Single Egress Stairway Apartment Building Study

TAG Meeting No. 3| December 12, 2025

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Welcome

Nicholas Ozog| Associate Principal - Wiss, Janney, Elstner Associates, Inc.
Kyle Christiansen | Consultant – Crux Consulting
Brian Meacham | Consultant – Crux Consulting
Carl Baldassarra| Senior Principal - Wiss, Janney, Elstner Associates, Inc.

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Agenda – TAG Meeting No. 3

1:00 – 1:15 p.m.	Restatement of Original Legislation
1:15 – 1:45 p.m.	Presentation of Draft Findings
1:45 – 2:45 p.m.	Questions and Answers / Comments from TAG
2:45 – 3:00 p.m.	Conclusions - DLI

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Recap of Objectives and Risk-Informed Approach

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

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Project Approach and Status Summary

- ☑ TAG Mtg No. 1 - Outline Approach
- ☑ Interviews with TAG members
- ☑ Collect data, papers, reports and perform literature review
- ☑ TAG Mtg No. 2 - Define fire scenarios, building geometry and event tree logic
- ☑ Reliability and operability of mitigating systems
- ☑ Modeling
- ☑ Analysis
- TAG Mtg No. 3 – Draft Findings
- Reporting

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Objectives for TAG Mtg No. 3

- Recap the risk-informed approach
- System reliability
- Consequence
- Draft results – Modeling and Analysis
- Draft conclusions and recommendations
- Obtain DLI and TAG Comments

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Risk-Informed Approach – TAG Mtg No. 1

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

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Event Tree Systems Reliability

Kyle Christiansen | Crux Consulting

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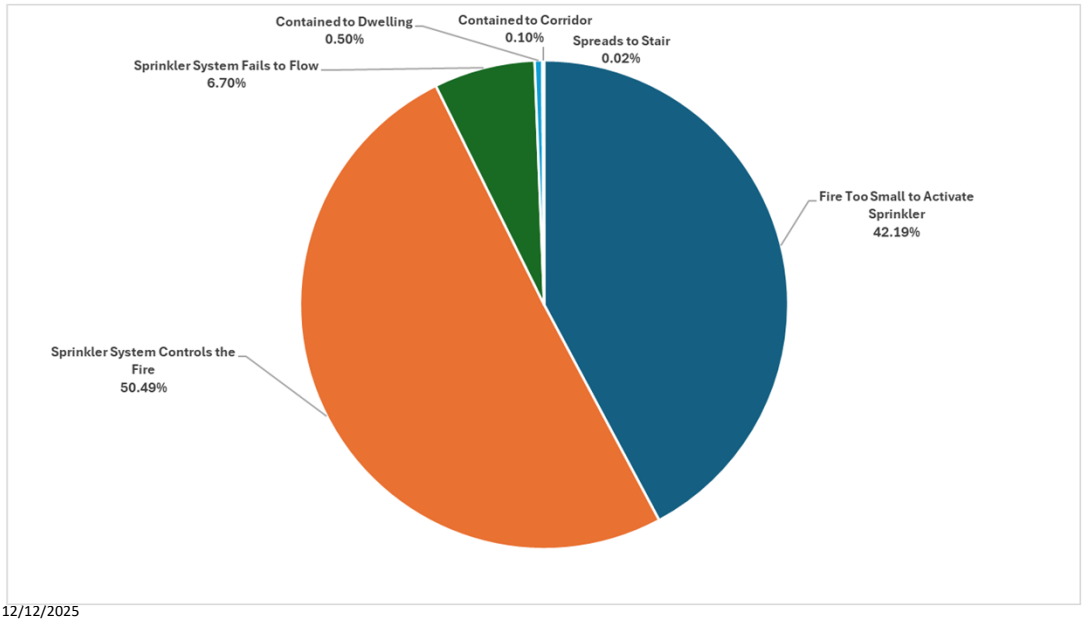
Event Tree

Ignition Occurs	Fire Too Small to Activate Sprinklers (/fire event)	Sprinkler Actuates on Demand (/fire event)	Sprinkler Controls Fire (/fire event)	Building Alarm Actuates on Demand (/fire event)	Dwelling Door Closed (/fire event)	Stair Door on Fire Level Closed (/fire event)	Stair Door Above Fire Level Closed (/fire event)	Conditional Probability (/fire event)	End State #
1	0.42							0.422	1
	0.58	0.88	0.99					0.505	2
			0.01	0.90	0.80			0.005	3
					0.20	0.86		0.001	4
						0.14	0.86	0.0002	5
							0.14	0.00002	6
				0.10				0.0007	7
		0.12						0.067	8

End State Likelihood



System Reliability Observations

- Automatic alarm activated ONLY by sprinkler system
- Sprinklers are reliable and effective
- Sprinkler failure to flow: no suppression, no building fire-alarm, no fire department notification
- Dwelling unit and stairway door positions relevant if sprinkler fails to control the fire (low likelihood)

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Consequence

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Consequence – TAG Mtg No. 2

- Two criteria:
  - Occupants do not receive notification to evacuate
  - Occupants notified to evacuate but cannot due to compromised tenability of egress path
- Defined at the building level
- Uncertainty with human behavior during fire event
- Predict the number of occupants the fire department may need to rescue
- Based on data review, engineering judgment, fire / egress modeling

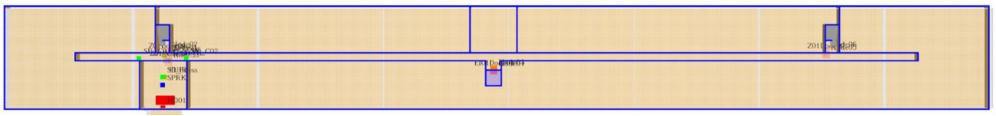
Building Geometry Summary – TAG Mtg No. 2

Building No.	Building Type	No. of Levels	Floor Area per Level (sf)	No. of Units per Level	No. of Exit Stairways	Occupants Per Level
1	MBC Compliant	8	40,625	No Limit	2	204
2	MBC Compliant	4	4,000	4	1	20
3	Prototype	8	6,000	8	1	30
4	Prototype	8	4,000	4	1	20

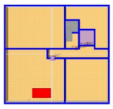
Modeling Approach

- Data indicates uncontrolled fires lead to largest consequences

Scenario	Fire Location	Fire Size (MW)
Sprinkler Fails to Control	Dwelling Unit[1]	~8 – 10 MW[3]
Sprinkler Fails to Control	Corridor[2]	~0.9 MW[4]
1: MFIRS 2: TAG 3: NIST 4: Institute of Applied Fire Safety Research		

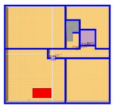


Building 1 Fire Floor



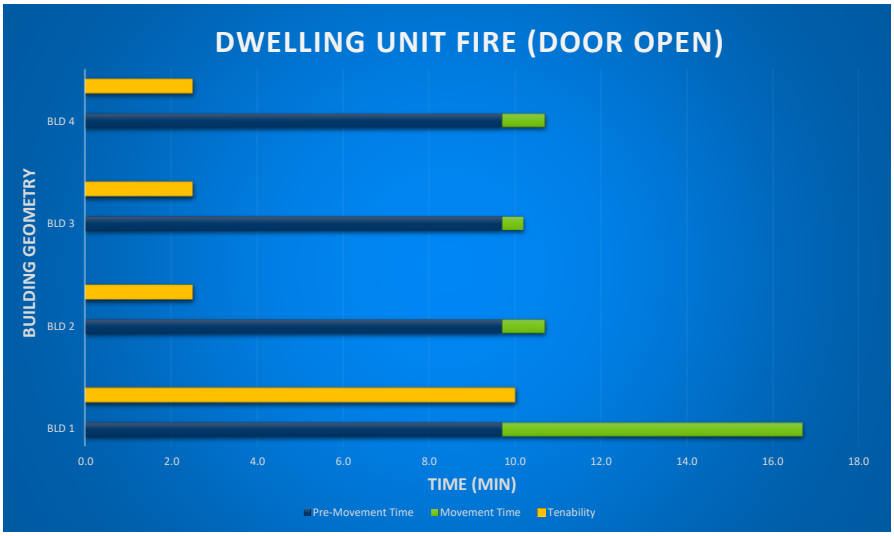
Building 2 Fire Floor

Building 3 Fire Floor



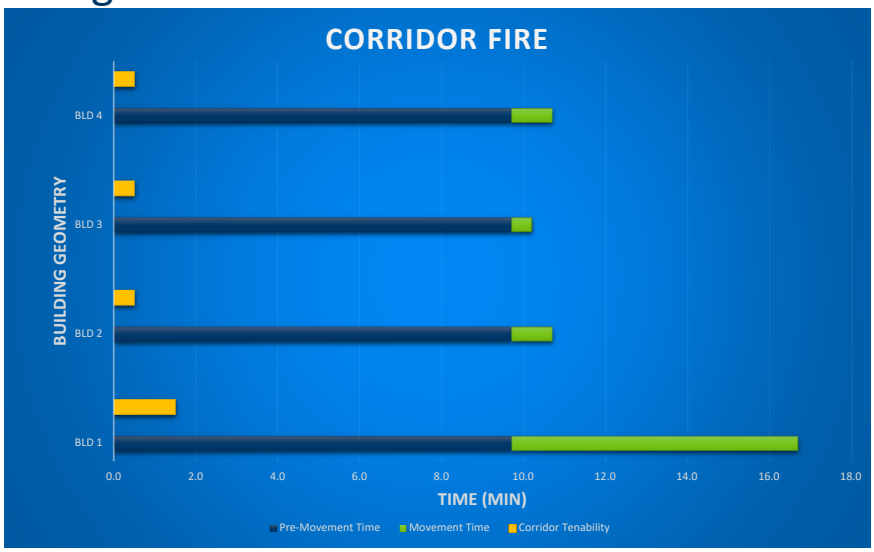
Building 4 Fire Floor

Modeling Results



Note: Door between the corridor and the dwelling unit of fire origin was modeled in the open position,120 seconds after fire ignition.

Modeling Results



Note: For the corridor fire location, the doors between the corridor and the dwelling units were modeled in the closed position

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Risk Results

Kyle Christiansen | Crux Consulting

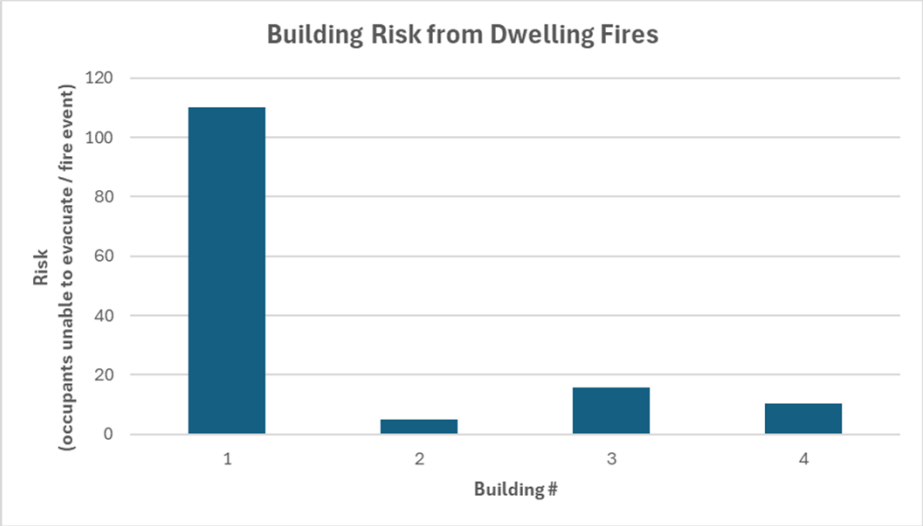
Risk Results Approach

- Calculate end state probability using the event tree
- Assign consequence to each end state
- End state risk = (End state probability) x (Consequence)
- Sum individual end state risk to calculate total building risk
- Calculate system importance
- Characterize uncertainty

Risk Calculation By Building – Dwelling Unit Fire

End State #	Probability	Building 1		Building 2		Building 3		Building 4	
		Consequence	Risk	Consequence	Risk	Consequence	Risk	Consequence	Risk
1	4.22E-01	0	0	0	0	0	0	0	0
2	5.05E-01	0	0	0	0	0	0	0	0
3	5.19E-03	0	0	0	0	0	0	0	0
4	1.10E-03	102	0.11	16	0.018	26	0.029	16	0.018
5	1.52E-04	120	0.018	76	0.012	236	0.036	156	0.024
6	2.42E-05	143	0.0035	76	0.002	236	0.006	156	0.004
7	7.06E-04	1628	1.15	76	0.054	236	0.167	156	0.110
8	6.65E-02	1628	108.3	76	5.06	236	15.7	156	10.4
		Total	**109.6**	**Total**	**5.1**	**Total**	**15.9**	**Total**	**10.5**

Dwelling Unit Fire Risk – By Building



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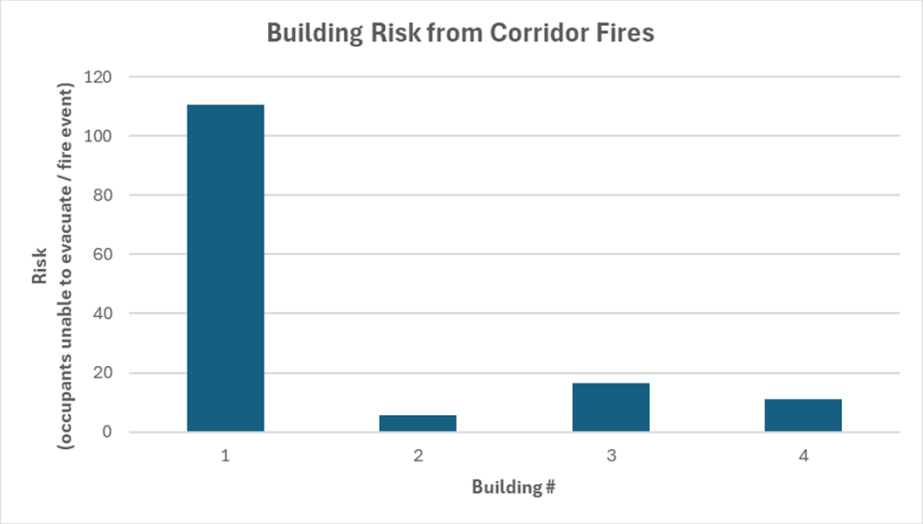
Corridor Fire Risk – By Building



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Risk Achievement Worth – Dwelling Unit Fires

System	Building #1	Building #2	Building #3	Building #4
Sprinkler	8.6	8.6	8.6	8.6
Fire Alarm	1.11	1.10	1.09	1.10
Dwelling Unit Door	1.00 *(1.001)*	1.05	1.02	1.02
Stairway Door + Dwelling Unit Door	1.00 *(1.004)*	1.10	1.09	1.10

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Risk Results and Observations

- Sprinkler protection provides most significant risk benefit
- Fire alarm system dependence on the sprinkler system success
- Exit stairway quantity impacts the risk calculation when:
  - The sprinkler system has failed to control the fire AND
  - The dwelling unit door is open AND
  - The stairway door is open
- ~1% of single-stairway buildings' risk includes scenarios with smoke in stairway
- ~97% of single-stairway buildings' risk from sprinkler failing to flow

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Limitations

- Data availability
  - Building attributes, construction year, why failures occurred
- Ignition frequency not available
- Quantitative basis for mitigation measures
- Fire service operational impact not included in event tree

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Potential Enhancements

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Potential Enhancements

- Common Corridor / Egress Path Smoke Detection
- Inspection, Testing, and Maintenance
- Additional Considerations
  - Voice Alarm System
  - Building Construction Type
  - Scissor Stairways
  - Smoke Control
  - 48-inch Wide Stairway

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Draft Conclusions

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Draft Conclusions

- A properly operating automatic sprinkler system provides the most significant comparative risk reduction impact.
- The most risk-significant failure is the sprinkler system failing to flow, as such a robust ITM program provides risk reduction value.
- Providing smoke detectors in the common egress area would allow for an independent system to activate the fire alarm system and notify occupants.
- The number of exit stairways factors into the risk calculation when the sprinkler system has failed to control the fire, AND when the door to the dwelling unit of fire origin is open, AND when the exit stairway door on the floor of fire origin is also open.
- Comments from TAG indicate that questions remain on tactical response for effectively fighting fires in a single-exit stairway buildings more than four stories in height.

Draft Conclusions

- Reliable door closers are important for containing combustion products within the dwelling unit of origin.
- In single-exit stairway buildings when the sprinkler system fails to control the fire, the corridor and exit stairway may fill with smoke before occupants make the decision to evacuate, when doors are open.
- Fire protection features and systems evaluated based on available data. The Consultants defer to the MBC where data could not support quantitative conclusions.
- Not an exhaustive evaluation of all possible mitigation measures.
- Purpose is to inform potential legislation.

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Draft Recommendations

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Draft Recommendations

Consistent with the stated purpose of this study, recommendations have been developed to reduce the risk of the prototype MFD single-exit stairway buildings to be less than or equal to that of a code-compliant single-exit stairway MFD. The recommendations are based upon the comparative RIA to identify features that significantly impact the risk.

1. Provide smoke detectors in the common means of egress in single-exit MFDs more than three stories tall.

Providing smoke detectors in common egress areas, such as corridors, in MFDs that are sprinklered throughout provides a diverse means of activating the building fire alarm system that is independent from the sprinkler system. The addition of the common area smoke detectors would reduce the comparative risk of the prototype single-exit stairway MFDs (Building 3 and Building 4) to be less than or equal to that of a code-compliant single-exit stairway MFD.

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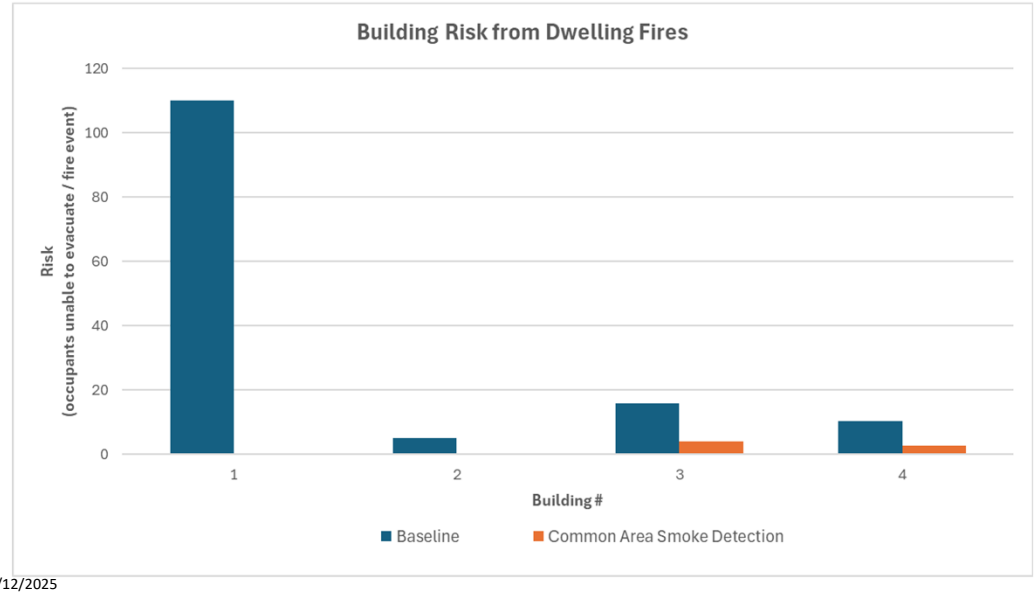
Draft Recommendation 1 – Common Area Smoke Detection



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Draft Recommendations

Consistent with the stated purpose of this study, recommendations have been developed to reduce the risk of the prototype MFD single-exit stairway buildings to be less than or equal to that of a code-compliant single-exit stairway MFD. The recommendations are based upon the comparative RIA to identify features that significantly impact the risk.

2. Increase enforcement of NFPA 25 and NFPA 72 inspection, testing, and maintenance (ITM) requirements in single-exit MFDs more than three stories tall.

Create a more robust ITM program to increase the reliability of a sprinkler system flowing on demand. Based on the MFIRS data, the current observed mean reliability of a sprinkler system flowing on demand is approximately 88%. If this reliability can be increased to approximately 96%, the estimated risk of both prototype single-exit stairway MFDs (Building 3 and Building 4) would be less than or equal to that of a single-exit stairway MFD compliant with the MBC having the observed sprinkler system reliability.

The ITM program should also include periodically inspecting that dwelling unit and exit stairway door closers function properly, and that doors are not propped open. The risk-significance of the dwelling unit and exit stairway doors will rise as the sprinkler system reliability increases.

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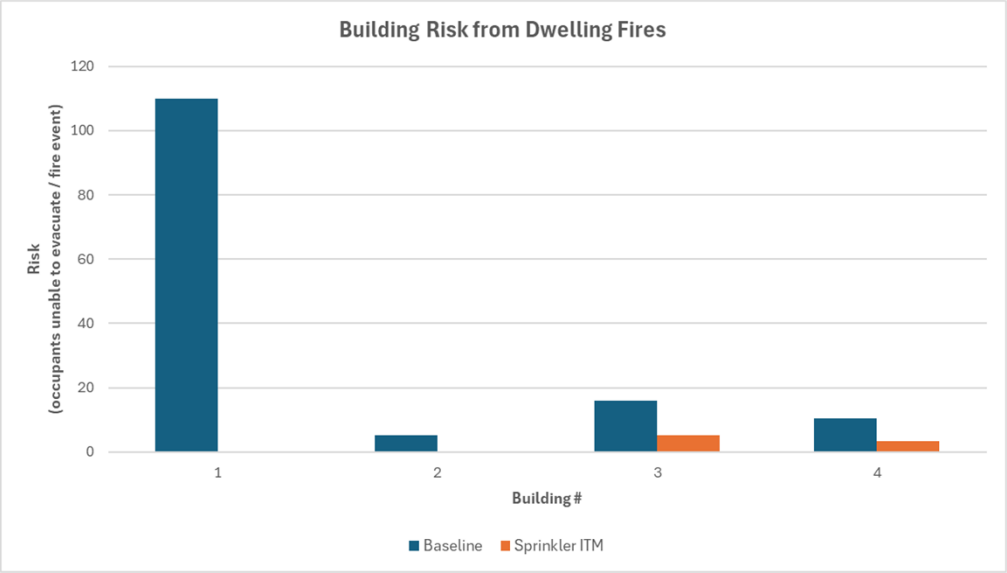
Draft Recommendation 2 – Sprinkler Reliability



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Next Steps

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Next Steps

- Consider comments from DLI and TAG
- Final report for DLI

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Thank You!

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