COLUMBIA CLIMATE SCHOOL
CENTER FOR INTEGRATED
EARTH SYSTEM INFORMATION

Data Release Notes

Name of the dataset	GRID3 COD - Travel Time Friction Surface v1.0
Name of the file	GRID3_COD_mix_travel_time_friction_surface_v1_0.tif GRID3_COD_walk_travel_time_friction_surface_v1_0 .tif
Date of data release	January 09, 2026
File format	Tiff
Dataset version	v1.0
Abstract	This document outlines the methodology and data sources used to produce the *GRID3 COD - Travel Time Friction Surface v1.0* dataset. This operational dataset has not been fully validated by government officials or ministries.
Dataset citation	Center for Integrated Earth System Information (CIESIN), Columbia University. 2026. GRID3 COD - Travel Time Friction Surface v1.0. New York: Columbia University. https://doi.org/10.7916/11yp-gs23. Accessed <DAY MONTH YEAR>.
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Contacts and data queries	The authors of this dataset appreciate feedback regarding the data, including suggestions, discovery of errors, difficulties in using the data, and format preferences. For dataset-related questions, please send an email to: info@ciesin.columbia.edu

I. Input Data

Multiple input data were used to create the *GRID3 COD - Travel Time Friction Surface v1.0,* see table 1 below.

Table 1. Data inputs

Name	**Data type/ format**	**Release year**	**Input data year**
Global elevation from Copernicus, at 30 m resolution	raster	2015	varies
Land use/ land cover (LULC) from ESRI's Living Atlas, using Sentinel-2 data, at 10 m resolution	raster	2024	2024
Rivers and water bodies from OpenStreetMap (OSM), downloaded in May 2025.	vector	2025	varies
GRID3 COD Roads v1.0	vector	2025	varies
Travel time data table derived from the GRID3 COD Roads v1.0	tabular	2025	varies

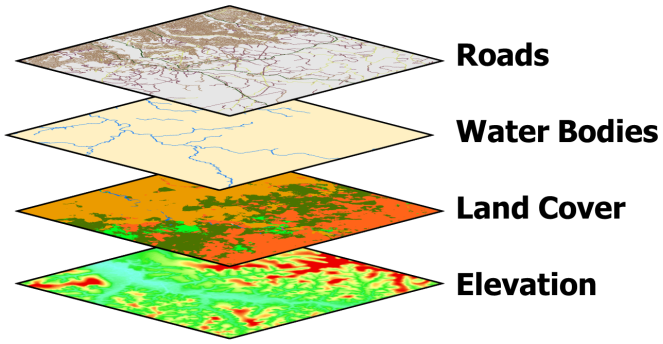
II. Methodology

In this work we generated two friction surfaces (walking and mixed) at a 30-m resolution for the entirety of the DRC. Friction surfaces are, raster-based models of accessibility, with each pixel representing the cost of traversing an area. The walking friction surface represents the cost of walking only, while the mixed friction combines walking and motorized travel speeds. Motorized speeds are applied exclusively on roads that are present and passable by vehicles; in all other areas, walking speeds were used. The units for both friction surfaces are minutes per meter, with larger values representing longer travel times. Other inputs included elevation, which was used to adjust walking speed, landcover which was used to set travel speeds for areas outside of roads, and water features which were used as barriers.

Friction Surface Workflow

The friction surface was created using multiple input layers including elevation, landcover, roads, and waterways.

Figure 1. Input data for the friction surface.



A 30-m Digital Elevation Model (DEM) data was obtained from Copernicus GLO-30. This DEM was used as the footprint for the friction surfaces, with other layers resampled to match the GLO-30 DEM. An elevation adjustment factor was calculated to represent the decrease in travel speed with increased altitude (Weiss et al., 2018).

$$Equation\ 1:\ 1.016e^{-0.0001072\ x\ elevation}$$

An additional slope layer was derived from the DEM using the Slope tool in ArcGIS Pro. The slope layer was used to adjust the walking travel time using Tobler's hiking function[2].

$$Equation\ 2:\ 6e\ *\ (-\ 3.5\ |tan\ *\ S\ /\ 57.296\ +\ 0.05|)\ /\ 5$$

Where S is the slope of a pixel (Tobler, 1993).

Land cover for 2024 was obtained from ESRI's Living Atlas. This data was developed using Sentinel-2 data at a 10-m resolution which we resampled to the GLO-30 DEM's 30-m footprint. Walking speeds were set for both the walking and mixed friction surface depending on the difficulty of traversing each land cover type. In general, walking speeds range from 3-5 km/h. Land covers without obstacles like urban areas and grass were set to the higher end of this range while those with obstacles like trees, shrubs, and crops were set to the lower end. Even more difficult to traverse land covers like ice and flooded areas were set even lower. The full list of travel speeds for each land cover type can be found in Table 1.

Road data was taken from GRID3's COD roads v1.0, which combines data from Overture/OSM, Meta, and field-collected GPS data. Roads were rasterized at a 30-m resolution to the GLO-30 DEM's 30-m footprint, retaining their travel speed in km/h as an attribute. Water cover was derived from both the ESRI landcover data and OSM's waterway lines layer where ESRI's data did not capture existing water bodies. OSM waterway lines were also rasterized at a 30-m resolution to the GLO-30 DEM's 30-m footprint. Both ESRI water bodies and rasterized OSM waterways were classified as natural barriers and assigned slow travel speeds of 0.0001 km/h. In the walking friction surface, roads corresponding to travel via boat (water tracks) were ignored as they are not accessible by walking. However, they are included in the mixed friction surface, where travel by boat may be an option.

Rasterized roads and rivers were stacked with land cover, with precedent given to roads, rivers, and then land cover. In the walking friction surface, travel speeds were used from the Walking speed column of

Table 2, and Motorized vehicle speeds were used for the mixed friction surface when available. Finally, elevation and slope adjustments were applied to walking speeds, and speed (km/h) was converted to minutes per meter[3].

$$Equation\ 3\text{: } (Speed\ *\ 1000\ /\ 60)^{-1}$$

Figure 2. Visualization of the friction surface and differences between the walking and mixed datasets.

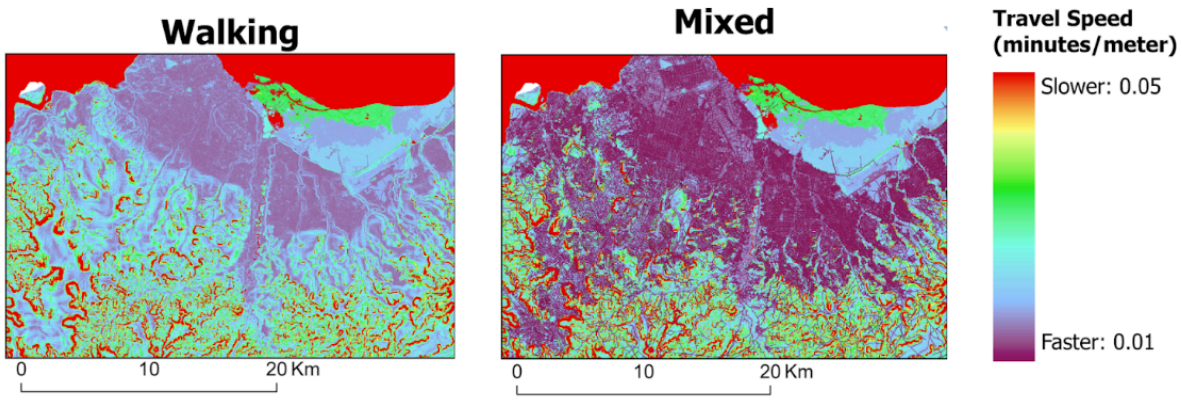


Table 2. Travel time based on feature class and type

Feature class	Feature type	Walk speed(kph)	Motorized vehicle speed(kph)	Estimated speed method
Road	Trunk	4.5	Variable	GPS/Modeled
Road	Primary	4.5	Variable	GPS/Modeled
Road	Secondary	4.5	Variable	GPS/Modeled
Road	Tertiary	4.5	Variable	GPS/Modeled
Road	Water track	-	Variable	GPS
Road	Motorway	4.5	80	Literature review
Road	Unclassified	4.5	40	Literature review
Road	Living street	4.5	20	Literature review
Road	Residential	4.5	20	Literature review
Road	Track	4.5	10	Literature review
Road	Service	4.5	10	Literature review

Feature class	Feature type	Walk speed(kph)	Motorized vehicle speed(kph)	Estimated speed method
Road	Footway	4.5	-	Literature review
Road	Path	4.5	-	Literature review
Road	Pedestrian	4.5	-	Literature review
Road	Steps	4	-	Literature review
Road	Unknown	4.5	Variable	Literature review/GPS
Land cover	Rivers/waterways	0.0001	-	Literature review
Land cover	Water bodies	0.0001	-	Literature review
Land cover	Trees	3	-	Literature review
Land cover	Grass	4.5	-	Literature review
Land cover	Flooded vegetables	2	-	Literature review
Land cover	Crops	2.5	-	Literature review
Land cover	Shrubs	3.6	-	Literature review
Land cover	Built areas	4.5	-	Literature review
Land cover	Bare ground	3	-	Literature review
Land cover	Snow/ices	1.6	-	Literature review
Land cover	Clouds	3	-	Literature review
Land cover	Rangeland	3.6	-	Literature review

Data Processing Outputs

Two friction surfaces were created based on travel modality:

- **Walking friction surface:** Applies walking speeds across the entire surface, adjusted for road class, slope, and elevation.
- **Mixed-mode friction surface :** Applies motorized speeds on roads and walking speeds in all other areas.

The unit of measurement in both surfaces is **minutes per meter**, representing the time required to traverse each cell.

III. Dataset Description

The *GRID3 COD - Travel Time Friction Surface v1.0* dataset is a spatial data layer in tiff format. The datasets contain 2 layers:

- GRID3_COD_walk_travel_time_friction_surface_v1_0.tif
- GRID3_COD_mix_travel_time_friction_surface_v1_0.tif

The resolution is 30 m. The unit of measurement in both surfaces is minutes per meter. The metadata file is included in xml format.

IV. Known Data Limitations and Disclaimer

CIESIN, Columbia University, and its co-authors follow procedures designed to ensure that data disseminated by the project are of reasonable quality. If, despite these procedures, users encounter apparent errors or misstatements in the data, they should contact CIESIN, info@ciesin.columbia.edu.

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V. Acknowledgements

Funding for the development and dissemination of this dataset was provided by GRID3 under the Gates Foundation's project INV-044979.

VI. References

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