

A Preliminary Analysis of Building Collapse Direction in La Guaira, Caraballeda, and Catia La Mar Following the 2026 Venezuela Earthquakes

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ABSTRACT

This study examines the estimated collapse directions of 158 completely collapsed buildings in La Guaira, Caraballeda, and Catia La Mar following the June 24, 2026 Venezuela earthquakes of moment magnitudes 7.2 and 7.5. Collapse direction was estimated from the vector joining the centroid of each pre-earthquake building footprint to the centroid of its post-earthquake debris footprint in satellite imagery. Each mapped collapse was independently reviewed by at least two members of the research team. For 140 buildings with sufficiently clear geometry, alignment between collapse direction and the short building dimension (SBD) was also evaluated.

The mapped azimuths show a concentration toward north and west. Fifty-eight buildings (36.7%) fall within 30° of north, and 98 (62.0%) fall within the 120° sector extending clockwise from 270° through north to 30°. The circular mean of the individual collapse azimuths is 326.12°, in the northwest quadrant.

In the building-relative analysis, 79 of 140 buildings (56.4%) have a collapse direction within 30° of the SBD. These results indicate a geographical directional tendency and a separate tendency for collapse to align with the building short dimension. The imagery-based method is descriptive and does not by itself establish the physical cause of the observed directional pattern.

Keywords: *earthquake, collapse direction, Venezuela, La Guaira, satellite imagery, GeoLibre*

1 INTRODUCTION

Two earthquakes of moment magnitudes 7.2 and 7.5 occurred in northern Venezuela on June 24, 2026 (USGS, 2026). The present study focuses on 158 buildings mapped as completely collapsed in La Guaira, Caraballeda, and Catia La Mar. The objective is to characterize the aggregate distribution of estimated collapse directions and to assess whether a preferred geographical direction is apparent.

A common mapped collapse direction may reflect several interacting influences, including ground shaking, structural configuration, terrain, urban layout, and the space available for debris to spread. An imagery-based direction estimate must also be distinguished from the trajectory of the building during failure. Here, a centroid-to-centroid vector is used as a proxy for collapse direction,

and the possible effects of measurement and environmental bias are considered when interpreting the distribution.

A second analysis compares collapse direction with the short building dimension (SBD). This building-relative measure is intended to distinguish alignment with plan geometry from the geographical azimuth of collapse. The SBD should not be interpreted automatically as a structural weak axis; establishing structural weakness would require additional information on the lateral-force-resisting system, stiffness, strength, and damage mechanism.

2 DATA AND METHODS

2.1 Satellite imagery

Pre- and post-earthquake satellite imagery was overlaid and visually compared using GeoLibre, an open-source geographic information system. We consider this GIS because of its web-based visualization. The imagery was used to delineate pre-event building footprints and post-event debris footprints. The images are not perfectly correlated; but conclusions on direction are considered valid.

2.2 Collapse-vector mapping

For each mapped building, a vector was drawn from the centroid or side of the pre-earthquake building footprint to the centroid or side of the corresponding post-earthquake debris footprint. The azimuth of this vector, measured clockwise from the adopted north reference, was used as the estimated collapse direction. Because the vectors were drawn manually, individual azimuths are subject to small deviations. These are not expected to affect the main results.

2.3 Review procedure

Each mapped collapse was independently reviewed by at least two members of the research team. This procedure provides a visual check of the footprint interpretation and the assigned vector direction.

2.4 Circular mean direction

Figures 1 and 2 use twelve equal 30° azimuth bins for visualization. The mean direction is calculated directly from the individual azimuths, with each building given equal weight. For azimuths α measured clockwise from north, the mean east and north components are the averages of $\sin(\alpha)$ and $\cos(\alpha)$, respectively. The circular mean is obtained as $\text{atan2}(\text{mean east}, \text{mean north})$ and expressed from 0° to 360° (Berens, 2009).

This circular calculation treats 0° and 360° as the same direction and avoids the artificial discontinuity of an arithmetic average of azimuths. Histogram bins are used only for visualization, not to compute the mean. In the rose diagram, radius is proportional to the square root of count, so equal-width sector areas are proportional to frequency.

2.5 Alignment with the short building dimension

The short building dimension (SBD) is treated as an unoriented line, so directions separated by 180° are equivalent. For collapse azimuth α and SBD orientation β , let $r = \text{mod}(\alpha - \beta, 180^\circ)$. The minimum angular deviation is $\delta = \min(r, 180^\circ - r)$, giving 0° for parallel alignment and 90° for perpendicular alignment.

This comparison includes 140 buildings (88.6% of the original sample). The remaining 18 buildings (11.4%) were excluded from the SBD analysis because their plan geometry did not allow a clear SBD to be identified. Deviations are summarized in 10° bins over 0° – 90° .

3 INTERACTIVE MAP

The mapping project contains four layers: Arrows, showing the mapped collapse vectors; Arrows, showing short building direction; Post Event, showing the post-earthquake imagery and debris; and Pre Event, showing the study areas before the earthquakes. A comparison slider allows users to inspect the two image dates and review vector placement.

Download Map: [10.5281/zenodo.2326566](https://zenodo.org/record/2326566)

Load to local Geolibre or web service (<https://web.geolibre.app/>)

Visualize in Web Browser: <https://venezuela-building-collapse.netlify.app>

4 RESULTS

4.1 Distribution by direction

Table 1 reports the 158 mapped collapse directions in twelve equal 30° azimuth bins. Using equal-width sectors avoids comparing counts over different angular exposures.

Azimuth interval	Buildings	Share
0° – 30°	29	18.4%
30° – 60°	11	7.0%
60° – 90°	6	3.8%
90° – 120°	1	0.6%
120° – 150°	2	1.3%
150° – 180°	5	3.2%
180° – 210°	12	7.6%
210° – 240°	9	5.7%
240° – 270°	14	8.9%
270° – 300°	20	12.7%



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Azimuth interval	Buildings	Share
300°–330°	20	12.7%
330°–360°	29	18.4%
Total	158	100.0%

4.2 Mean collapse direction

The circular mean calculated from the individual collapse azimuths is 326.12° , in the northwest quadrant. The two bins adjacent to north (330° – 360° and 0° – 30°) contain 58 buildings (36.7%). The four bins from 270° through north to 30° contain 98 buildings (62.0%). These summaries describe the geographical distribution but do not identify its physical cause.

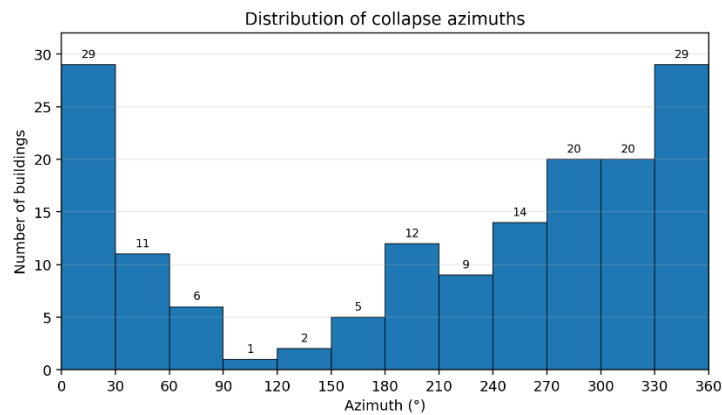


Figure 1. Estimated collapse azimuths for 158 buildings in equal 30° bins. Heights and labels give counts; the first and last bins are adjacent around north.

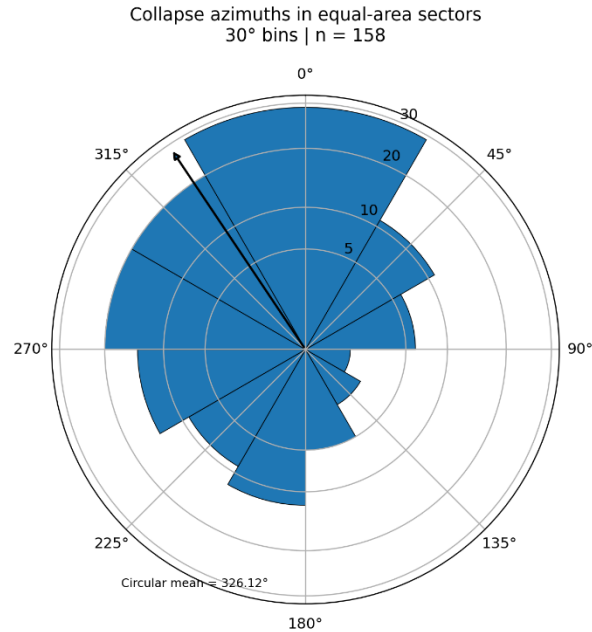


Figure 2. Equal-area rose diagram of the 158 collapse azimuths in 30° bins. North is at 0° and azimuth increases clockwise. Petal area is proportional to count. The arrow marks the circular mean of 326.12°; its length is illustrative and is not a statistical measure.

4.3 Alignment between collapse direction and the SBD

Figure 3 shows a concentration at small angular deviations from the SBD. The successive 10° bins from 0° to 90° contain 36, 28, 15, 15, 9, 8, 8, 12, and 9 buildings, respectively, summing to the 140 analyzed buildings. The modal interval is 0°–10°, with 36 buildings (25.7%); the first two intervals together contain 64 buildings (45.7%).

The first three bins, spanning 0°–30°, contain 79 buildings (56.4%). The 30°–60° and 60°–90° ranges contain 32 (22.9%) and 29 (20.7%), respectively (Table 2). Thus, the largest share is close to parallel with the SBD, although 61 buildings (43.6%) occur between 30° and 90°.

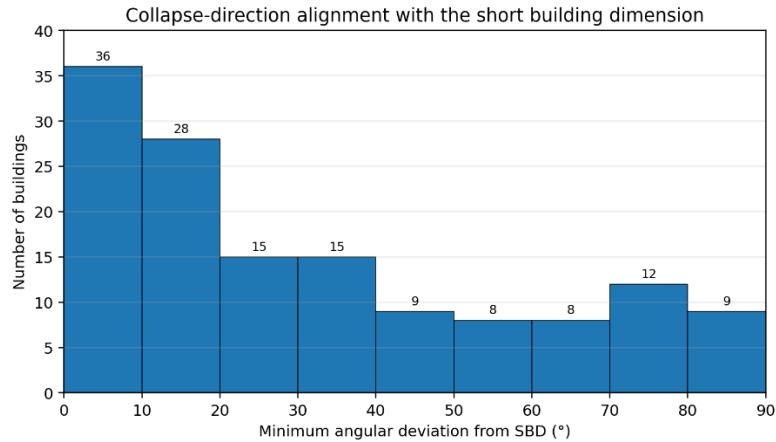


Figure 3. Minimum angular deviation between estimated collapse direction and the identified short building dimension (SBD) for 140 buildings, in 10° bins. Opposite directions along the SBD are equivalent: 0° denotes parallel alignment and 90° perpendicular alignment. Eighteen buildings with geometrically ambiguous SBD were excluded.

Table 2. SBD angular deviation grouped into equal 30° ranges. The last range includes 90°.

Deviation range	Interpretation	Buildings	Share
0°–30°	Closer to parallel	79	56.4%
30°–60°	Intermediate	32	22.9%
60°–90°	Closer to perpendicular	29	20.7%
Total		140	100.0%

5 DISCUSSION

5.1 Terrain, urban layout, and image-based debris geometry

The reported sample shows a concentration toward north and west, but the mapped vectors describe the displacement of debris-footprint centroids rather than the physical trajectory of a building during failure. Local slopes may favor downslope debris movement, while streets, adjacent open areas, and neighboring buildings may constrain the final debris footprint. The SBD comparison provides a building-relative measure, but it does not isolate the effects of street orientation or local terrain.

5.2 Building geometry

The SBD analysis shows that 56.4% of the 140 evaluable buildings have a mapped collapse direction within 30° of the short plan dimension. This is a meaningful descriptive association with building geometry, but the SBD is not necessarily the structural weak axis. Confirming a structural

mechanism would require information on the lateral-force-resisting system, stiffness and strength distribution, torsional characteristics, irregularities, and observed damage sequence.

6 CONCLUSIONS

Collapse directions were estimated for 158 completely collapsed buildings from vectors joining pre-earthquake building-footprint centroids to post-earthquake debris-footprint centroids. The mapped azimuths show a directional concentration: 58 buildings (36.7%) lie within 30° of north, and 98 (62.0%) lie in the 120° sector extending clockwise from 270° through north to 30° . Only 8 buildings (5.1%) lie in the 90° – 180° sector.

The circular mean of the individual collapse azimuths is 326.12° , indicating an average direction in the northwest quadrant. This result summarizes the geographical tendency of the mapped vectors without establishing the physical cause of that tendency.

For the 140 buildings with an identifiable short building dimension, 79 (56.4%) have a collapse direction within 0° – 30° of the SBD, compared with 32 (22.9%) at 30° – 60° and 29 (20.7%) at 60° – 90° . This supports a descriptive tendency for mapped collapse direction to align with the building short dimension. The 18 exclusions with ambiguous geometry should be considered when generalizing the result.

The observed distribution does not by itself establish ground-motion polarization, rupture directivity, or a structural weak-axis mechanism. Image geometry and registration, terrain, urban layout, building structural characteristics, and the limitations of the centroid method should be evaluated before a physical explanation is assigned.

DATA AVAILABILITY

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

AI USE

AI was used to improve the writing of this document.

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