Single Egress Stairway Apartment Building Study

TAG Meeting No. 2| June 26, 2025

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Welcome

Nicholas Ozog | Associate Principal - Wiss, Janney, Elstner Associates, Inc.

Kyle Christiansen | Consultant – Crux Consulting

Carl Baldassarra | Senior Principal - Wiss, Janney, Elstner Associates, Inc.

Agenda – TAG Meeting No. 2

9:00 – 9:30 a.m.	Introduction - DLI
9:30 – 9:45 a.m.	Recap and Update Since Last TAG Mtg
9:45 – 10:45 a.m.	Review of Findings to Date
10:45 – 11:30 a.m.	Review of Modeling Information
11:30 a.m. – 12:00 p.m.	Conclusions - DLI

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Recap and Update Since Last TAG Meeting

Nicholas Ozog | Wiss, Janney, Elstner Associates, Inc.

Plan from TAG Meeting No. 1

- [x] Interviews with TAG members
- [x] Collect data, papers, reports and perform literature review
- [x] Define fire scenarios
- [x] Investigate reliability and operability of mitigating systems
- [x] Model geometry
- [ ] Modeling
- [ ] Analysis
- [ ] Reporting

Objectives for TAG Meeting No. 2

- Recap the risk-informed approach
- Interview takeaways
- Insights from national and Minnesota data
  - Civilian fatalities, firefighter injuries
  - Fire scenarios
  - Equipment reliability
- Model geometries

Future Work After TAG Meeting No. 2

- Evaluate feedback received from TAG #2
- Finalize floor geometries
- Probability data for mitigating equipment
- Event tree / fault tree structure logic and quantification
- Modeling: fire, smoke, egress
- Draft report

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Summary of Risk-Informed Approach

Kyle Christiansen | Crux Consulting

Risk-Informed Approach

- Review data, literature
- Identify systems that mitigate consequences
- Assign probabilities of success / failure for each system
- Calculate the likelihood of each end state occurring
- Define and model fire scenarios to evaluate the consequence
- Perform comparative risk assessment for model geometries
- Understand the risk-significant mitigating systems

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Review of Findings to Date
TAG Interview Summary

Nicholas Ozog | Wiss, Janney, Elstner Associates, Inc.

TAG Interview Summary

- Thank you!
- Significant input and efforts from the group
- Representation from all the general sub-groups
- Not too late – Reach out to us

TAG Interview Summary

TAG Interview Summary

- Quantitative risk modeling using event trees and fault trees.
- Focus on sprinkler reliability, door closure effectiveness, and stairwell integrity.
- Seek Minnesota-specific data to improve modeling accuracy.
- Concerns about fire department staffing limitations, especially in rural areas.
- Highlight sprinkler system failures often due to human error (e.g., valve shutoffs).
- Stress the importance of education, maintenance, and realistic expectations for shelter-in-place strategies.

TAG Interview Summary

- Variability in enforcement, inspection, and reporting.
- Elevator inclusion driven by practicality, not just code.
- Emphasize the need for smoke control systems and compartmentalization in single-stair designs.
- Concerns about egress width, stretcher maneuverability, and elevator access.
- Flexible units, garden-level units offer design opportunities.
- Market drives requirements of affordability, lot size constraints, and unit sizing.
- Larger units more desirable post-COVID.
- Single-stair designs viable in smaller lots/buildings.
- Examples from New York, Seattle, and Europe where single-stair buildings are common.
- Emphasize the importance of passive systems, building separation, and realistic modeling.

TAG Interview Summary – Opportunities and Questions

- Sprinkler performance data (especially MN-specific, NFPA 13 vs 13R systems).
- Fire incident data (e.g., ignition sources, fire spread, injuries).
- Inspection and maintenance records (e.g., door closers, alarm systems).
- Building stock characteristics (e.g., construction type, floor count, elevator presence).
- Human behavior modeling (e.g., door propping, e-bike charging in stairwells).
- Potentially incomplete or inconsistent data (e.g., NFIRS, NFPA reports).
- Political and emotional issue.
- Importance and potential variability in enforcement and inspection across jurisdictions.
- Design trade-offs between safety, cost, and practicality.

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National Data Sources and Insights

Kyle Christiansen | Crux Consulting

Data Overview Summary

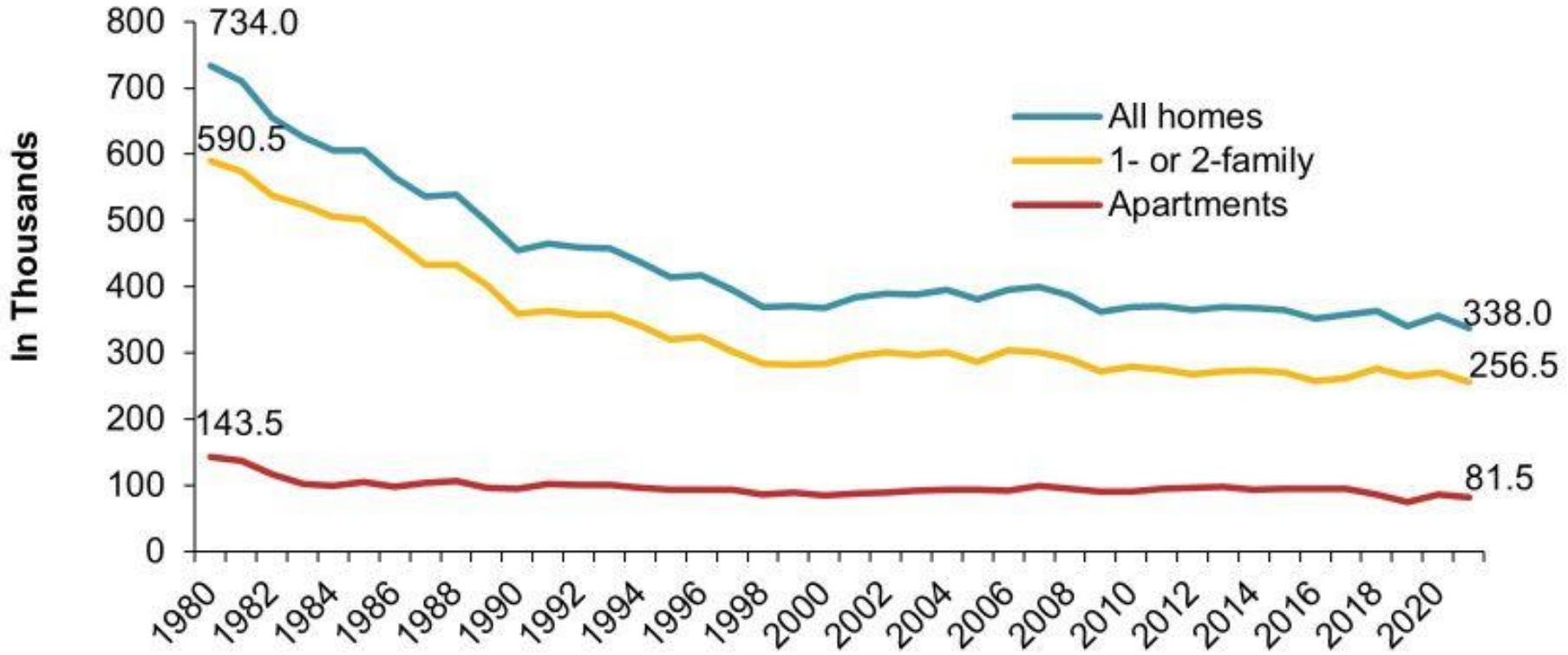
- Literature review
  - 40+ papers, reports, and journal articles (domestic, international)
- Stakeholder interviews
  - 12 TAG members interviewed for perspective and insights
- Data requests
  - NFPA, Minnesota State Fire Marshal's Office, National Fire Sprinkler Association, Housing First, Center for Building

National Fire Event Data Received

- National Fire Protection Association (NFPA)
  - Paid NFPA to perform custom analysis for MFH fire events from 1999 - 2023
- NFIRS data collection approach changed in 2003 (version 5.0)
- Current data limitations
  - NFIRS estimated to capture ~70% of annual fire events
  - NFPA applies scaling factor to reflect national data set
  - Number of exit stairs in a building not available
  - Variability in user interpretations of fields
  - Firefighter injuries not available

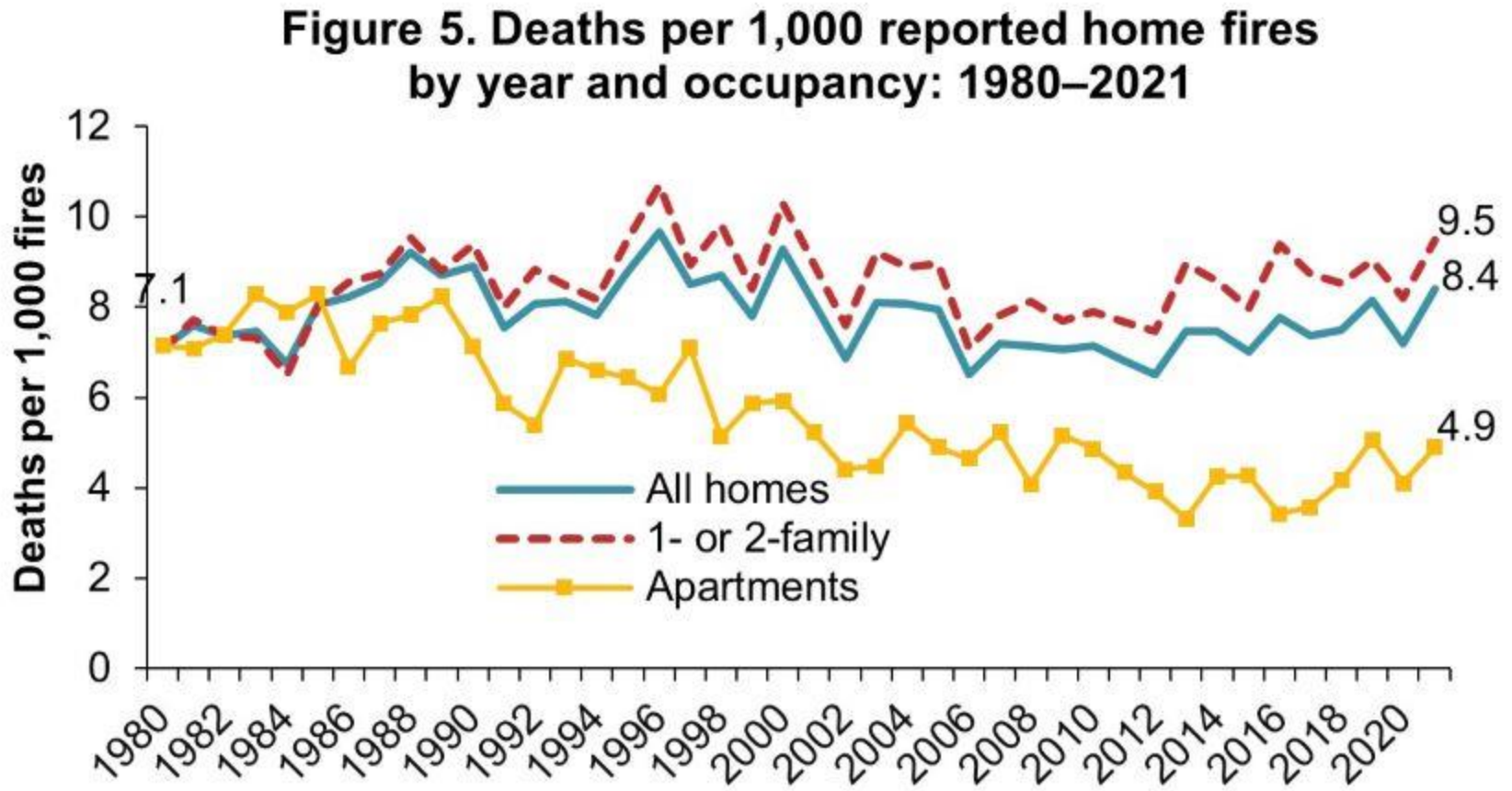
Residential Home Structure Fires (National)

Figure 1. Reported home structure fires by year: 1980–2021



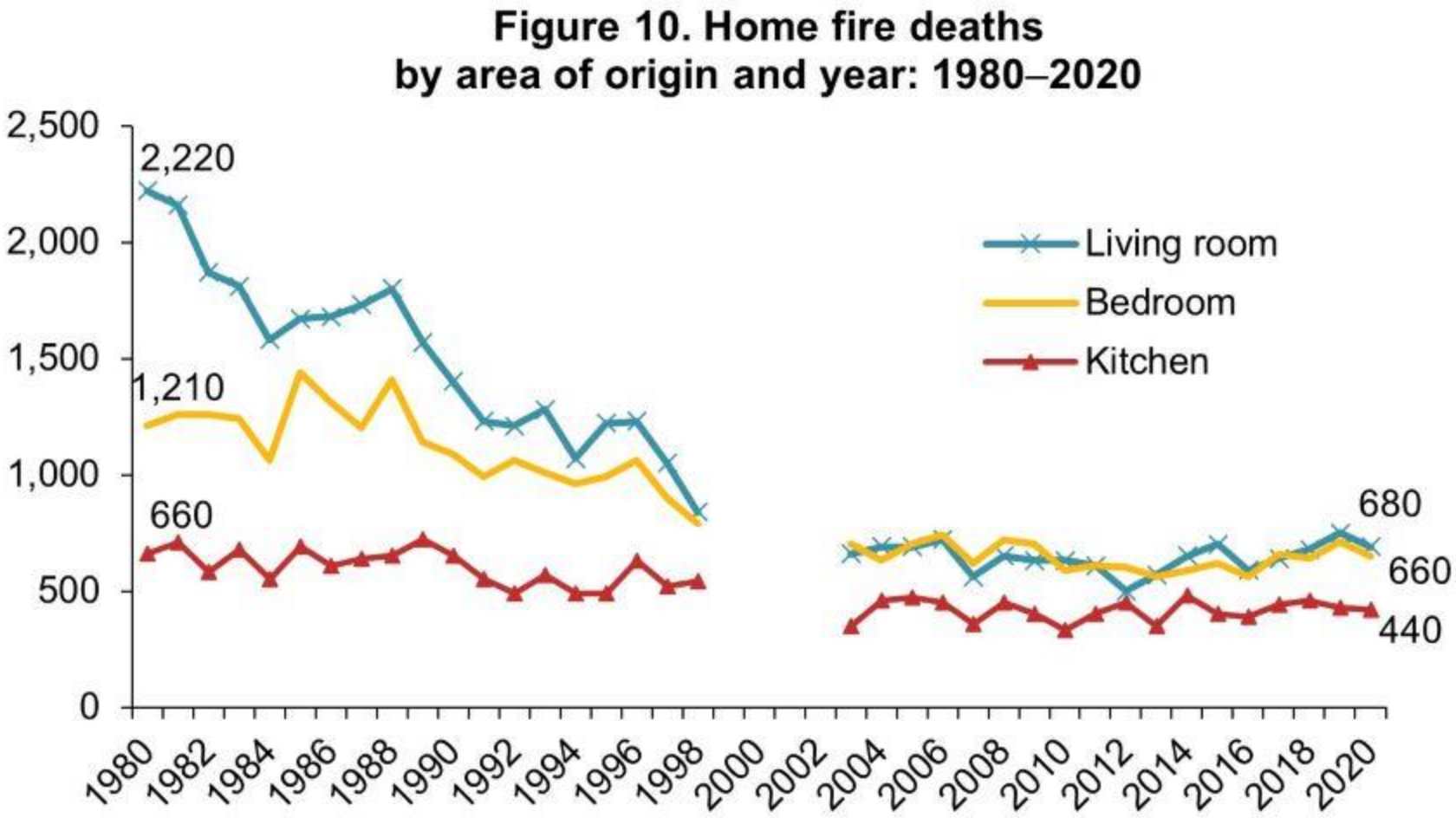
https://www.nfpa.org/education-and-research/research/nfpa-research/fire-statistical-reports/home-structure-fires

Normalized Residential Death Rate (National)



https://www.nfpa.org/education-and-research/research/nfpa-research/fire-statistical-reports/home-structure-fires

Home Fire Deaths by Area of Origin (National)



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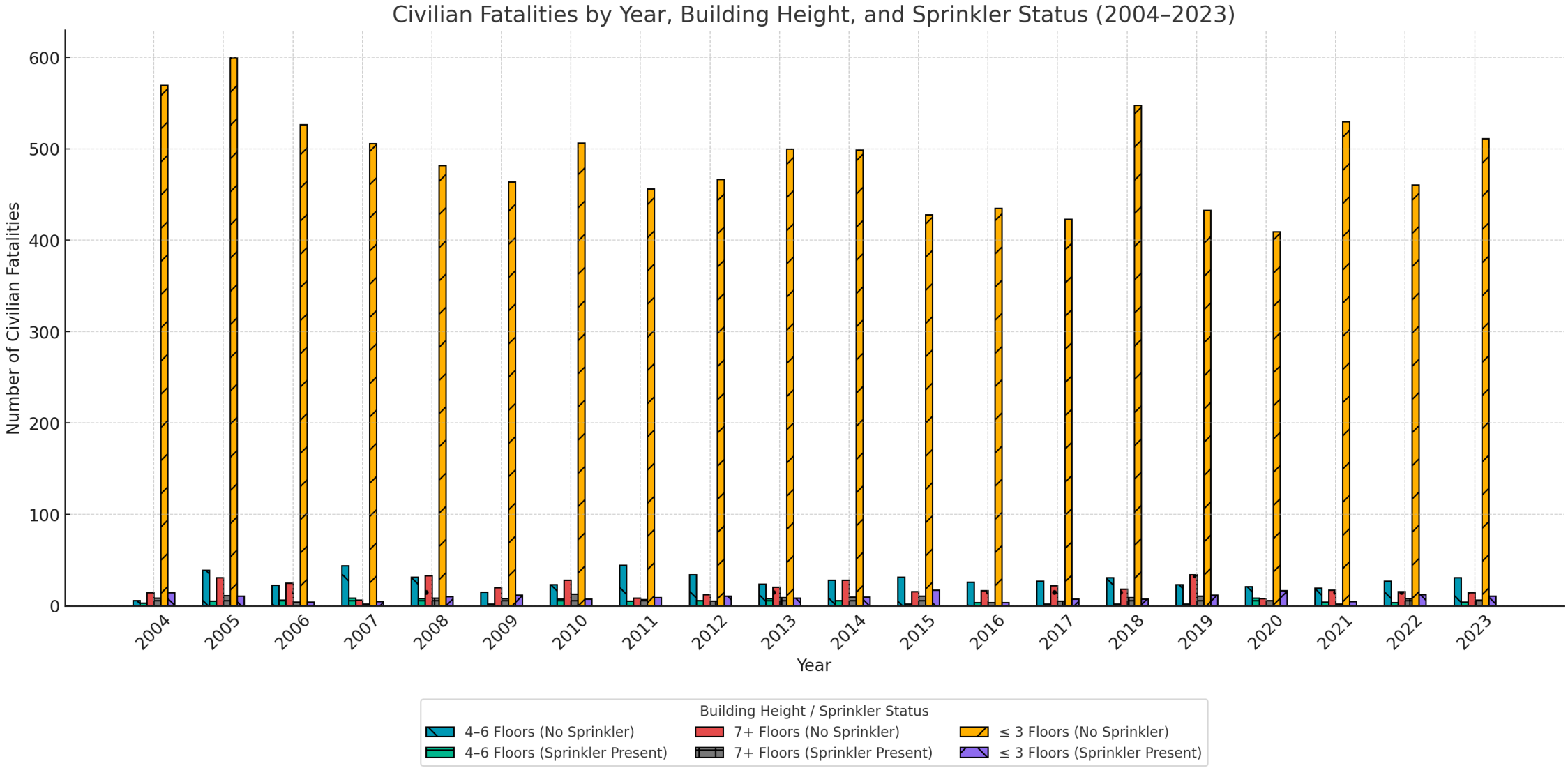
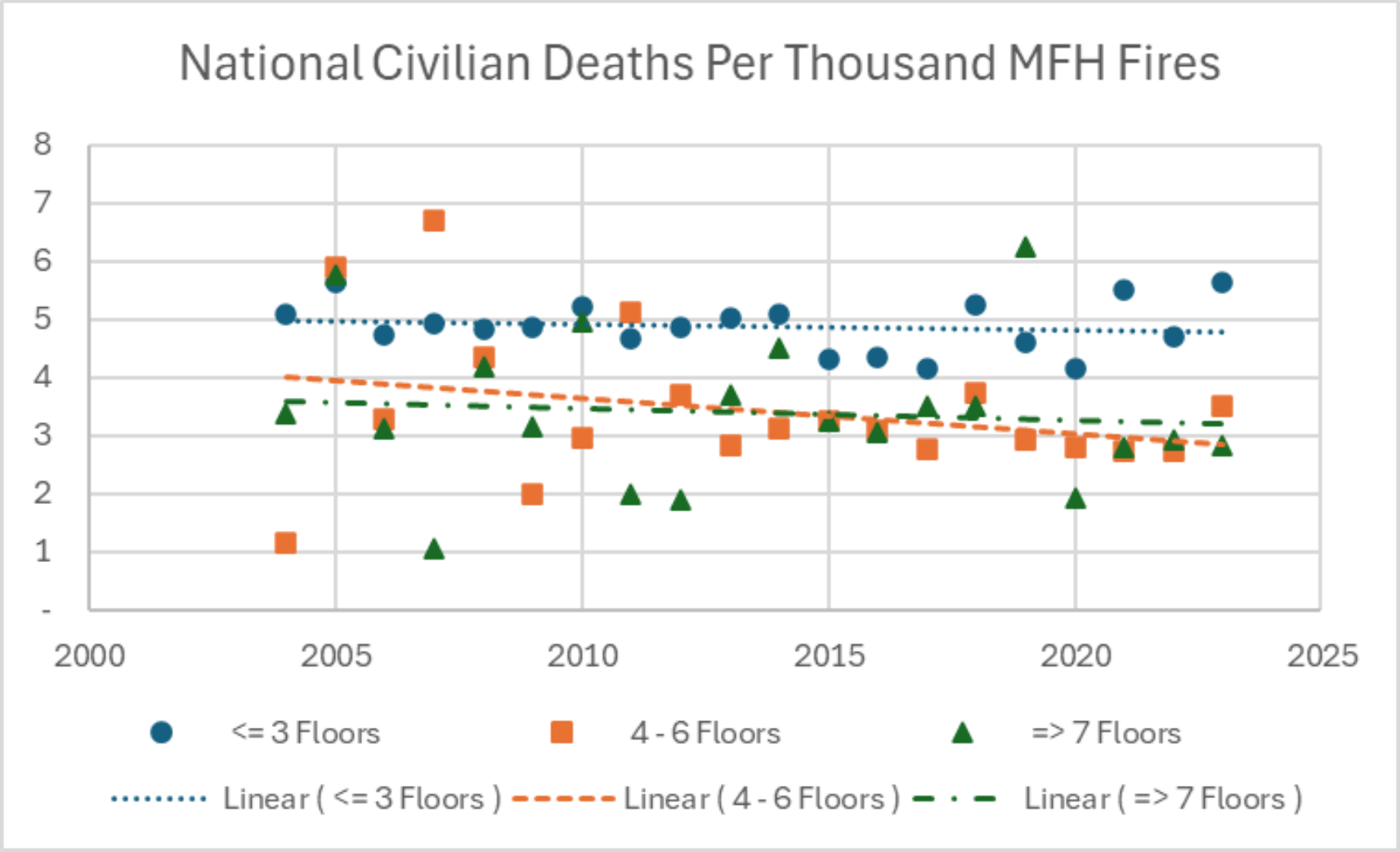
Civilian Fatalities in Multi-Family Housing (National)



NFPA Custom MFH Fire Event Data (2004 – 2023)

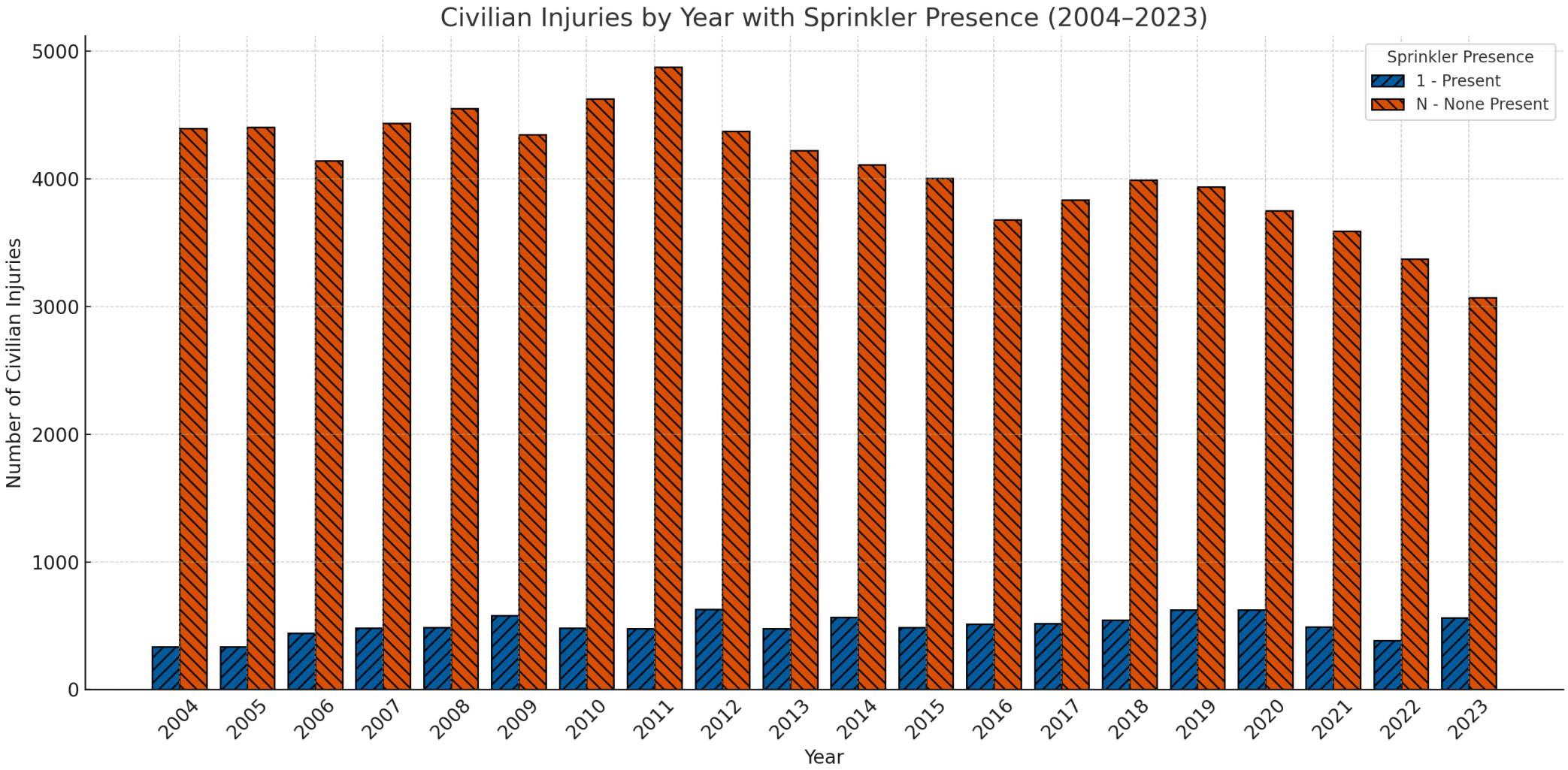
6/25/2025

Civilian Deaths vs Building Height (National)



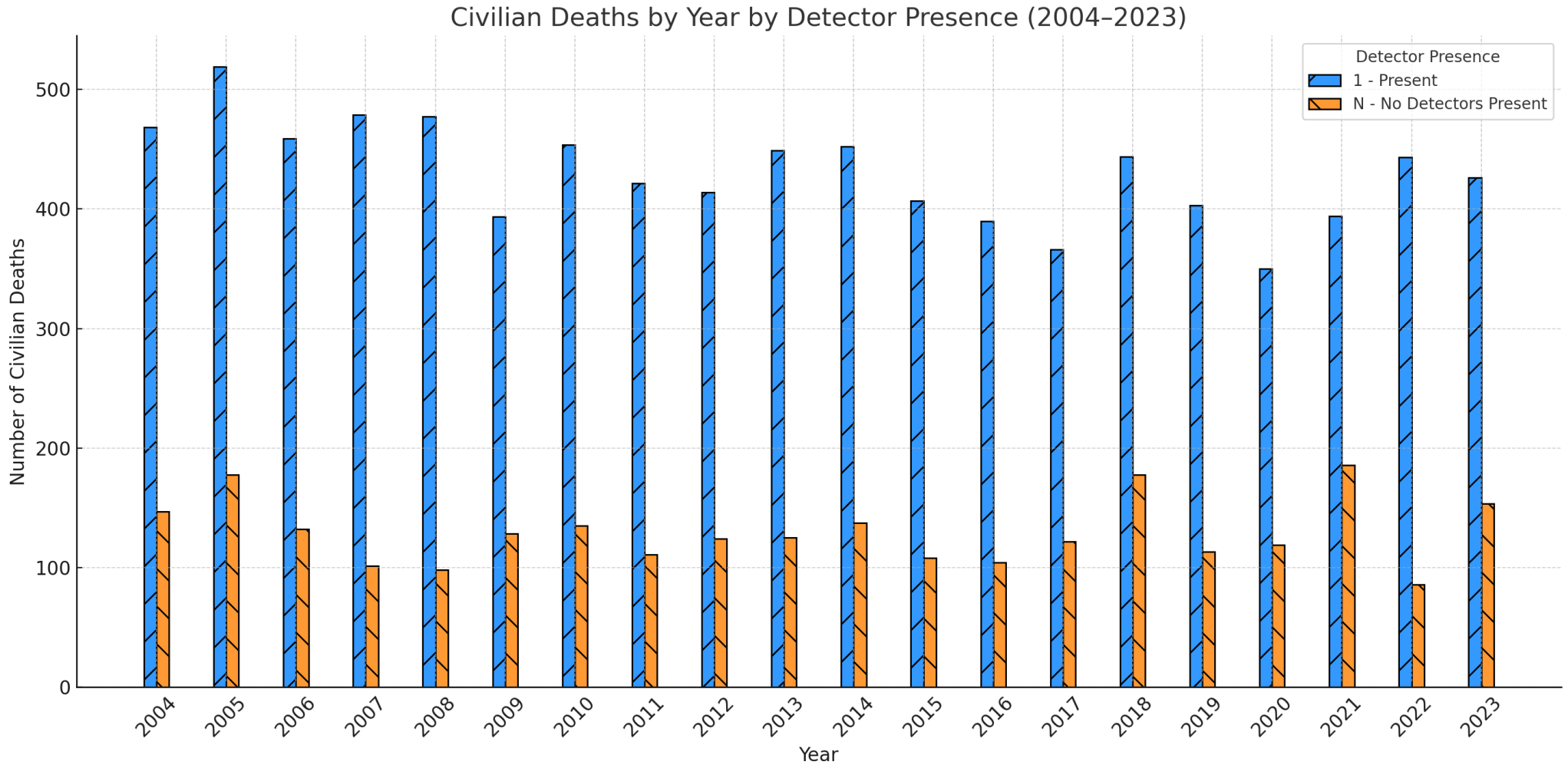
NFPA Custom MFH Fire Event Data (2004 – 2023)

Sprinkler Systems vs Civilian Injuries in MFH Fires (National)



NFPA Custom MFH Fire Event Data (2004 – 2023)

Smoke Detectors vs Civilian Deaths in MFH Fires (National)



NFPA Custom MFH Fire Event Data (2004 – 2023)

Smoke Detectors vs Deaths Per 1,000 Events in MFH Fires (National)

NFPA Custom MFH Fire Event Data (2004 – 2023)

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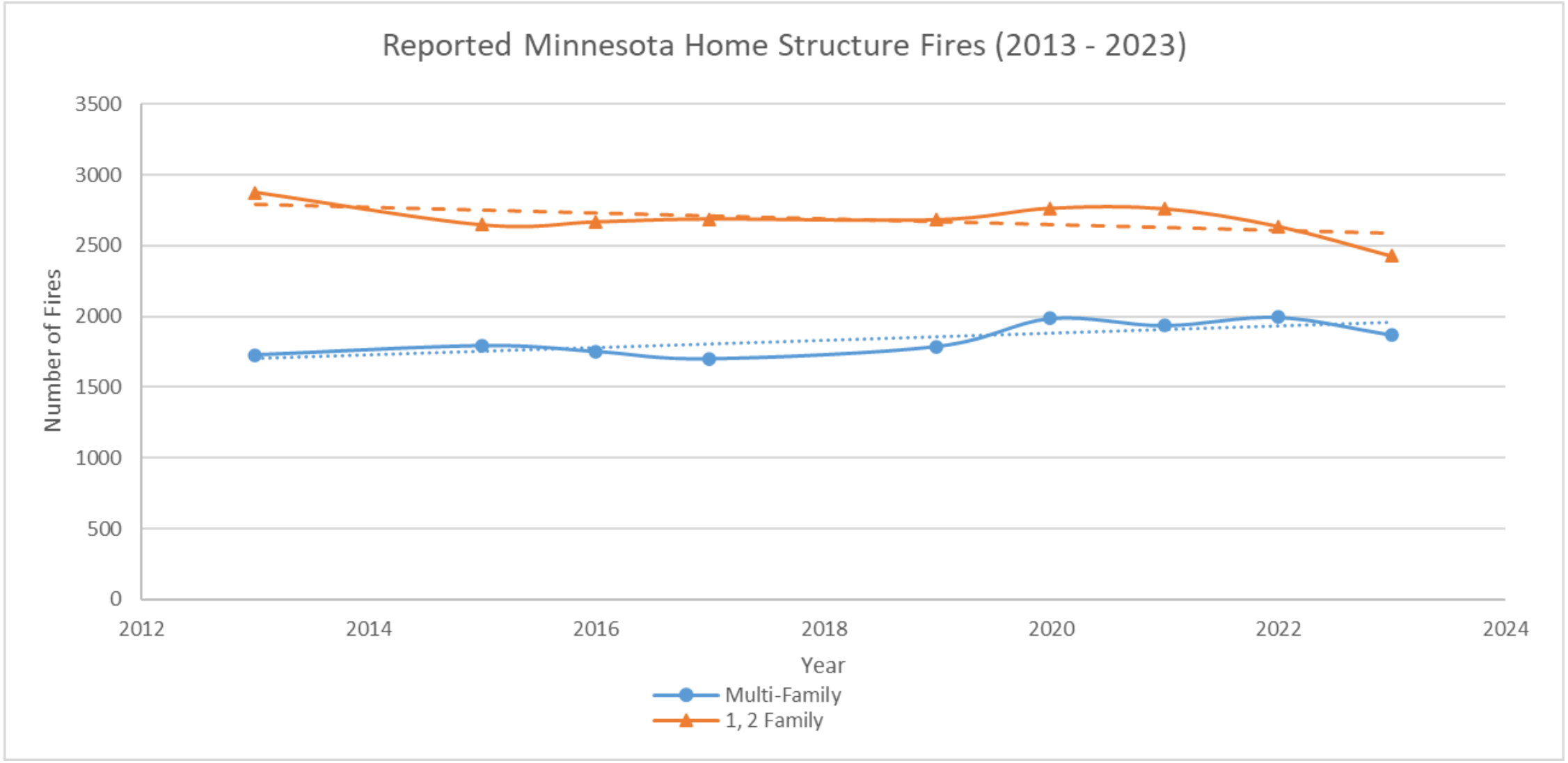
Minnesota Data Sources and Insights

Kyle Christiansen | Crux Consulting

Minnesota Fire Event Data Received

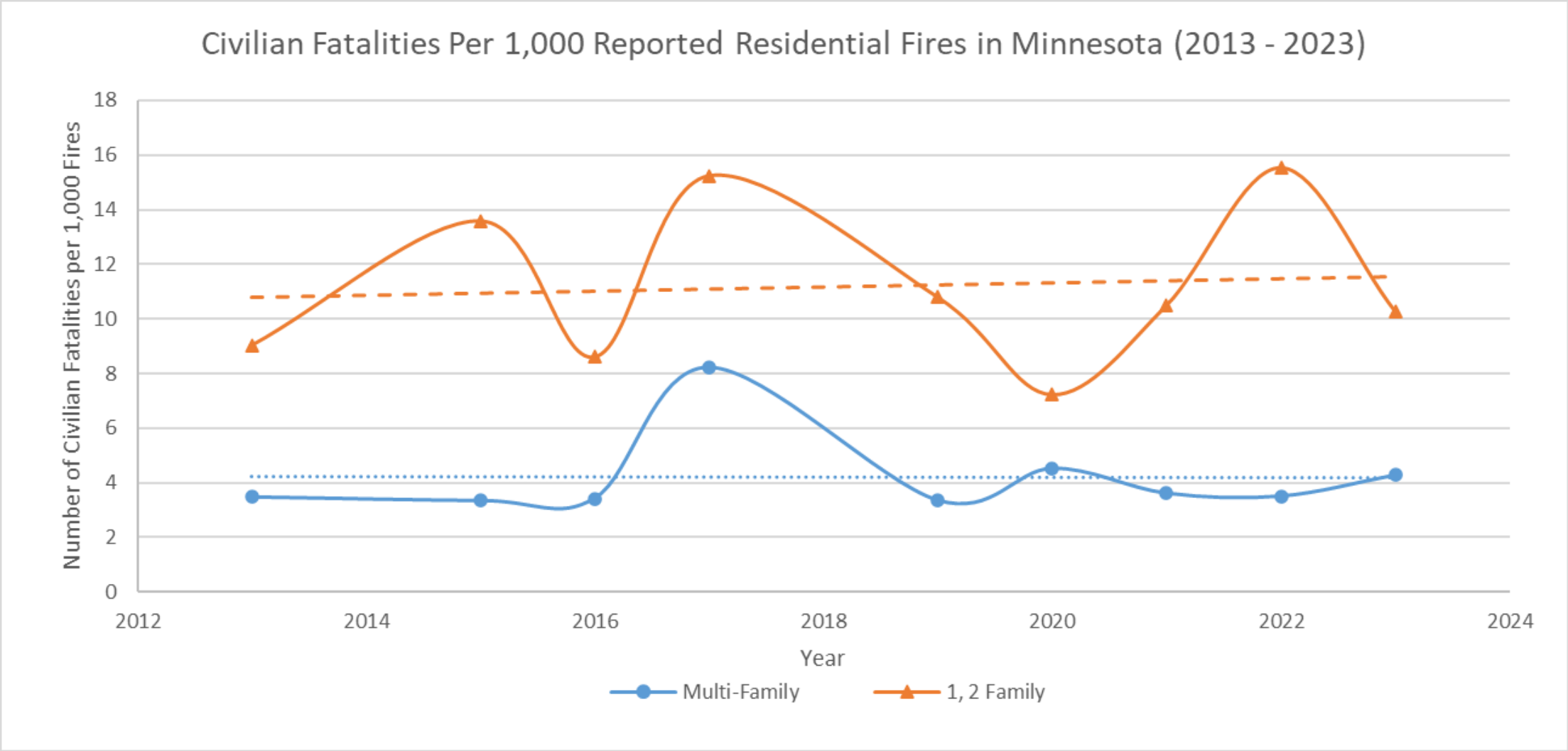
- Residential fires provided from 2002 - 2025
  - Data range analyzed: 2004 - 2024
- Minnesota data from the State Fire Marshal Division
- Consistently high (> ~92%) reporting from MN fire departments
- Minnesota Fire Statistics Reports published annually

Residential Home Structure Fires (Minnesota)



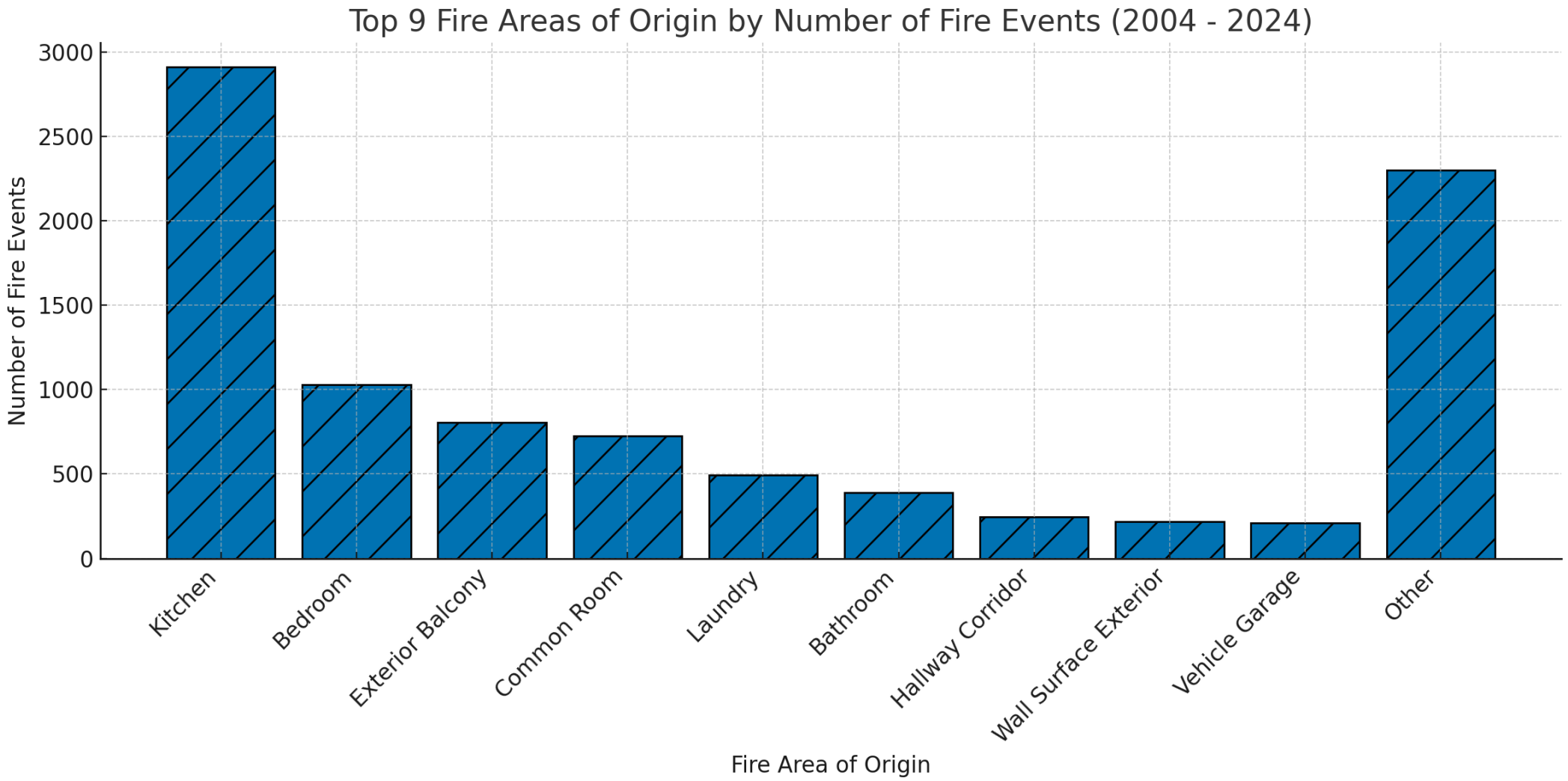
"Annual Fire in Minnesota" Reports, Minnesota Department of Public Safety's State Fire Marshal Division

Normalized Residential Death Rate (Minnesota)



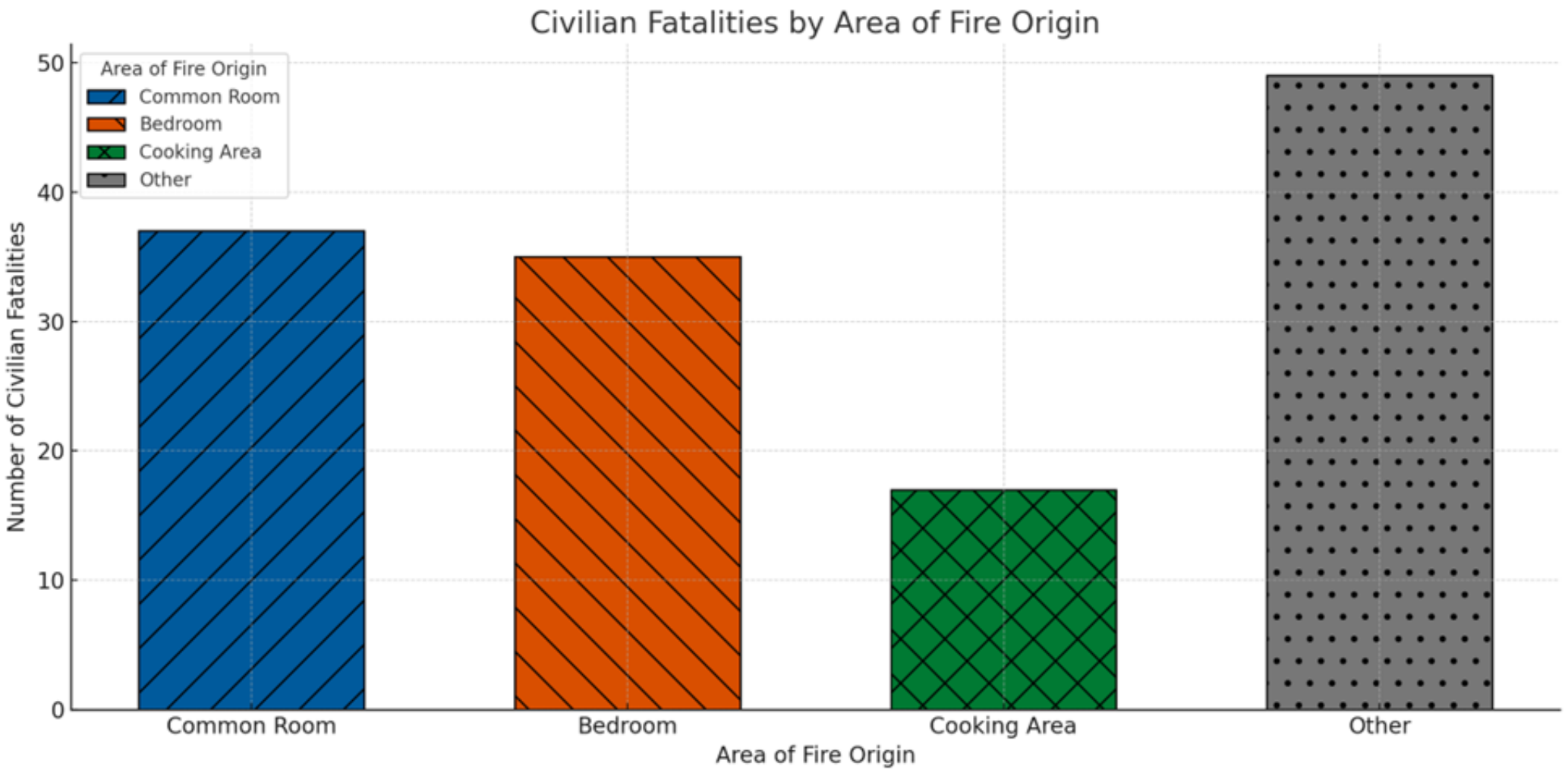
"Annual Fire in Minnesota" Reports, Minnesota Department of Public Safety's State Fire Marshal Division

MFH Fire Area of Origin (Minnesota)



Minnesota Fire Event Data (2004 – 2024, Multifamily Dwelling), State Fire Marshal's Office

MFH Fire Area of Origin Versus Civilian Fatalities (Minnesota)



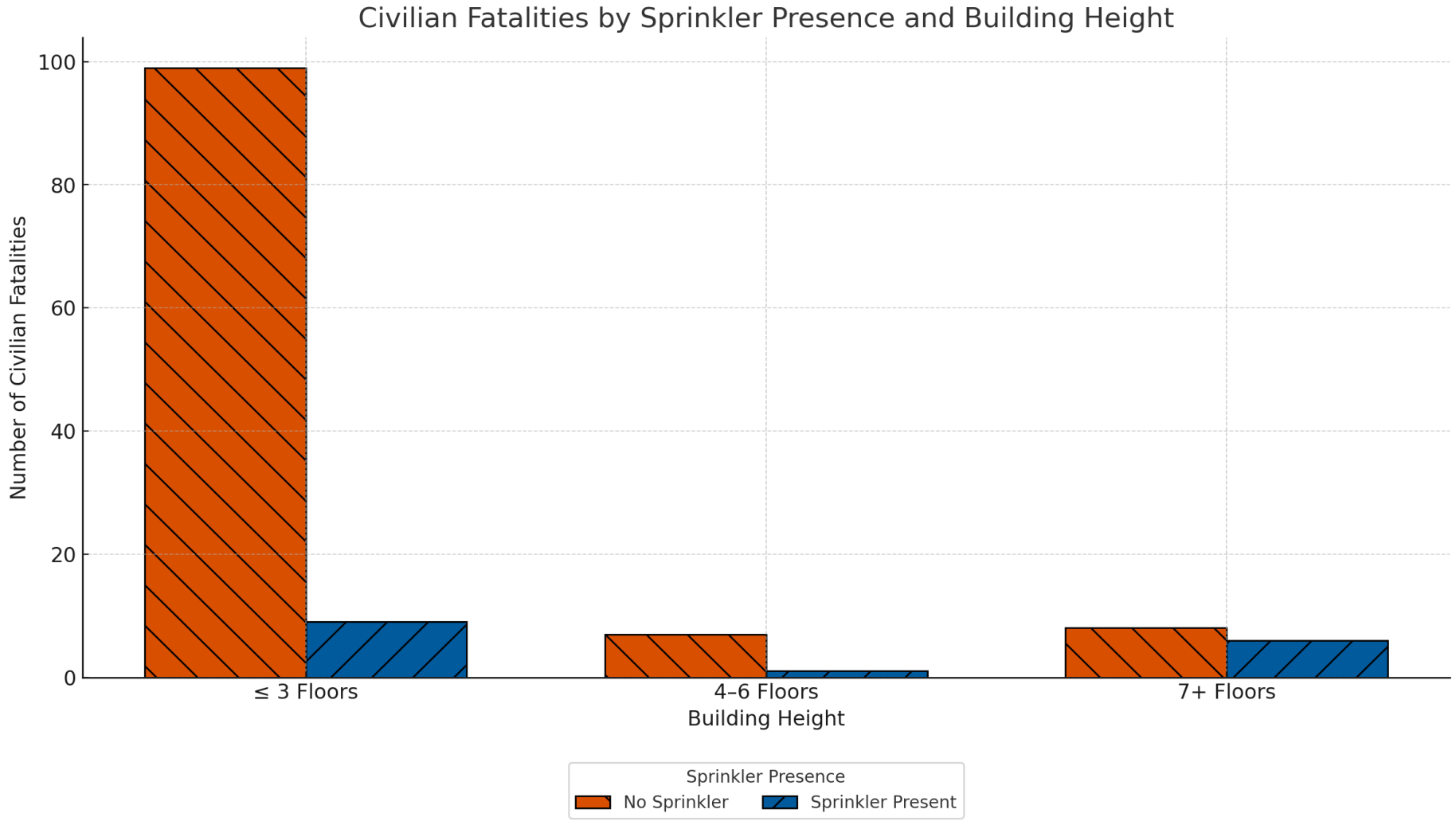
Minnesota Fire Event Data (2004 – 2024, Multifamily Dwelling), State Fire Marshal's Office

Fire Summary in MFH Common Spaces (Minnesota)

- 179 fires occurred in interior stair or ramp
  - 0 civilian deaths
  - 6 firefighter injuries
  - 164 of these fires occurred in buildings with 1 – 3 stories
- 244 fires occurred in hallway corridors
  - 0 civilian deaths
  - 11 firefighter injuries
  - 188 of these fires occurred in buildings with 1 – 3 stories

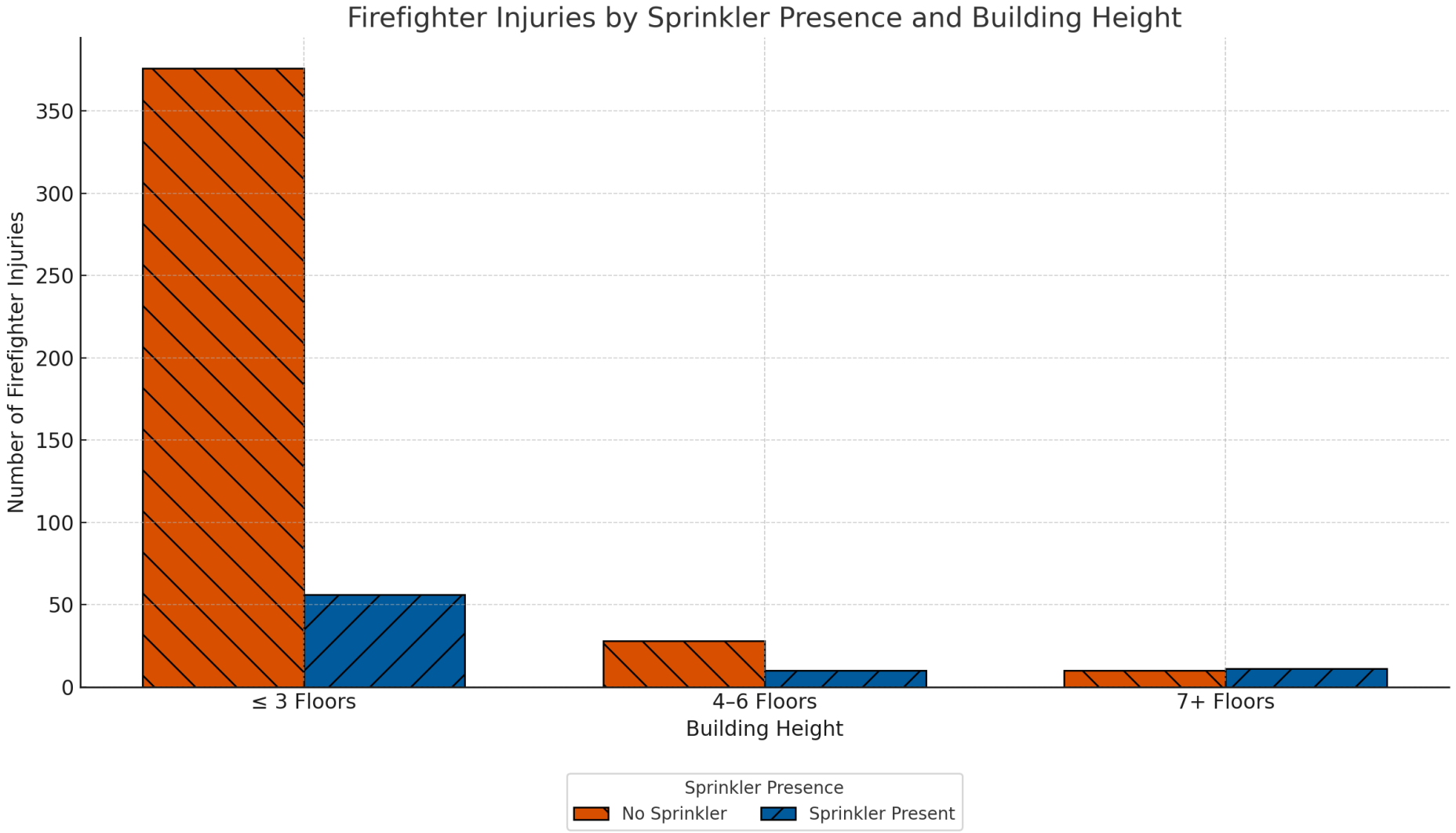
Minnesota Fire Event Data (2004 – 2024, Multifamily Dwelling), State Fire Marshal's Office

Civilian Fatalities in Multi-Family Housing (Minnesota)



Minnesota Fire Event Data (2004 – 2024, Multifamily Dwelling), State Fire Marshal's Office

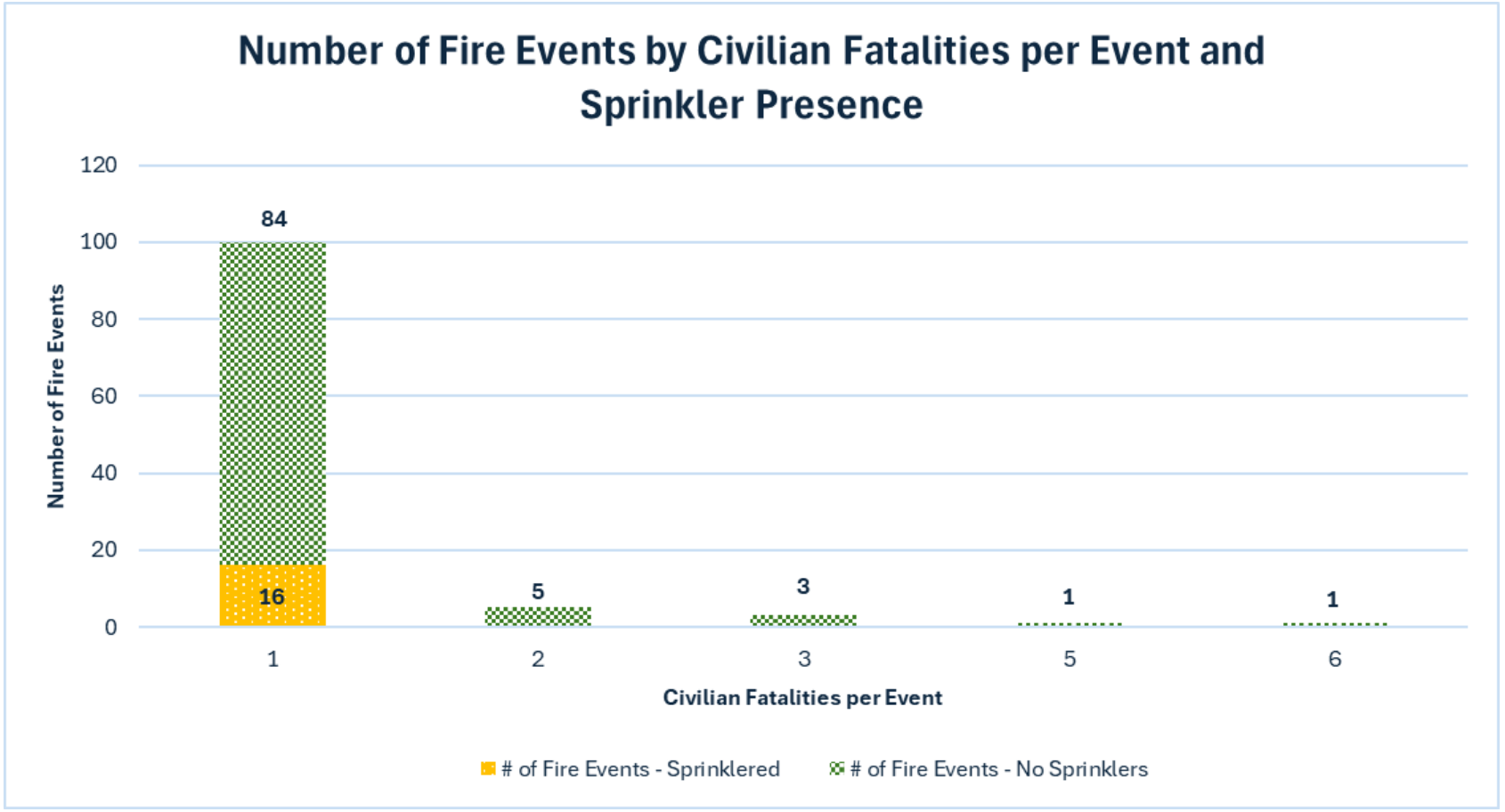
Firefighter Injuries in Multi-Family Housing (Minnesota)



Minnesota Fire Event Data (2004 – 2024, Multifamily Dwelling), State Fire Marshal's Office

Magnitude of Events that Occur – Civilian Fatalities

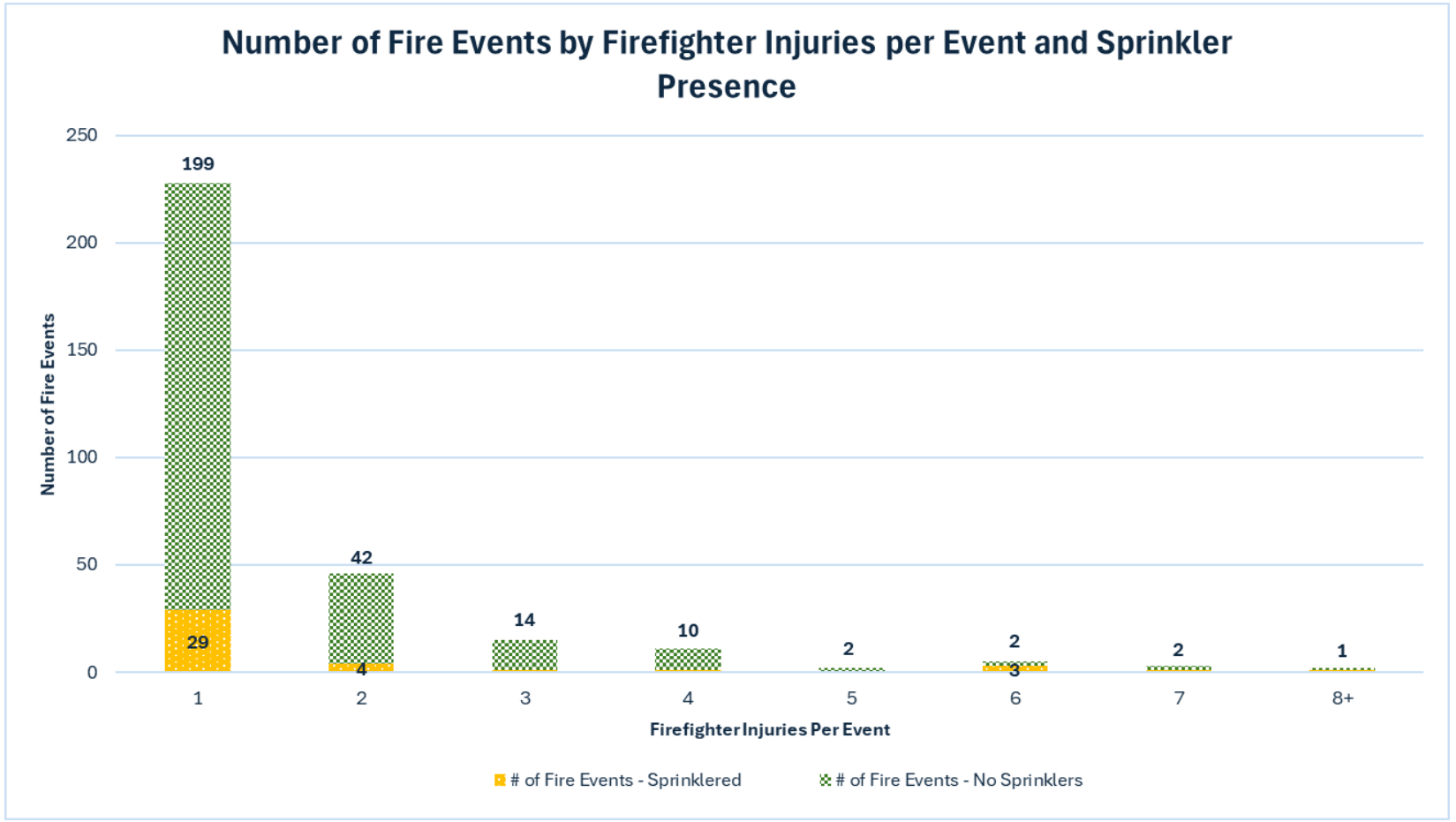
- 9,694 (98.8%) of MFH fires between 2004 - 2024 resulted in 0 civilian deaths



Minnesota Fire Event Data (2004 – 2024, Multifamily Dwelling), State Fire Marshal's Office

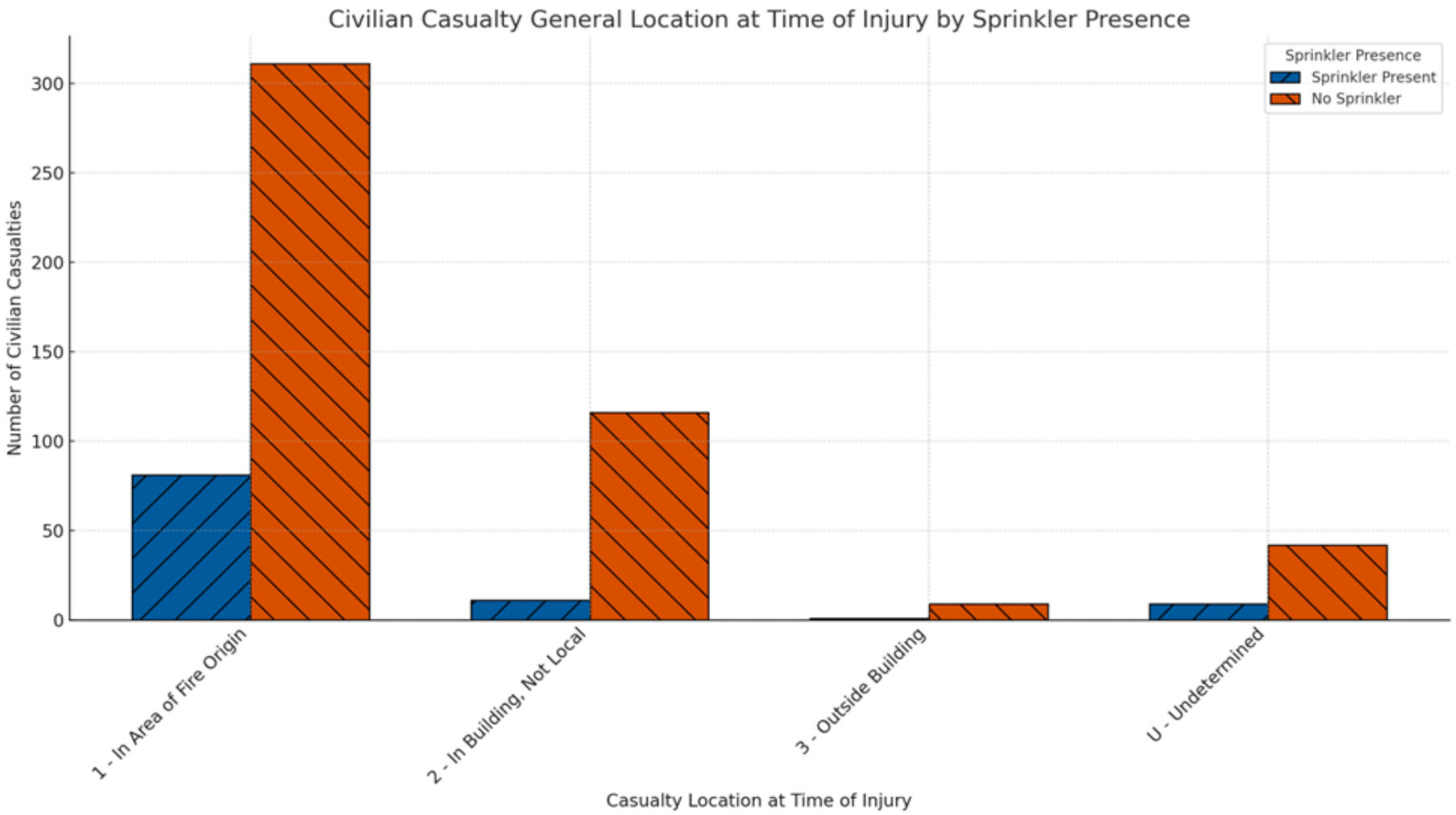
Magnitude of Events that Occur – Firefighter Injuries

- 9,467 (96.5%) of MFH fires between 2004 – 2024 resulted in 0 firefighter injuries



Minnesota Fire Event Data (2004 – 2024, Multifamily Dwelling), State Fire Marshal's Office

Civilian Fatality Based on Location and Sprinklers (MN)



Minnesota Fire Event Data (2004 – 2024, Multifamily Dwelling), State Fire Marshal's Office

What Has the Data Told Us?

- Difference in risk between 1, 2 family homes and multi-family structures
- Most fires start in the kitchen but living room / bedroom fires result in more civilian fatalities per event
- Sprinklers are effective at reducing civilian fatalities and firefighter injuries
- Fire events with multiple civilian fatalities / firefighter injuries are low in sprinklered MFH
- Fires in means of egress have not resulted in civilian deaths
- Civilian fatalities outside the fire origin are rare in sprinklered MFH

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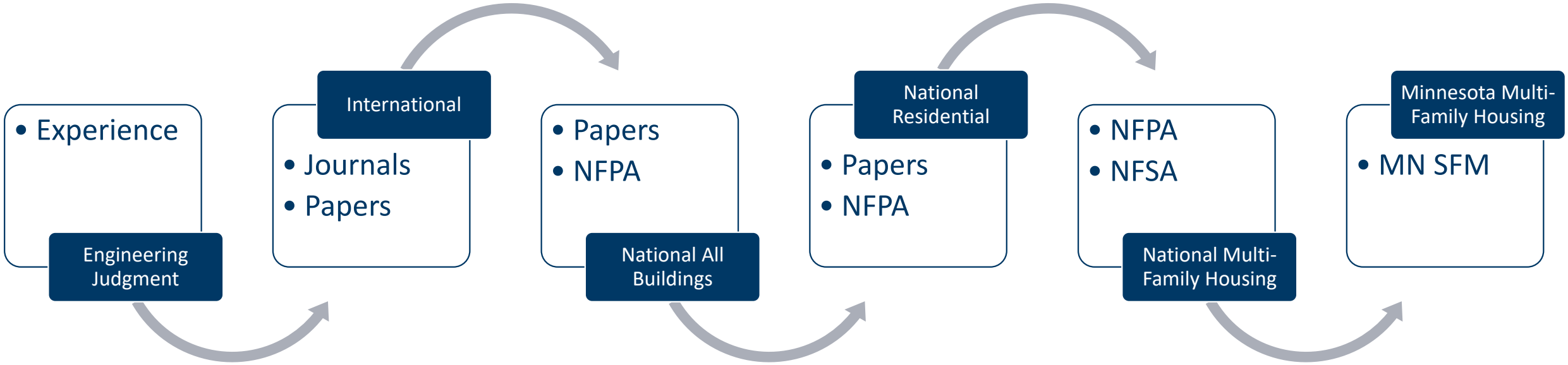
Equipment Reliability

Kyle Christiansen | Crux Consulting

Reliability Data Approach



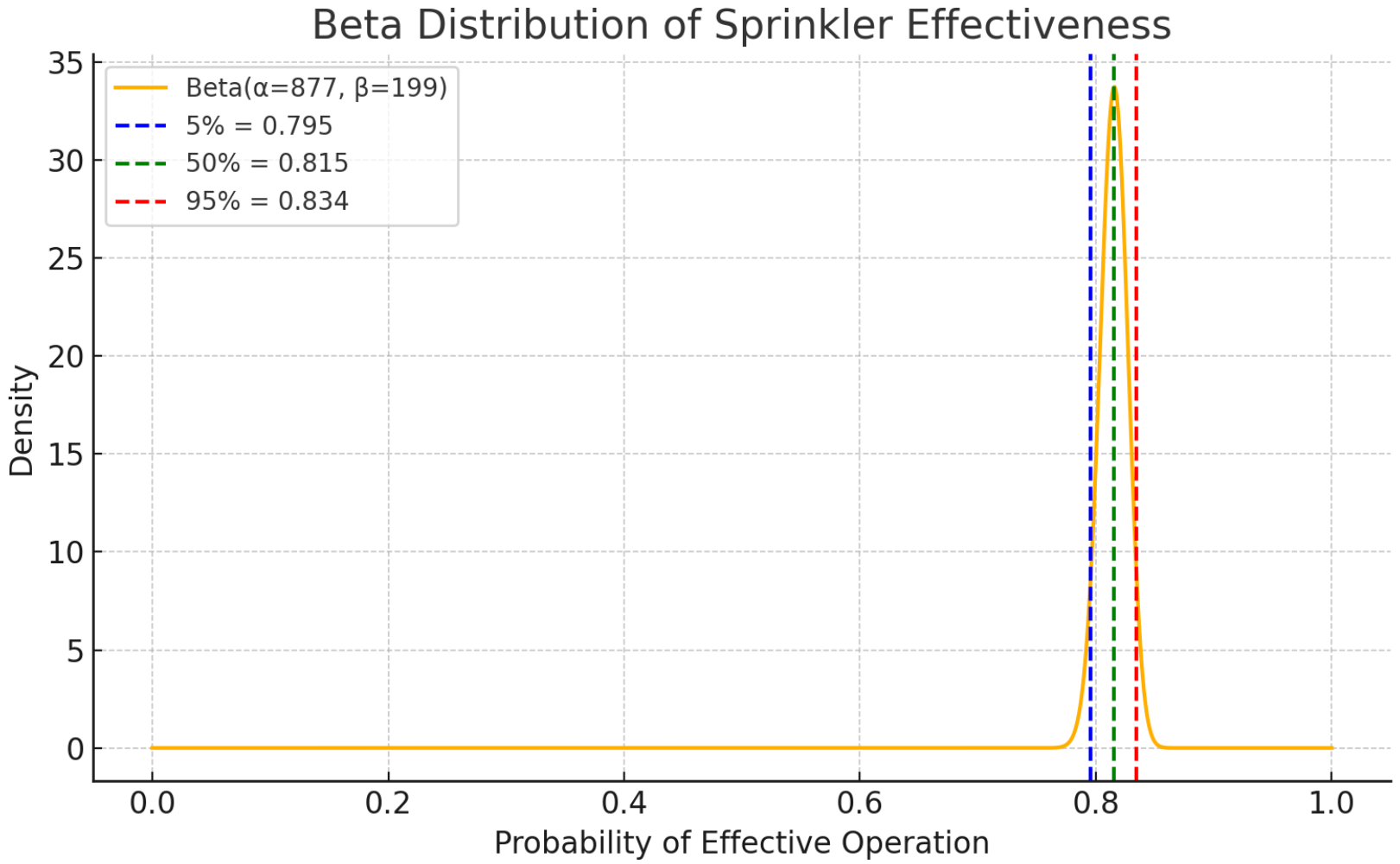
Sprinkler Reliability Data for MFH

Type	Source	Fires in Completely Sprinklered MFH	Operation of AES, Other	Operated and Effective	Operated and NOT Effective	Fire Too Small to Operate	Failed to Operate	Undetermined
National	NFSA[1]	1,988	8	876	81	438	117	84
Minnesota	MN SFM[2]	1,936	5	759	11	631	101	29

- Success = operated and effective
- Failure = operated and NOT effective, failed to operate

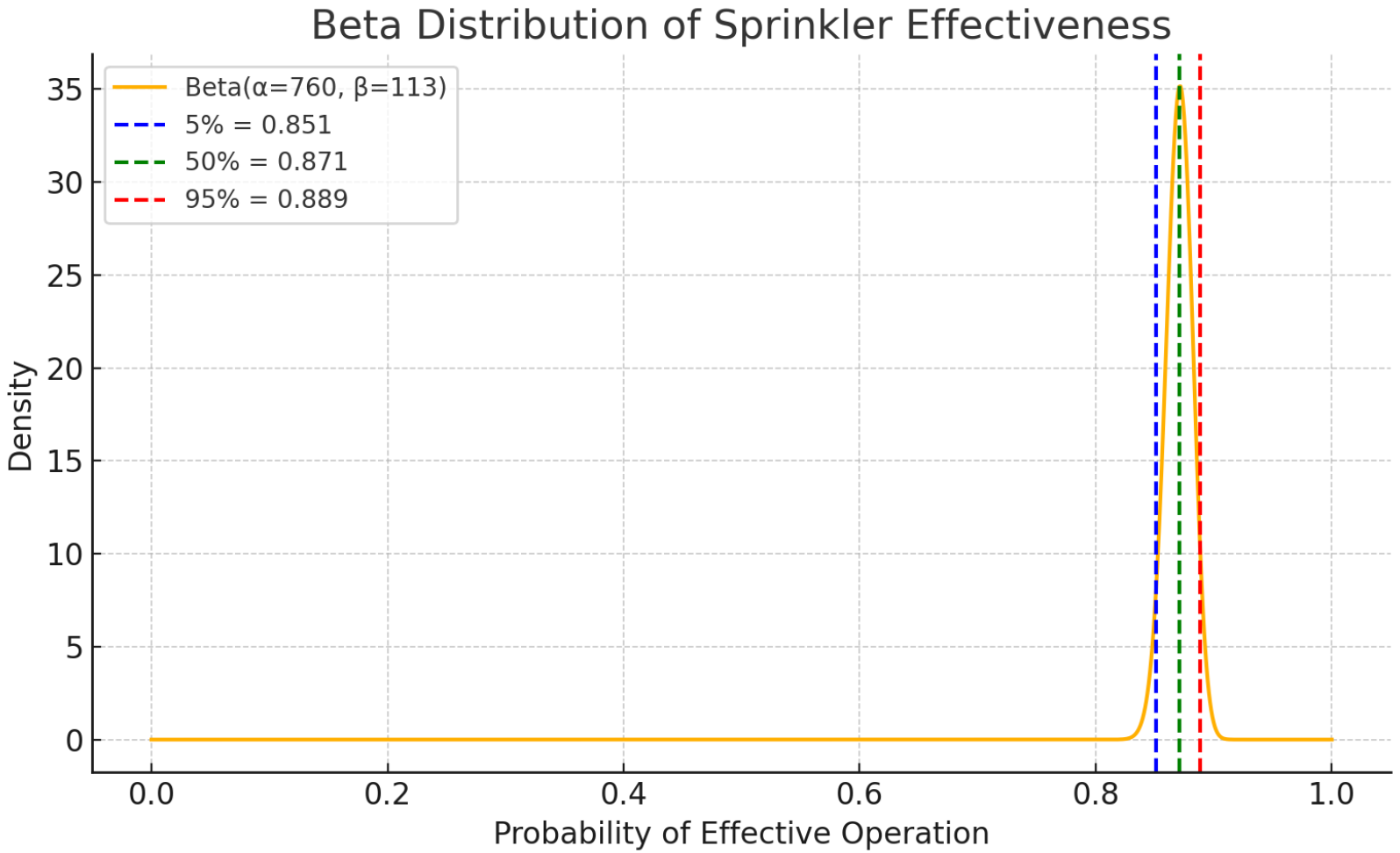
[1]National Fire Sprinkler Association Fire Event Data (2014 – 2023, Multifamily Dwelling)
[2]Minnesota Fire Event Data (2004 – 2024, Multifamily Dwelling), State Fire Marshal's Office

Sprinkler Reliability Beta Distribution (MFH, National)



National Fire Sprinkler Association (2014 – 2023, Multifamily Dwelling)

Sprinkler Reliability Beta Distribution (MFH, MN)



Minnesota Fire Event Data (2004 – 2024, Multifamily Dwelling), State Fire Marshal's Office

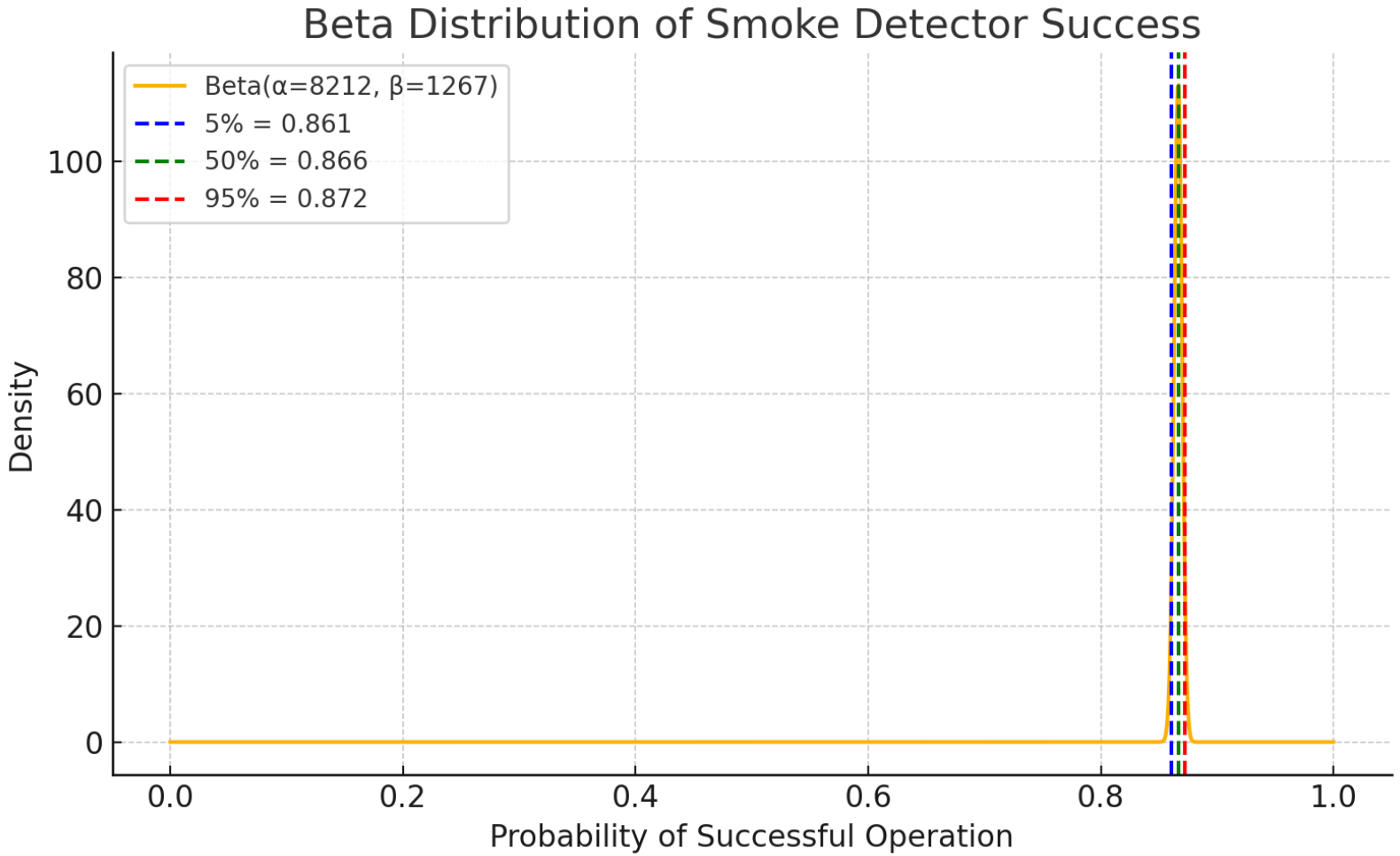
Smoke Detector Reliability Data for MFH

Type	Source	Fire Events with Detection Present	Fire Too Small to Operate	Operated	Failed to Operate	Undetermined
National	NFSA[1]	12,106	508	8,211	1,266	2,121
Minnesota	NFSA[1]	324	9	243	35	37

- Success = operated
- Failure = failed to operate

[1]National Fire Sprinkler Association Fire Event Data (2014 – 2023, Multifamily Dwelling)

Detector Reliability Beta Distribution (MFH, National)



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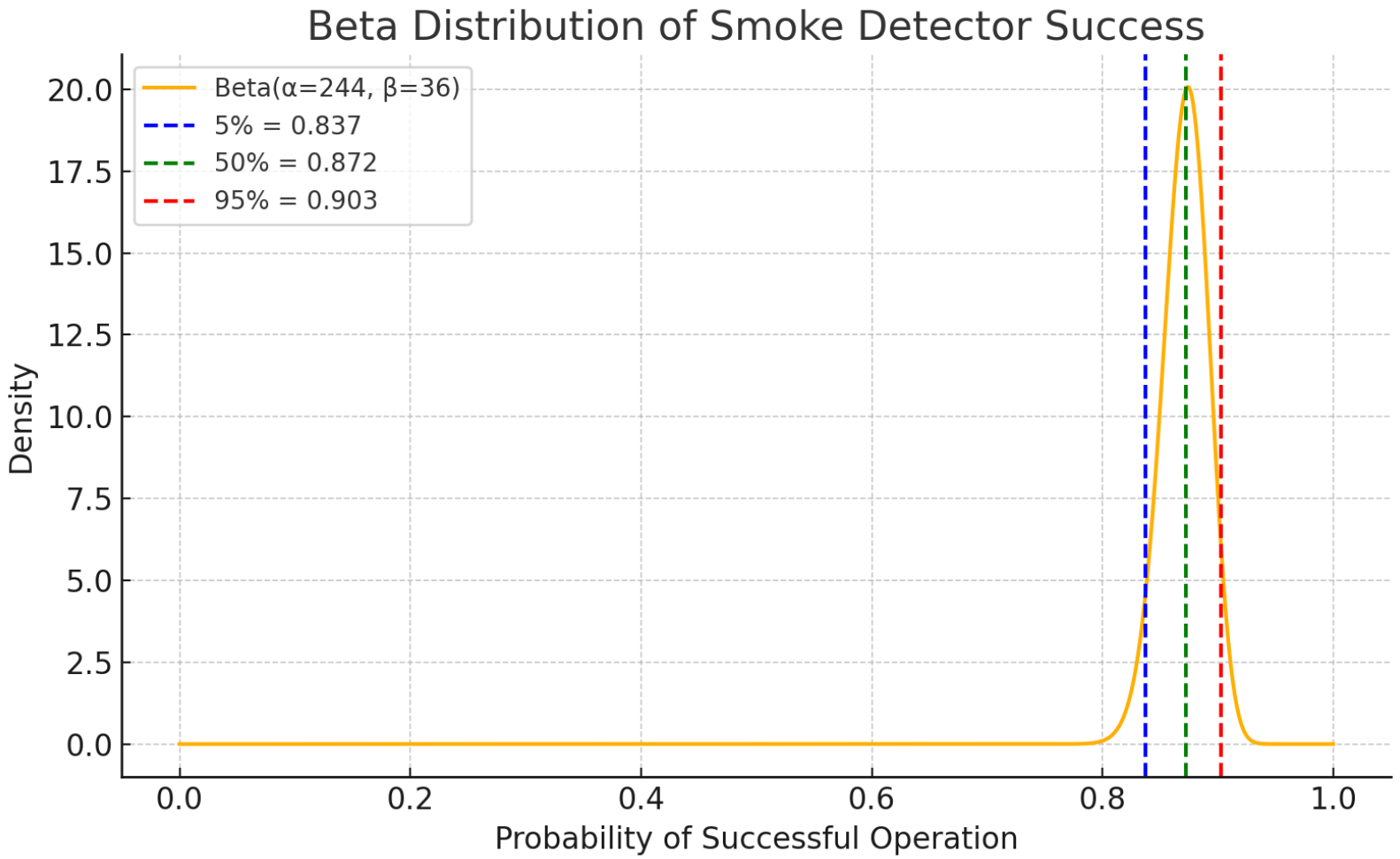
Detector Reliability Beta Distribution (MFH, MN)



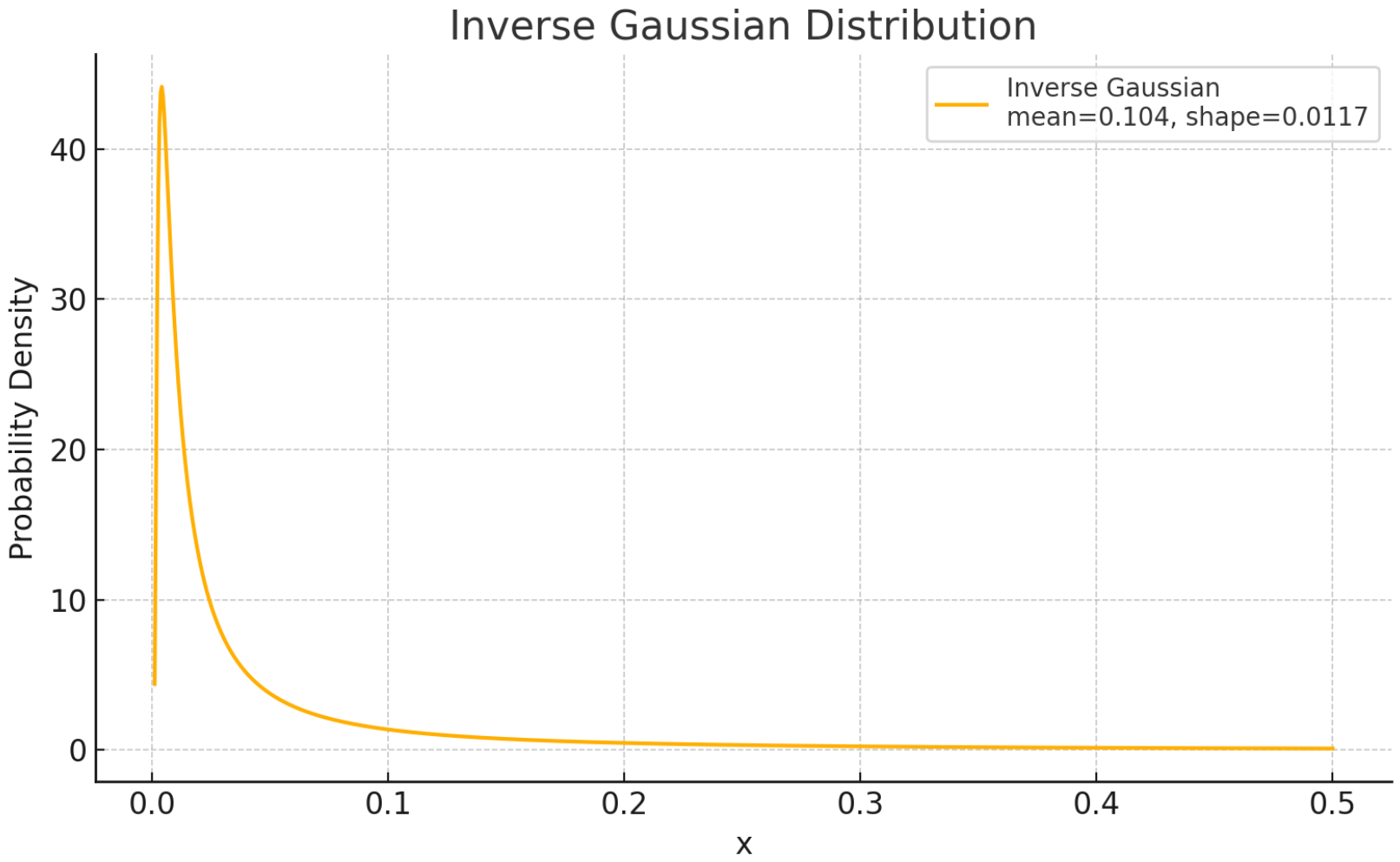
National Fire Sprinkler Association Fire Event Data (2014 – 2023, Multifamily Dwelling)

Door Closer Reliability

- New Zealand study used devices to record 180 days of data from 52 doors in four different sleeping occupancies (hotels, apartments, dorm, rest homes)
- 5 exit stair doors tested (not dwelling unit doors) in 2 apartment buildings
- Door reliability for *apartments / condos* in closed position:
  - Mean = 0.86

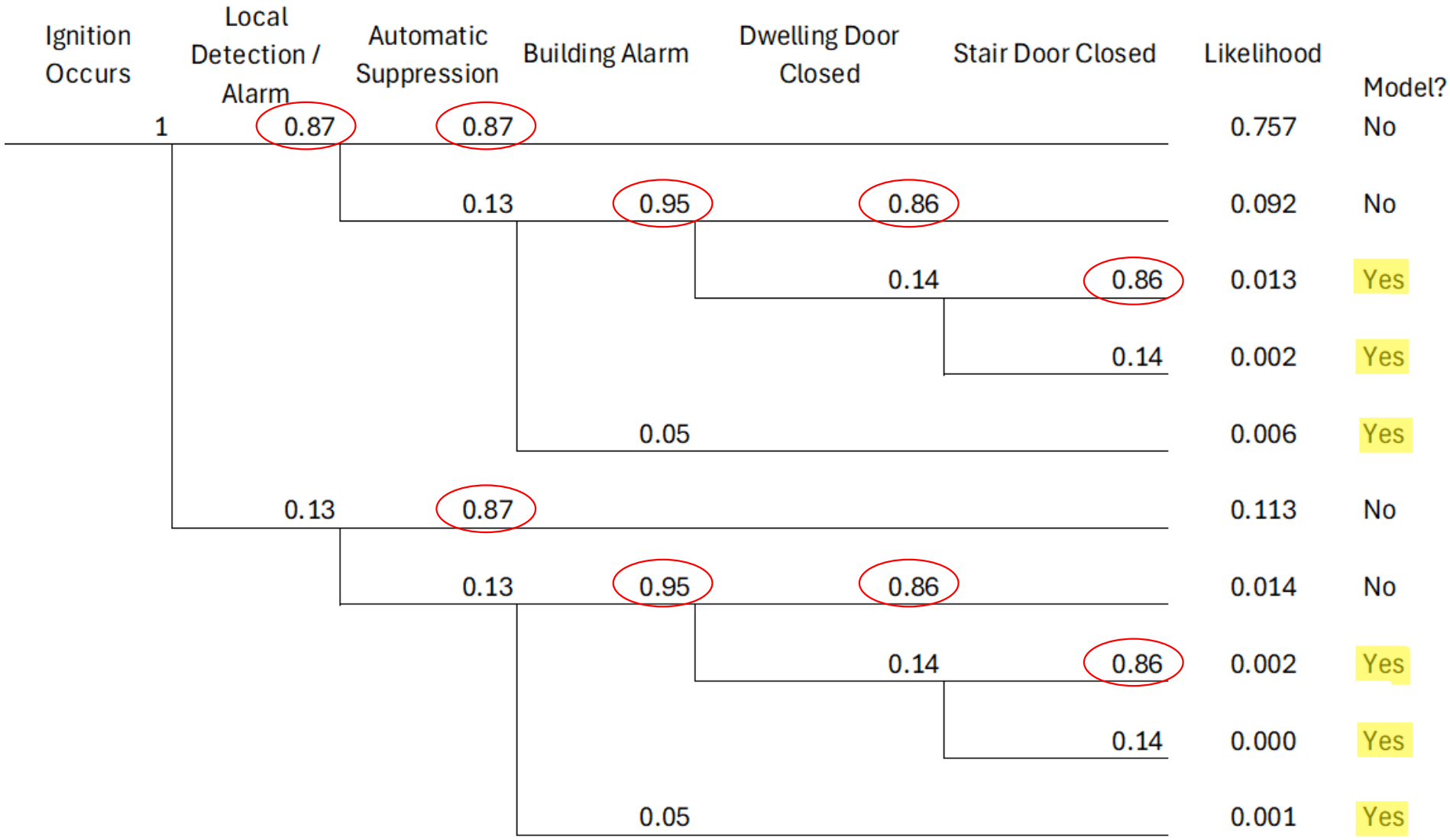
Finding the Probability of Doors Being Open Using a Continuous Position Logger, Kevin Frank, Michael Spearpoint, and Steve Weddell, University of Canterbury, 2014 International Association for Fire Safety Science

Door Closer Reliability For *All* Sleeping Occupancies



"Finding the Probability of Doors Being Open Using a Continuous Position Logger", Kevin Frank, Michael Spearpoint, and Steve Weddell, University of Canterbury, 2014 International Association for Fire Safety Science

Incorporating Data into the Event Tree



Mitigation with Lacking Reliability Data (To Date)

- Manual suppression by building occupants
- Dwelling door position
- Fire barrier
- Building construction type
- Elevator
- Building-wide fire alarm notification systems
- Fire rescue operation effectiveness
- Pressurization systems / smoke evacuation
- Inspection, testing, and maintenance

Equipment Reliability Takeaways

- Breadth and depth of data reviewed
- Minnesota sprinkler and detector systems trend higher than national averages
- Data availability varies by type of mitigation measure
- Adequate data to perform comparative risk analysis

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Model Floor Plans

Nicholas Ozog | Wiss, Janney, Elstner Associates, Inc.

Overstory - Recap

- No building can ever be considered risk free or 100% safe.
- A risk-informed approach, which considers fire loss data, fuel loading, and system efficacy and reliability data is also critical to developing appropriate scenarios for fire effects modeling and evacuation modeling.
- Obtain consensus on what needs to be studied further.
- Continue to listen and learn from you.

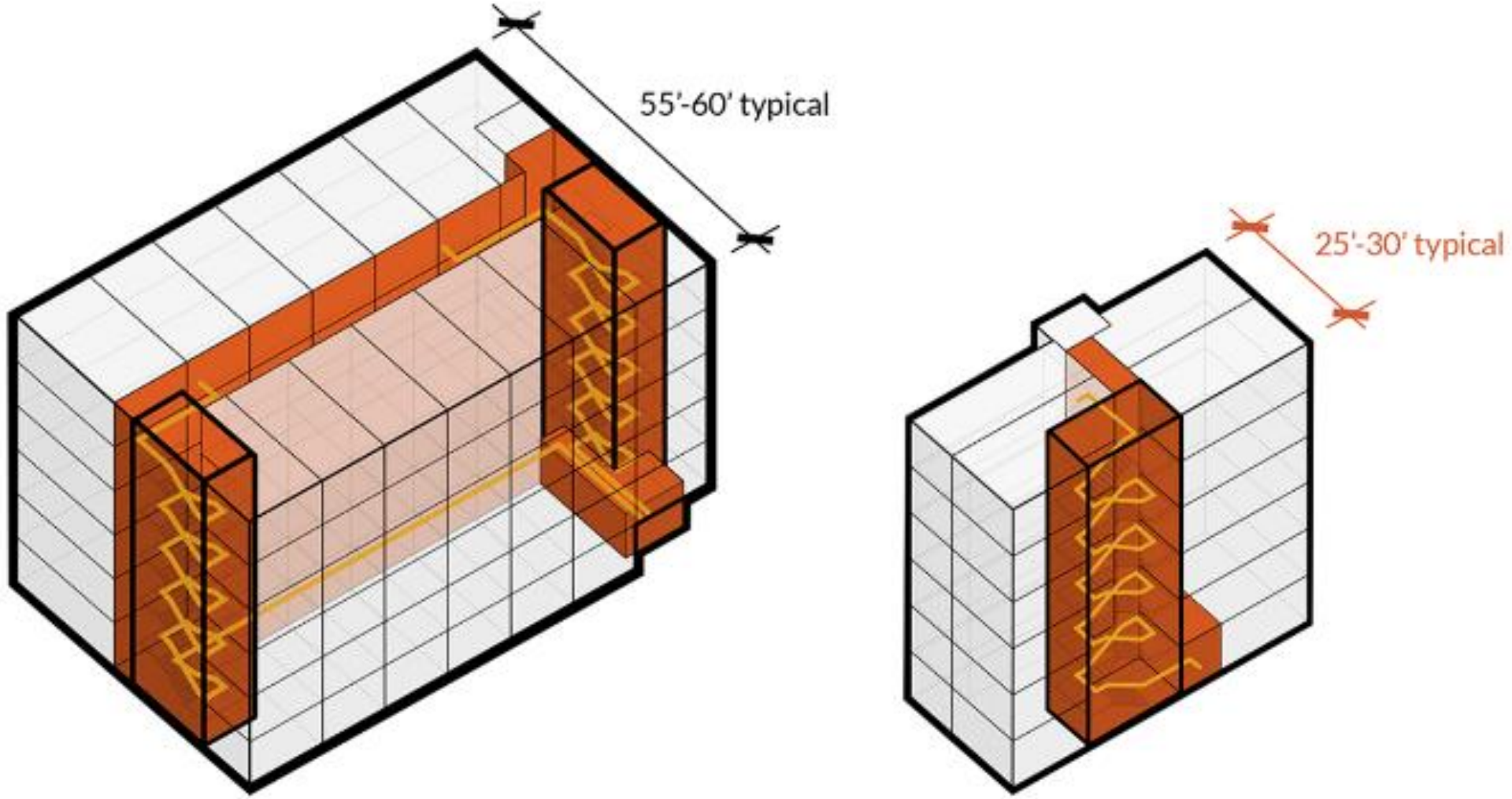
Housing Information

- Floor Area
  - Studio = 457 SF
  - One Bedroom = 735 SF
  - Two Bedroom = 1,097 SF
  - Three Bedroom =1,336 SF
- National Average = 908 SF
- Average for St. Paul MN = 761 SF
- Average for Minneapolis MN = 766 SF

- Approximate Percent of New Apartments By Unit Type in the Last Ten Years:
  - Studios = 5.1%
  - One Bedroom = 48.2%
  - Two Bedroom = 38.3%
  - Three Bedroom = 6.6%

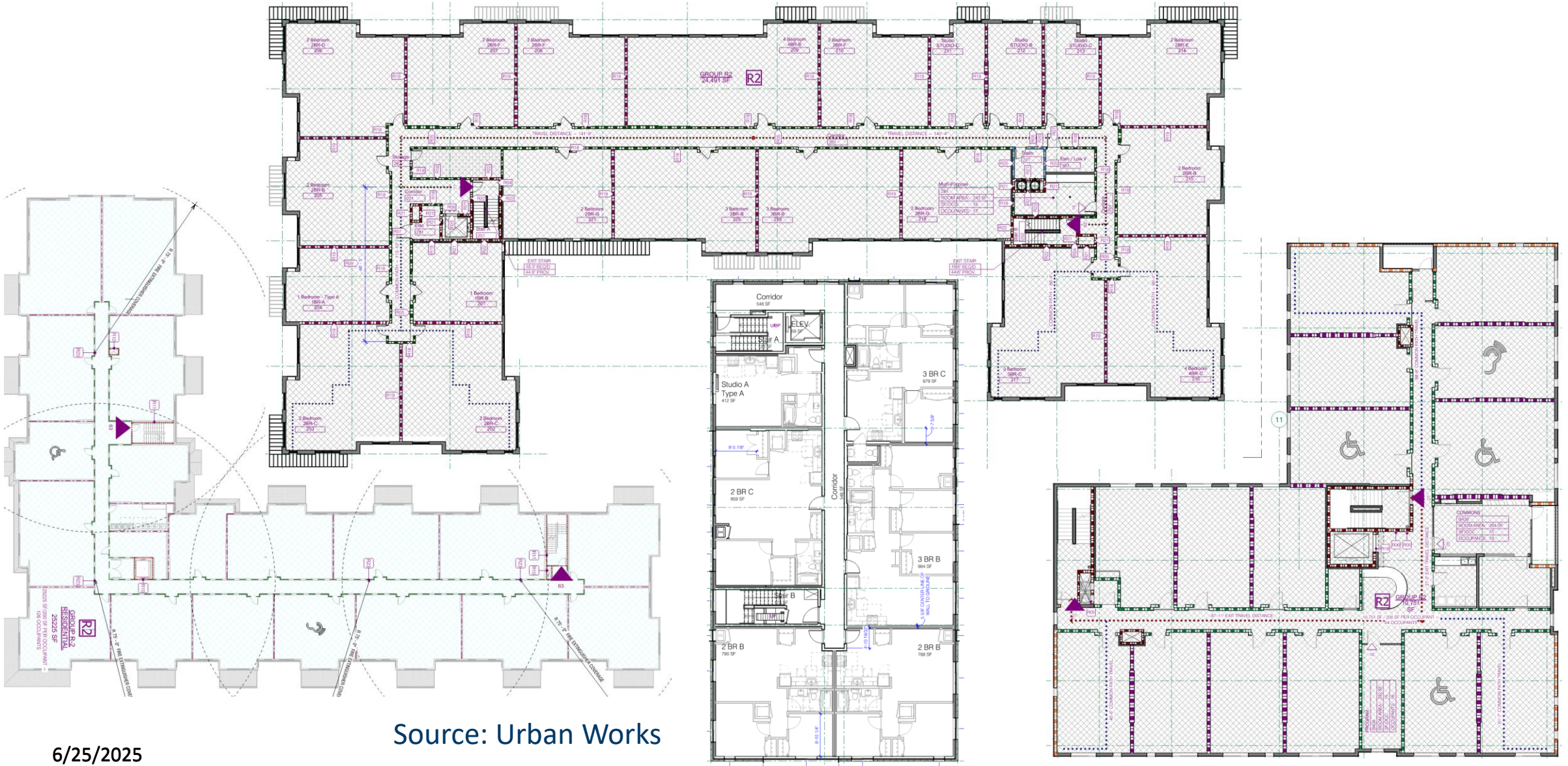
Source: https://www.rentcafe.com/

General Floor Plan Observations



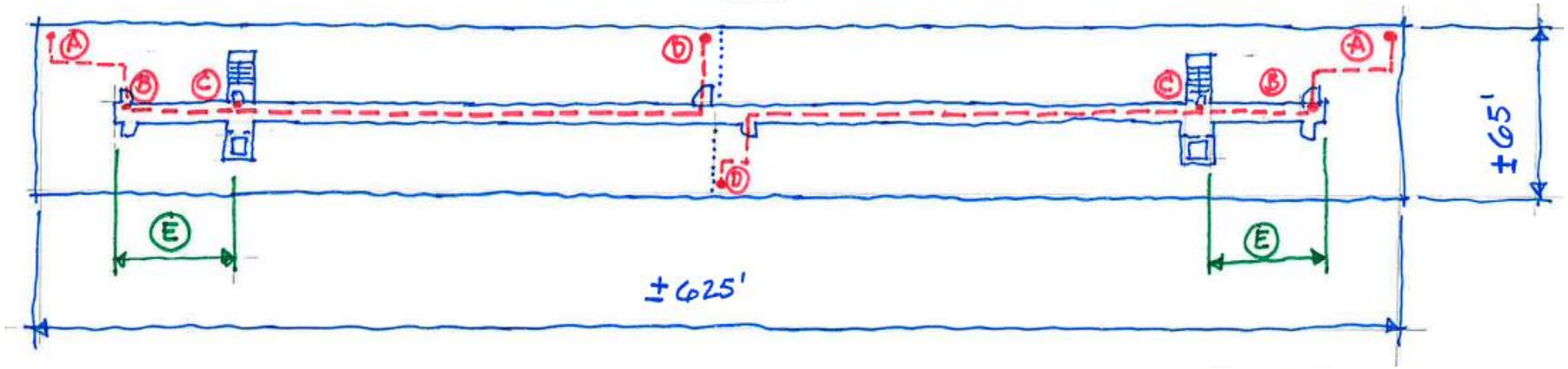
Source: SAR+ Architects via 2025 The Pew Charitable Trusts “Small Single-Stairway Apartment Buildings Have Strong Safety Record”

General Floor Plan Observations



Source: Urban Works

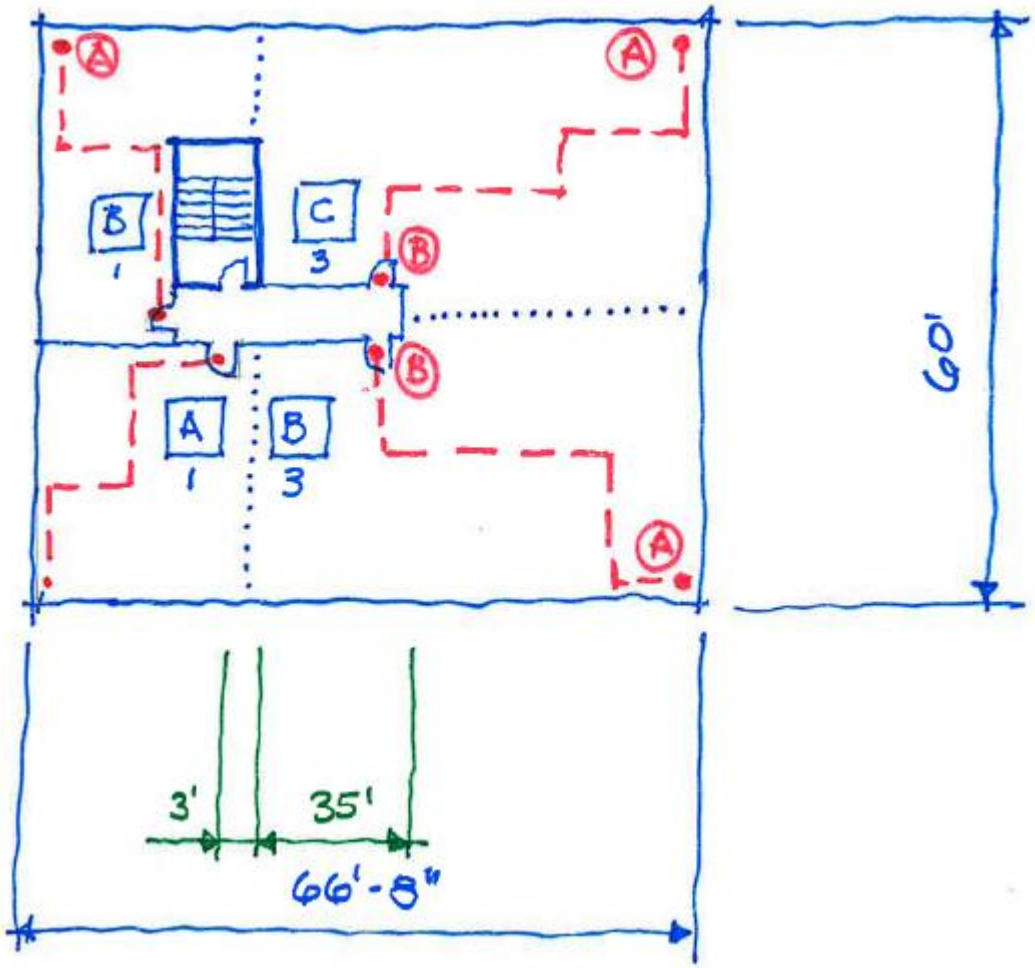
Layout ID 1: Two Exit Stair Building Floor Plan



Source: Center for Building in North America

- Floor Plan: 40,625 SF – 8 stories
- Travel Distance (250 FT)
- Common Path (125 FT)
- Dead End (50 FT)
- Number of Units: No Limit
- Unit sizing may vary

Layout ID 2: Single Exit Stair Building Floor Plan



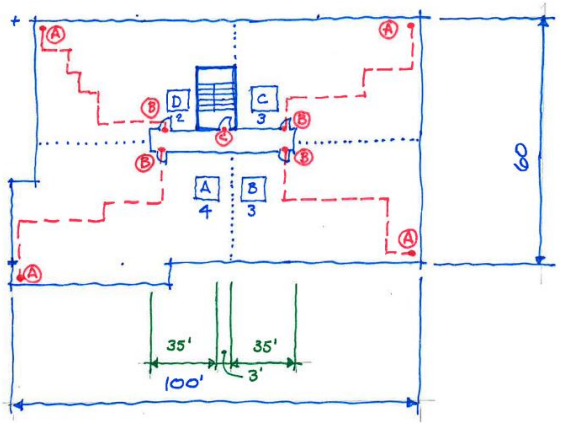
- Floor Plan: 4,000 SF – 3 stories
- Travel Distance (125 FT)
- Corridor Travel (35 FT)
- Number of Units (Limit 4)
- Unit sizing may vary
  - A and B: Studio/1 BDRM
  - C and D: 3 BDRM

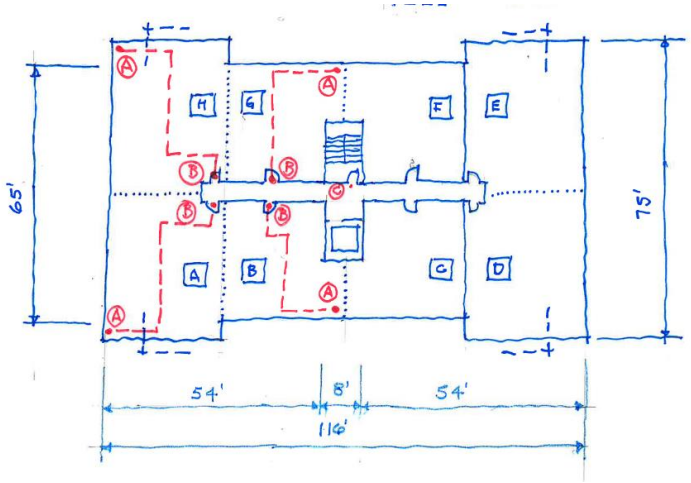
Variables Discussed

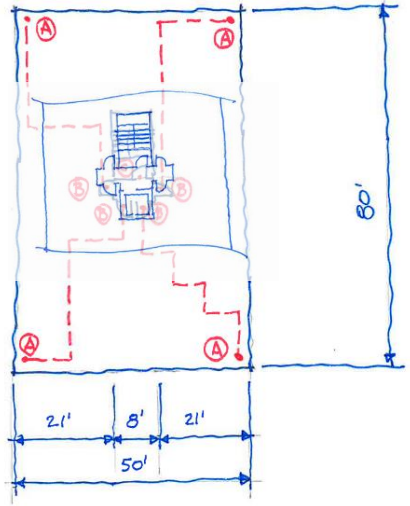
- **Floor Area**
- **Number of Stories**
- **Elevator**
- **Number of Dwelling Units**
- **Stair Width**
- Fire Location
- Fire Scenario
- Dwelling Unit Door Location
- Sprinkler Operation
- Dead End Distance
- Corridor Fire Resistance Rating
- Stair Fire Resistance Rating
- Compartmentation (Other)
- Construction Type
- Common Area Electrical Outlets
- Other Occupancies
- Details of Fire Alarm System (Notification)
- Emergency Escape and Rescue Openings
- Smoke Control Systems
- Travel Distance / Common Path

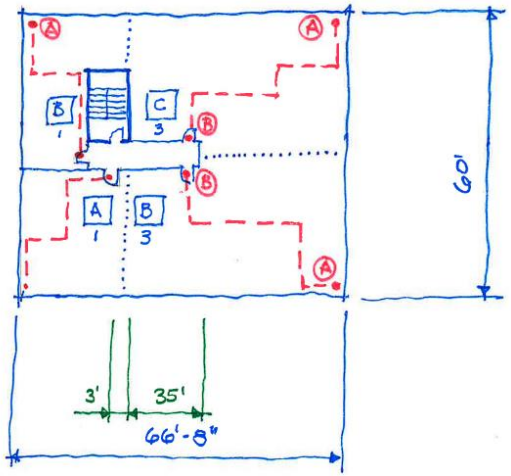
Layout ID 3: Single Exit Stair - Input from TAG

- Square footage:
  - **6,000 SF**
- Number of stories:
  - **8 stories**
- Elevator: **Yes**
- Number of dwelling units per floor:
  - **8 units**
- Stair width:
  - **48 inches**









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Modeling

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Fire Modeling Scenarios (No Sprinkler Intervention)

Model ID	Floor Plan	Number of Stories (Up to 75 ft in Building Height)	Living Room Fire		Corridor Fire	
			Dwelling Unit Door Position[1]	Stair Door Position[2]	Dwelling Unit Door Position	Stair Door Position[2]
1	2-Exit Stair (Allowed)	8?	Open	Closed	Closed	Closed
				Open		Open
2	1-Exit Stair (Allowed)	3	Open	Closed	Closed	Closed
				Open		Open
3	1-Exit Stair (Floor Plan TBD)	8?	Open	Closed	Closed	Closed
				Open		Open

1. Dwelling unit of fire origin
2. Stair door on floor of fire origin

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Next Steps

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Next Steps

- Model floor plans from TAG Meeting No. 2
- Further investigation where data is lacking
- Define design fire scenarios using event tree
- Risk achievement worth (RAW) for system importances
- Prepare report for DLI

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Thank You!

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