3D Analysis of Mountain Bike Trail Difficulty in Whistler, British Columbia

Introduction

Whistler Mountain Bike Park in British Columbia is one of the world's top lift-accessed bike parks. With over 130 trails across four zones, it offers routes for all skill levels, from beginner-friendly paths to expert-level descents. Spanning 80 km and reaching 2,182 m in elevation, its rugged terrain and steep slopes make it ideal for geospatial analysis of how elevation and slope impact trail difficulty. This study focuses on an area extending from 50°08'48"N to 50°08'50"N and 122°54'25"W to 122°54'35"W.

Mountain bike trails are ranked based on factors like slope, elevation changes, surface conditions, and obstacles. The IMBA Trail Difficulty Rating System categorizes trails from easy to expert using metrics like trail grade and terrain roughness. Slope is a key factor, where gentle inclines suit beginners, while steep grades with sharp elevation changes demand technical skill. These ratings help riders choose trails that match their experience level.

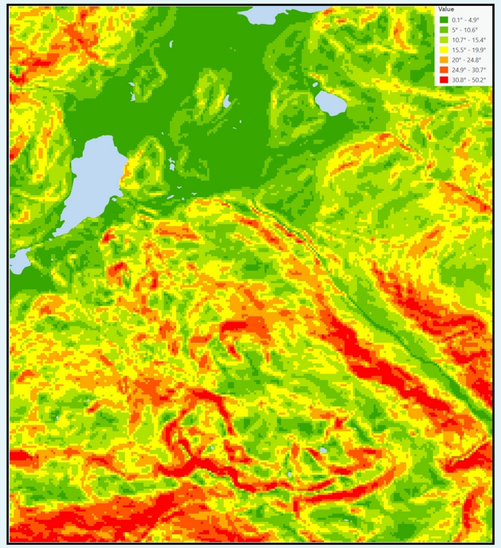

Figure 2: Slope raster showing terrain steepness across the study area. Steeper slopes in red indicate more difficult trails Values in degrees.

Future Improvements

This analysis focused only on elevation and slope, but other factors like surface conditions, obstacles, and weather can also play a role in determining the difficulty of mountain bike trails. Future improvements could also use other sources of high-resolution elevation data, and land cover such as forests and water bodies to refine classifications. Furthermore, aspect could help analyze trail exposure and sun direction, while viewpoints could highlight visibility and scenic value. In particular viewshed analysis could also identify good rest spots, assess trail visibility, and help plan signage for navigation and safety.

Data Sources:
Digital Elevation Model and Elevation Features data provided by Government of Canada; Natural Resources Canada; Earth Sciences Sector
Whistler Trails Polylines data provided by Trailforks (https://www.trailforks.com/region/whistler/)
World Imagery Basemap provided in ArcGIS Pro by Esri Canada

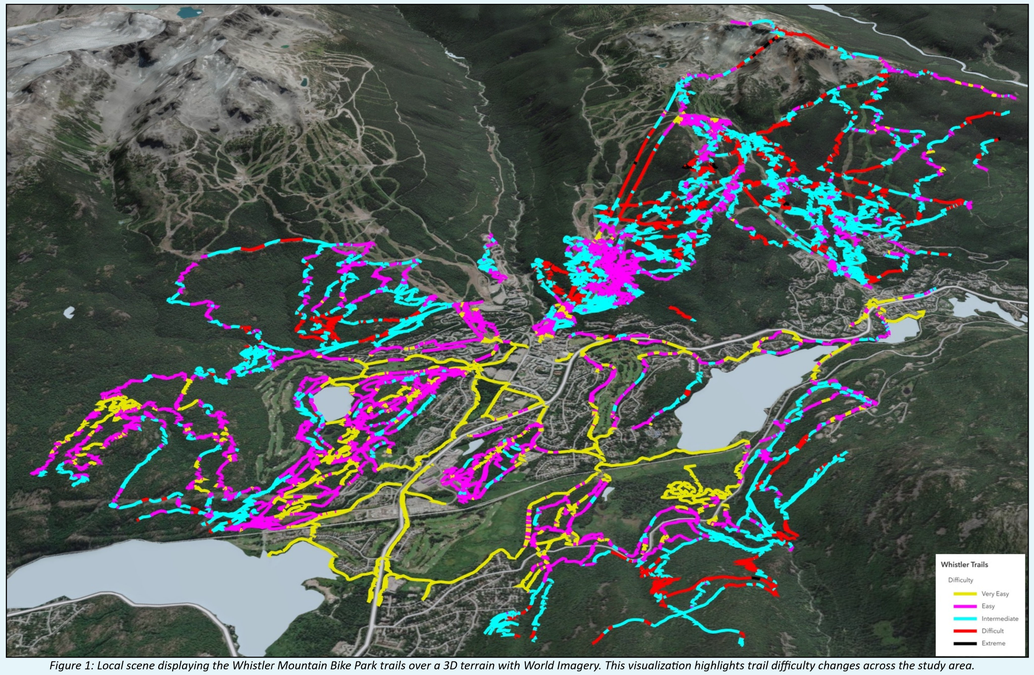

Figure 1: Local scene displaying the Whistler Mountain Bike Park trails over a 3D terrain with World Imagery. This visualization highlights trail difficulty changes across the study area.

Process

This project used a step-by-step GIS workflow to analyze trail difficulty based on elevation and slope within a 10 × 10 km study area of Whistler Mountain Bike Park. Elevation data was sourced from Canada's Open Maps, while trail polylines came from Trailforks.

First, a TIN was created from contour data to visualize terrain. The Slope tool was then used to generate a slope raster, which calculates terrain steepness—critical for classifying trail difficulty. An aspect raster was also created using the Aspect tool to determine slope direction, though it was not used for classification.

Next, the Reclassify tool grouped slope values into five difficulty levels, simplifying interpretation by converting continuous slope values into ranked categories. The Spatial Join tool was then used to assign classified slope difficulty and aspect values to trail polylines, allowing for detailed queries based on trail conditions. To create the Web Scene, trails were draped over the 3D elevation surface to match the terrain accurately. The DEM-derived surface served as the elevation source, aligning trail polylines for realistic placement. Symbology was adjusted to highlight trail difficulty, enhancing visualization for exploring and analyzing riding conditions.

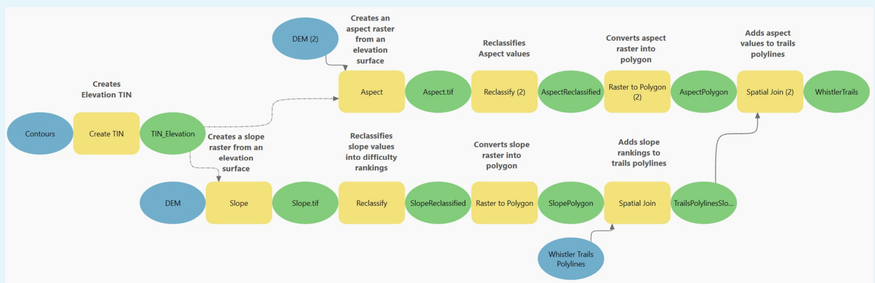

Figure 4: Model used in the project to automate slope and aspect raster creation, classifying trail difficulty, and assigning values to trails for visualization and analysis.

Purpose

GIS technology enables advanced 3D analysis, transforming elevation data into highly accurate digital landscapes. Digital Elevation Models (DEM) and Triangulated Irregular Networks (TIN) visualize terrain, allowing trails to be classified by slope and orientation. This helps assess difficulty in real-world conditions, aiding both riders and land managers in data-driven decisions for trail maintenance, safety, and route recommendations.

The purpose was to use GIS-based 3D analysis to assess and visualize mountain biking trail difficulty. By processing elevation data and analyzing slope values, trails were classified by difficulty. A 3D surface was built, trail data overlaid, and slope analysis integrated to accurately represent riding conditions.

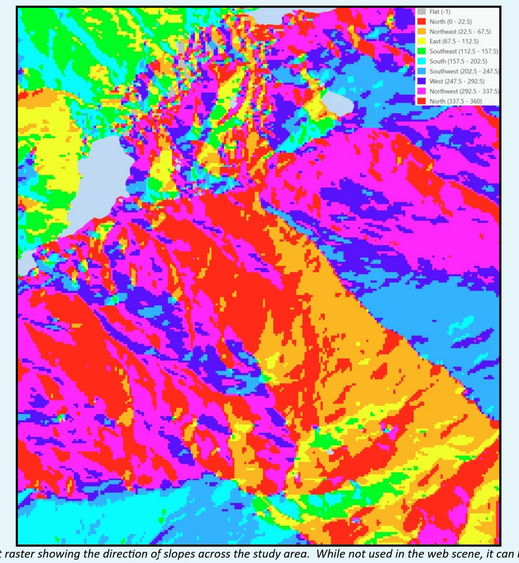

Figure 3: Aspect raster showing the direction of slopes across the study area. While not used in the web scene, it can help analyze factors such as sun exposure, erosion, and trail conditions.

Conclusion

Trails were ranked into five difficulty levels—very easy, easy, intermediate, difficult, and extreme—based on slope. Steeper trails were classified as more challenging and were primarily found in mountainous areas, while flatter trails were ranked as easier. The analysis showed that extreme and difficult trails followed steep, rugged terrain, whereas very easy and easy trails were on gentler slopes. In the web scene, this gradient is visible in 3D, allowing for a clear visualization of how slope changes across the trails. This classification provides insight into trail accessibility and can assist riders in route planning based on skill level.

This poster is produced as a portion of of the requirements of the Geographic Information System Certificate Program at the Centre of Geographic Sciences, NSCC, Lawrencetown, Nova Scotia

Produced by Antonio Hernandez for GISY6020: Advanced GIS course
February 28, 2025

Centre of Geographic Sciences COGS | nscc
esri Canada | Centre of Excellence