

Installation-Sensitive Empirical Fragility Assessment of Manufactured Housing under Hurricane Wind Hazards in Florida

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Preliminary results suggest post-2008 manufactured homes in Florida perform better at the lowest damage state: DS1+ exceedance is lower than for 1994–2007 homes in every shared wind-speed bin.

DS1+ exceedance

share of FEMA-inspected homes per wind bin, 40–80 mph

86–92%

1994–2007 homes

VS

62–71%

Post-2008 homes

Preliminary · FEMA proxy damage states

Introduction

Manufactured home hurricane vulnerability is influenced by more than wind intensity alone. Construction era, installation and anchorage quality, retrofits, deterioration and accessory structures can all affect observed damage.

This study asks: *at comparable wind speeds, do 1994–2007 and post-2008 manufactured homes in Florida differ in the exceedance of proxy damage states?*

Regulatory Milestones

- 1994**
HUD revision introduces Wind Zones I–III
- 1999**
Florida anchorage and installation rules
- Oct. 2008**
24 CFR Part 3285 installation standards
- 1994–2007 | Post-2008**
Built 1994–2007 vs. 2008 or later (DOR)

Methods

Dataset, Florida 2004–2025

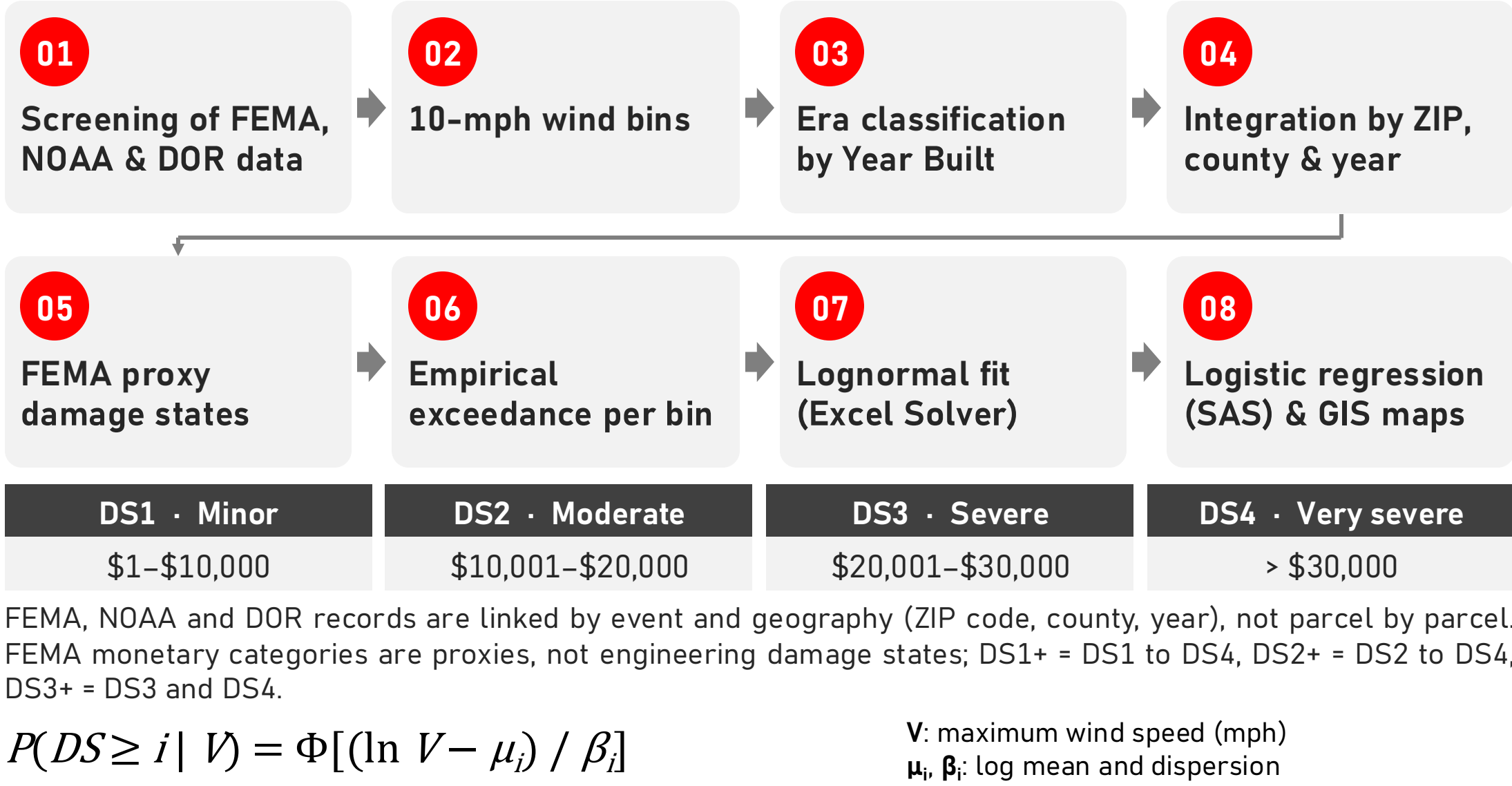
1,665,032
FEMA inspections, both eras

847,879
inspections, 1994–2007 homes

817,153
inspections, post-2008 homes

61.2 / 55.6 mph
mean maximum wind, by era

Research Workflow and Proxy Damage States



Next Steps

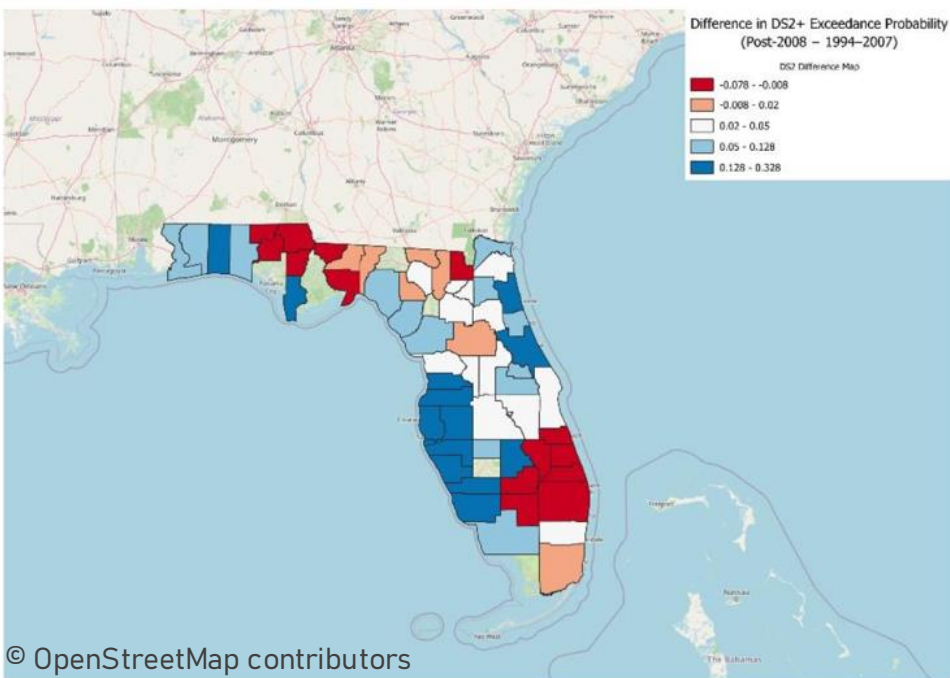
- Robustness:** leave one hurricane out, resample records, and use common-dollar losses.
- Explanation:** test if accessory and proxy effects drive the higher post-2008 DS2+ to DS4.
- Mechanics:** model pre-1994, 1994–2007 and post-2008 anchorage configurations.

Aggregate Exceedance

Damage state	1994–2007	Post-2008
DS1+	88.63%	64.55%
DS2+	2.98%	14.21%
DS3+	1.12%	5.67%
DS4	0.77%	2.50%

Aggregate rates do not account for wind speed, and the post-2008 inventory is concentrated in the 50-mph bin, so the eras are also compared within each wind bin.

DS2+ Spatial Difference and Observed Damage



County DS2+ difference (post-2008 minus 1994–2007)

Red counties: lower post-2008 DS2+; blue counties: higher. Both occur in several regions, consistent with local exposure and aggregation effects.

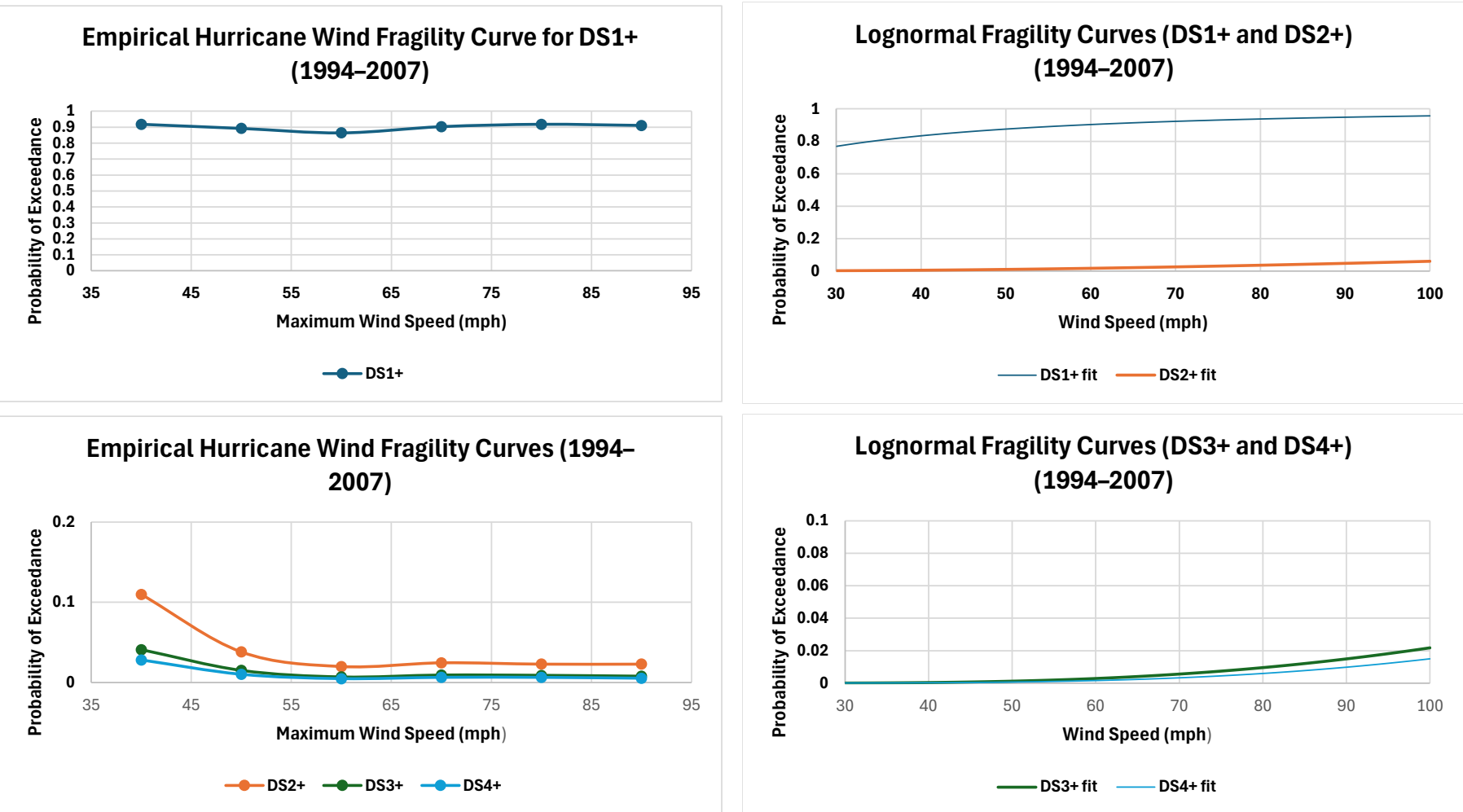


Example of interior damage of DS2+ severity

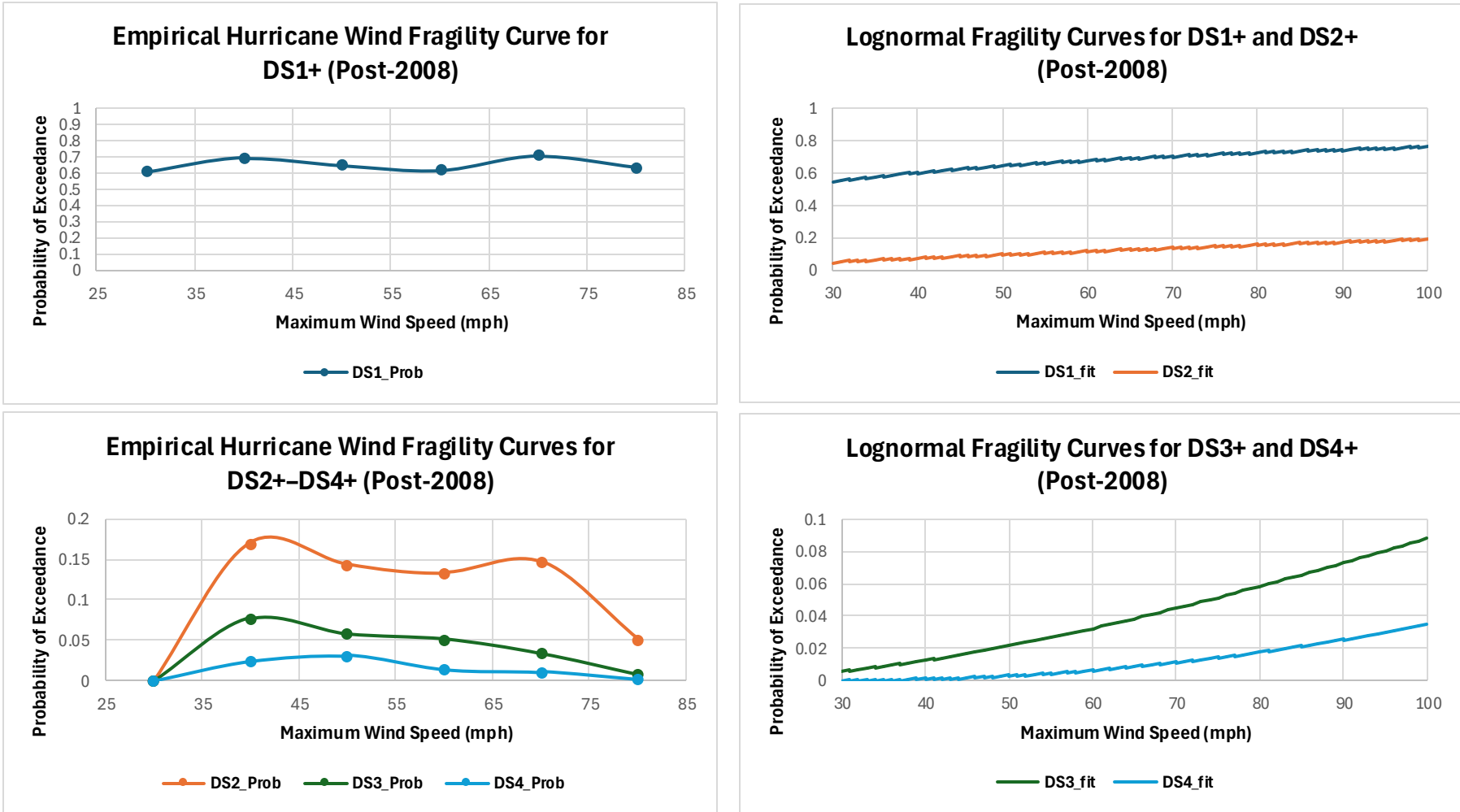
Preliminary Results

- DS1+** was lower for post-2008 homes in every shared wind bin from 40 to 80 mph: 62–71% versus 86–92%.
- Logistic regression:** compared with 1994–2007 homes, post-2008 homes show lower odds of DS1+ and higher odds of DS2+.

(a) 1994–2007 homes



(b) Post-2008 homes



Preliminary Conclusions

- Damage is not governed by wind speed alone:** exceedance differs by era at comparable wind speeds in the preliminary results.
- Higher post-2008 DS2+ to DS4 is being tested:** it is not direct evidence of weaker homes.
- Accessories escalate damage:** reconnaissance reports show that newer homes often stay on their foundations while carports and roof-over systems fail; mitigation should extend beyond the primary home.

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References

- HUD (2007). *Model Manufactured Home Installation Standards; Final Rule* (24 CFR Part 3285). Federal Register, 72(202).
- Sutley, E. J., et al. (2020). *Performance of manufactured housing during Hurricanes Irma and Michael*. J. Perform. Constr. Facil., 34(4).
- Marquez, P. J., et al. (2026). *Performance of manufactured home anchorage systems after Hurricane Michael*. J. Perform. Constr. Facil., 40(3).
- FLHSMV (2022). *Hurricane Ian Storm Damage Assessment*. Florida Dept. of Highway Safety and Motor Vehicles.
- Data: FEMA Individual Assistance housing inspections; NOAA NCEI Storm Events Database; Florida DOR property records.