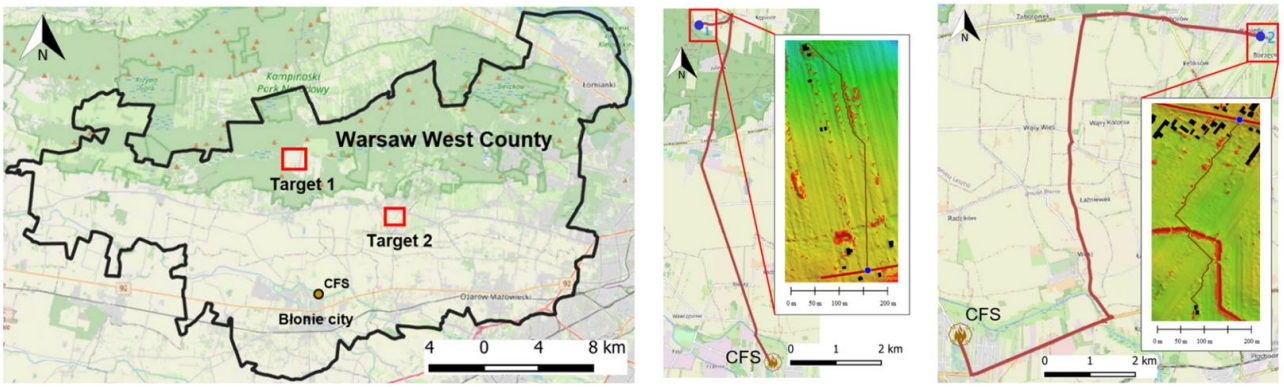

Figure 2. Study area and determined routes to two objects.

In conclusion, effective crisis management depends on accurate spatial information to ensure swift access to emergency sites, especially in remote areas. This study showcases a methodology for determining access routes to hard-to-reach locations by combining passability maps, terrain models, and vehicle traction parameters. The approach, validated through a case study in Warsaw-West County, involves first mapping routes via paved roads and then optimizing cross-country access. This methodology improves navigation through challenging terrains, enhancing overall emergency response effectiveness.

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