

Dynamic Cartography of Terrain Mobility: A GeoAI and Web Mapping Approach to Passability Assessment

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Abstract:

Cartographic representations of terrain accessibility have traditionally relied on relatively static interpretations of land cover, relief, and surface conditions. Yet terrain passability is inherently dynamic: it is shaped by the interaction of topographic structure, land-use patterns, soil properties, meteorological variability, and the operational context of movement. This creates a methodological and cartographic challenge. The problem is not only how to estimate passability more effectively, but also how to represent it in a way that supports comparison, interpretation, and decision-oriented map use. This paper presents a dynamic cartographic framework for terrain mobility assessment that combines GeoAI-based modelling, GIS-derived spatial analysis, and interactive web mapping in a single analytical environment.

The proposed approach is based on the transformation of heterogeneous geospatial data into a regular representation of elementary spatial units. Terrain is divided into a grid of 100×100 m cells, and each cell is assigned a continuous passability coefficient normalized to the range from 0 to 1. This coefficient expresses the relative difficulty of movement across the terrain and serves as the central cartographic variable of the study. Within each elementary unit, vector data are translated into quantitative descriptors, including the area of surface features, the length of linear objects, the number of point features, and terrain-slope characteristics. In this way, a discrete vector description of geographic space is converted into a continuous analytical surface suitable for both statistical modelling and thematic mapping.

On this basis, passability is estimated using an artificial neural network trained on terrain-related attributes derived from geospatial data. At the same time, GIS-based modelling pathways are retained, making it possible to compare two different representational logics within one cartographic framework: rule-based spatial modelling and data-driven prediction. The paper argues that this comparative dimension is especially important for contemporary cartography. GeoAI should not be understood only as a computational tool that improves prediction; it should also be treated as a generator of alternative map outputs whose spatial patterns, local discrepancies, and interpretive consequences can be explored visually.

The framework is extended through the integration of soil and weather information, including time-dependent environmental conditions. As a result, passability is represented not as a fixed terrain property, but as a dynamic spatio-temporal layer. This shift has important cartographic implications. It transforms terrain mobility from a static thematic topic into a processual phenomenon that can be examined under changing scenarios and at different moments in time. To support this type of analysis, the study implements a thematic geoportal that provides access to processed spatial information through interactive map services. The application supports layer management, split-screen comparison of modelling results, point-based querying of local conditions, temporal exploration using a time slider, and route planning based on passability-aware cost functions. In this environment, the map becomes not merely a final visualization, but the principal interface for analytical reasoning.

The paper also addresses the issue of reliability and interpretive limits. The source studies indicate that discrepancies may appear where training data are sparse, incomplete, or poorly representative of local terrain complexity, including wetland areas and land-use categories insufficiently captured in the input datasets. They also point to the broader problem of spatial and temporal generalizability: a model trained on one region or one implicit seasonal context may not perform identically in another. From a cartographic perspective, these limitations are not peripheral. They raise the question of how uncertainty, inconsistency, and contextual dependency should be communicated through dynamic thematic maps.

The contribution of the study is therefore threefold. First, it proposes a cartographic representation of terrain passability as a continuous and time-sensitive spatial variable. Second, it demonstrates how GeoAI- and GIS-derived outputs can be brought into a shared comparative mapping framework. Third, it shows that web cartography can function as an analytical medium for exploring, not merely displaying, complex modelled geographies of accessibility. In this sense, the paper positions dynamic passability mapping as a broader problem of representation, comparison, and interpretation in contemporary cartography.

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References

- Dawid, W., Pokonieczny, K. and Wyszyński, M., 2022. The methodology of determining optimum access routes to remote areas for the purposes of crisis management. *International Journal of Digital Earth*, 15, pp. 1905–1928. <https://doi.org/10.1080/17538947.2022.2134936>
- Pokonieczny, K. and Wyszyński, M., 2016. Automation of the terrain assessment classification due to passability for the needs of crisis management. <https://doi.org/10.5593/SGEM2016/B23/S11.016>