NASFM FIRE RESEARCH & EDUCATION FOUNDATION

The Goals and Objectives of Project FAIL-SAFE

The addition of redundant layers of safety is a well-established practice within the safety community, and one the National Association of State Fire Marshals (NASFM) has championed for nearly two decades. We are reminded of the aviation industry's duplicative efforts to guard against catastrophic failure, and the automotive industry's exhaustive pursuit of higher levels of safety. As buildings get larger, taller, and more complex, NASFM remains steadfast in our pursuit to ensure buildings are designed and constructed with the same care and concern for safety that we have come to expect from the transportation industry.

The research documents that follow have been produced under the NASFM Fire Research & Education Foundation's Project FAIL-SAFE. This research effort is charged with establishing valid scientific information to serve as a baseline for understanding the effects of incorporating safety layers into the built environment. It must be noted, clearly and distinctly, that this is not a discussion advocating one product over another, or active vs. passive; but rather it is a discussion around safety and resiliency of the built environment. In short, FAIL-SAFE is a research project designed to evaluate existing levels of redundancy to determine acceptable levels of safety should any individual system within the protective envelope fail to function as designed.

Each parcel of the research effort is designed to provide information to advance the understanding of the value of safety layers. As such, they should not be taken individually, but considered holistically with a focus of developing a baseline of knowledge from which further discussion and research will emanate. To that end, the NASFM Foundation commissioned an analysis of tradeoffs in the IBC based on both occupancy and building type to provide focus for subsequent phases of the project. Utilizing the results of the analysis for clarity, the following literature review report was completed by Worcester Polytechnic Institute (WPI). Its goal was to identify what is known scientifically, and what is not known, about how fire protection features interact with one another to increase safety and building resiliency.

Again, building on the direction gleaned from the code analysis and literature review, computer modeling was designed to better understand the knowledge gaps identified by the previous work. WPI was commissioned to continue their work by developing a fire modeling plan designed provide initial answers to the identified knowledge gaps.

Simultaneously, we have undertaken development of the NASFM Foundation Risk Evaluation MATRIX™. The MATRIX™ is an on-line application that applies standing International Existing Building Code evaluation techniques to understand the overall fire risk associated with existing buildings. Utilizing the data input from the application, an analysis was being performed to study the impact of various fire protection features in the building co and their resultant impact on fire risk.

Evaluating a real-world collection of building inventory from representative areas across the country, with the academic research performed by WPI, a comprehensive picture is being developed to advance the discussion and importance of redundant layers of safety in the built environment.

The principal membership of the National Association of State Fire Marshals (NASFM) comprises the senior fire officials in the United States and their top deputies. The primary mission of NASFM is to protect human life, property and the environment from fire and related hazards. A secondary mission of NASFM is to improve the efficiency and effectiveness of State Fire Marshals' operations. Learn more about NASFM and its issues at www.firemarshals.org.

PG PublicServices

Analysis of the Impact of Trade-offs of Passive and Active Building Safety Features

Submitted to:

National Association of State Fire Marshals (NASFM) Fire Research & Education Foundation

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SUMMARY

The NASFM Foundation Risk Evaluation MATRIX™ tool is a significant aid in the measurement of building safety parameters and provides a foundation for the collection and analysis of the evolution of the building code and its impact on occupant and building safety. The MATRIX™ uses the specifications as detailed in Chapter 14 of the 2015 Edition of the International Existing Building Code (IEBC) to assess a building's fire and life safety risk.

Within the IEBC, Chapter 14 *Performance Compliance Methods* details how evaluations are based on a numerical scoring system which encompasses twenty-three separate safety parameters. Additionally, Chapter 14 details how these safety parameters can be combined into three aggregate safety metrics: fire safety, means of egress, and general safety.

Prior to 2000, there were several independent code systems. These independent codes, commonly referred to as the Legacy Codes, were synthesized into the single comprehensive code system known as the International Codes (I-Codes). The I-Codes were first published in 2000.

One aspect of the I-Code development was the incorporation of many trade-offs from the three Legacy Codes. A trade-off is an exchange of one item in return for another, especially in the exchanging of one benefit or advantage for another regarded as more desirable. In modern buildings, the concept of allowing trade-offs of built-in protection in exchange for the installation of properly designed, installed, and maintained fire sprinkler systems is a customary practice.

The question addressed by this analysis therefore is: Has the adoption of various trade-offs had an impact on the overall safety of the building inventory?

From the current sample, the adoption of the I-Codes appears to have had a statistically significant impact to two individual safety parameters of buildings built post adoption of the I-Codes. Specifically, means of egress capacity individual safety scores increased and the standpipe individual safety score decreased.

For reference, a decreased safety score, whether for an individual parameter or overall, is indicative of increased risk as quantified within the I-Codes. Likewise, an increased safety score is indicative of decreased risk. Further explanation of the risk evaluation process is explained later in this report.

It should be noted however, that despite various individual safety parameters displaying either increased or decreased safety scores, all three aggregate building safety scores – fire safety, means of egress, and general safety – have decreased after the adoption of the I-Codes. With additional data, it may be possible to further determine if this decline was statistically significant and the root causes of these decreases.

Additionally, there were changes in other safety parameters that indicate a shift of structural trade-offs with the adoption of the I-Codes. For example, the trade-offs of the decline of passive building features such as compartmentation, tenant / dwelling separation, and travel distances compared with the increased reliance of active building features such as automatic fire detection, fire alarm systems, and automatic sprinklers.

It should also be noted that the initial findings described herein may change as additional data is collected.

BACKGROUND

The International Existing Building Code

The International Codes (I-Codes), developed by the International Code Council (ICC), provide a comprehensive family of codes that are used in the design, build, and compliance processes of building construction. While they are not the sole codes and standards available to guide building construction, the comprehensive nature of the I-Codes provides guidance on the minimum safeguards needed to protect the public in their homes, schools, and places of work.

Prior to the first edition of the I-Codes in 2000, there were several independent code systems. These independent codes, commonly referred to as the Legacy Codes, included the Building Officials and Code Administrators, International (BOCA); the International Conference of Building Officials – Uniform Building Code (UBC); and the Southern Building Code Congress, International (SBCCI). In creating the I-Codes, these Legacy Code systems were synthesized into a single comprehensive code.

Specifically, the ICC's International Existing Building Code (IEBC) contains the code requirements for the alteration, repair, addition, and change of occupancy of existing structures, including historic and moved structures. Within the IEBC, Chapter 14 *Performance Compliance Methods* details how evaluations are based on a numerical scoring system, established through the consensus process, which encompasses twenty-three separate safety parameters. Additionally, Chapter 14 details how these safety parameters can be combined into three aggregate safety metrics: fire safety, means of egress, and general safety. The degree of compliance is based on a minimum compliance threshold, based on the occupancy type of the building. The I-Codes standards evolve over time to incorporate new knowledge and allow trade-offs between various active and passive safety features within a building. Chapter 14 of the IEBC provides a basis for evaluating the various safety features within a building and the degree to which those safety features may have been affected.

The IEBC aggregation of the individual safety parameters into the broader metrics of fire safety, means of egress, and general safety is detailed in Table 1, *IEBC Safety Parameter Model*.

Table 1. IEBC Safety Parameter Model

IEBC Code Section	Safety Parameter	Fire Safety (FS)	Means of Egress (ME)	General Safety (GS)
1401.6.1	Building Height			
1401.6.2	Building Area			
1401.6.3	Compartmentation			
1401.6.4	Tenant and Dwelling Unit Separations			
1401.6.5	Corridor Walls			
1401.6.6	Vertical Openings			
1401.6.7	HVAC Systems			
1401.6.8	Automatic Fire Detection			
1401.6.9	Fire Alarm Systems			
1401.6.10	Smoke Control	NA		
1401.6.11	Means of Egress Capacity	NA		
1401.6.12	Dead Ends	NA		
1401.6.13	Maximum Exit Access Travel Distance	NA		
1401.6.14	Elevator Control			
1401.6.15	Means of Egress Emergency Lighting	NA		
1401.6.16	Mixed Occupancies		NA	
1401.6.17	Automatic Sprinklers			
1401.6.18	Standpipes			
1401.6.19	Incidental Uses			
1401.6.20	Smoke Compartmentation			
1401.6.21.1	Patient Ability for Self-preservation	NA		
1401.6.21.2	Patient Concentration	NA		
1401.6.21.3	Attendant-to-patient Ratio	NA		
Total Building Score				

One aspect of the I-Code development was the incorporation of trade-offs from the three Legacy Codes. While the concept of trade-offs is not new, a recent study by Dempsey et al notes they were first introduced in fire protection engineering in the groundbreaking report *America Burning*. (Dembsey, Meacham, & Wang, p. 8) *America Burning* recognized the concept of reducing the requirements of other fire protection features in exchange for the installation of automatic fire sprinkler systems. (The National Commission on Fire Prevention and Control, 1973, p. 73) In modern buildings, the concept of allowing trade-offs in exchange for the installation of properly designed, installed, and maintained fire sprinkler systems is a customary practice.

While the concept of trade-offs was present in the Legacy Codes, the emergence of the I-Codes accentuated trade-offs between various active and passive safety features within a building.

The results of these trade-offs can be seen in impacts to the various aspects of the greater fire problem including building resiliency and the health and safety of building occupants and firefighters who respond to incidents in these buildings. There is little real-world knowledge of how those trade-offs perform once built, however, and there is much debate about the efficacy of the trade-offs. Dembsey et al has summarized the debate as:

- Sprinkler systems effectiveness is widely accepted by both opponents and proponents
- Most, if not all, trade-off opponents advocate a balanced fire protection system including both sprinklers and passive fire protection approaches
- Most, if not all, trade-off proponents believe sprinklers deserve more trade-offs in passive fire protection approaches
- Both the opponents and proponents failed to persuade the other side by demonstrating necessary proofs that are reasonable, scientific, and quantitative
- Sprinklers are effective in protecting both life safety and property
- Without deeper research that could provide enough scientific and quantitative proof for each side, this kind of debate will continue in the future. (Dembsey, Meacham, & Wang, pp. 9-10)

Specifically, the underlying question that remains to be answered is how the trade-offs between active and passive safety features impact the resiliency of building, the safety of the occupants, and the health and safety of firefighters who respond to incidents in these buildings.

Study Question

Chapter 14 of the IEBC provides a basis for evaluating the various safety features within a building and the degree to which trade-offs have been used. It is thus possible to directly score the active and passive safety features of a building and to analyze the impact to building risk and safety subsequent to the adoption of the I-Codes.

The question addressed by this analysis therefore is: Has the adoption of various trade-offs had an impact on the overall safety of the building inventory?

DATA COLLECTION

Fire department partners were engaged to use the MATRIX™ to collect building characteristics including, but not limited to, building dimensions, occupancy type, construction type, systems, and means of egress. Additionally, the department partners collected the building code under which the building was permitted.

The MATRIX™ is a fire risk indexing tool for fire departments and others to use in determining the fire and life safety risk of a building. The MATRIX™ uses the specifications as detailed in Chapter 14 of the 2015 Edition of the IEBC to assess a building's fire and life safety risk. The specifications consist of a series of equations, parameters, conversion tables, and cross-references. The necessary calculations to determine compliance, though, are complex, detailed, and time-consuming. The MATRIX™ simplifies these calculations by providing an online questionnaire for fire and building inspectors to collect the necessary inputs and determine the building's overall safety scores. In addition to the three aggregate metrics outlined in Chapter 14, the twenty-three intermediate safety parameter scores are calculated and are included as part of the MATRIX™ output.

The MATRIX™ output facilitates the analysis of the individual and aggregate safety metrics by eliminating the calculation overhead and streamlining the collection of building characteristics. We found the MATRIX™ output to be essential for the analyses of building trade-offs.

Summary of Data Collected

Participating fire departments collected a wide variety of buildings across multiple areas of the United States, built under multiple building codes, age constructed, occupancy type, construction type, height, and size. Additionally, the buildings collected included a variety of active building protection features. Tables two through ten below detail how the collected data is dispersed within each of the categories identified in the MATRIX™.

While the total data collected during the trial was limited, we do not believe that there is inherent bias in the data set for further analysis.

Table 2. Distribution by Geographic Region

Region	Percent
Mid-Atlantic	21.9%
Mid-West	59.4%
New England	9.4%
South	9.4%
Total	100.0%

Table 3. Distribution by Building Code

Code	Percent
BOCA	12.5%
SBCCI	0.0%
UBC	6.3%
Other	46.9%
I-Codes 2003	12.5%
I-Codes 2006	12.5%
I-Codes 2009	3.1%
I-Codes 2012	6.3%
Total	100.0%

Table 4. Distribution by Year Built

Year Built	Percent
Prior to 1950	21.9%
1950s	6.3%
1960s	12.5%
1970s	9.4%
1980s	9.4%
1990s	9.4%
2000s	21.9%
2010s	9.4%
Total	100.0%

Table 5. Distribution by Occupancy Type

Occupancy Type	Percent
A2	3.1%
A3	3.1%
B	18.8%
E	15.6%
M	31.3%
R2	28.1%
Total	100.0%

Table 6. Distribution by Construction Type

Construction Type	Percent
1A	9.4%
1B	9.4%
IIA	15.6%
IIB	15.6%
IIA	12.5%
IIIB	15.6%
VA	3.1%
VB	18.8%
Total	100.0%

Table 7. Distribution by Building Height, Stories

Stories	Percent
1 story	50.0%
2 stories	28.1%
3 stories	6.3%
5 stories	6.3%
6 stories	3.1%
7 stories	6.3%
Total	100.0%

Table 8. Distribution by Building Size, Square Feet

Square Feet	Percent
< 10,000	43.8%
10,000-20,000	12.5%
20,000-50,000	9.4%
50,000-100,000	12.5%
100,000-200,000	3.1%
200,000-300,000	15.6%
300,000-400,000	3.1%
Total	100.0%

Table 9. Distribution by Sprinklers Present

Sprinklers	Percent
Not-Present	53.1%
Present	46.9%
Total	100.0%

Table 10. Distribution by Alarm Installed

Alarms	Percent
Not Installed	25.0%
Installed	75.0%
Total	100.0%

Analysis

Using the data collected by the MATRIX™ we analyzed the relationship between safety parameters and the impact of the adoption of the I-Codes compared to Legacy Code systems. Specifically, we analyzed the change in parameters before and after the adoption of the I-Codes and identified those parameters whose change is statistically significant. Additionally, we analyzed the impact to the fire safety (FS), means of egress (ME), and the general safety (GS) scores described within the IEBC to see if adoption of the I-Codes created a statistically significant change.

It should be noted, the initial findings described herein may change as additional data is collected.

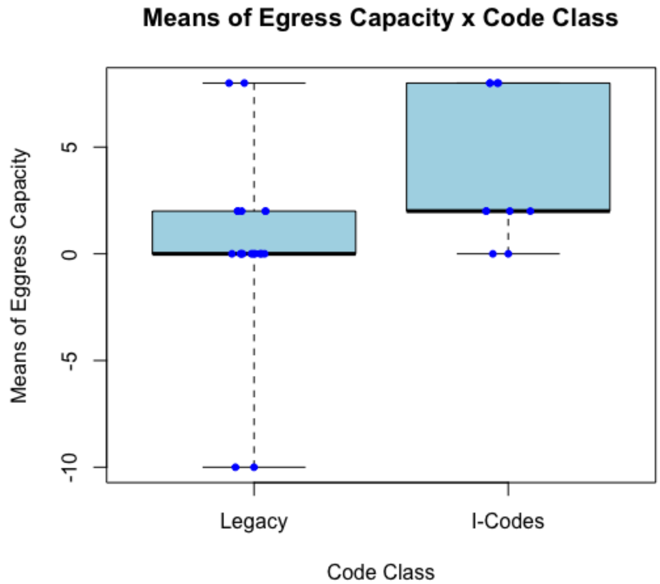
Findings

We grouped buildings into two "code classes" based on the code under which the building was built: either Legacy (UBC, BOCA, SBCCI, and Other) or I-Codes for the years through 2012. We compared the mean safety parameters and safety scores using the Student t-test.

Within the sample set, there were two safety parameters that were found to have a statistically significant change with the adoption of the I-Codes: means of egress capacity and standpipes.

Means of egress capacity increased significantly with the adoption of the I-Codes; scores rose from an average of 0.32 to an average score of 4. This increase can be seen in Figure 1, *Comparison of Means of Egress Capacity*.[1]

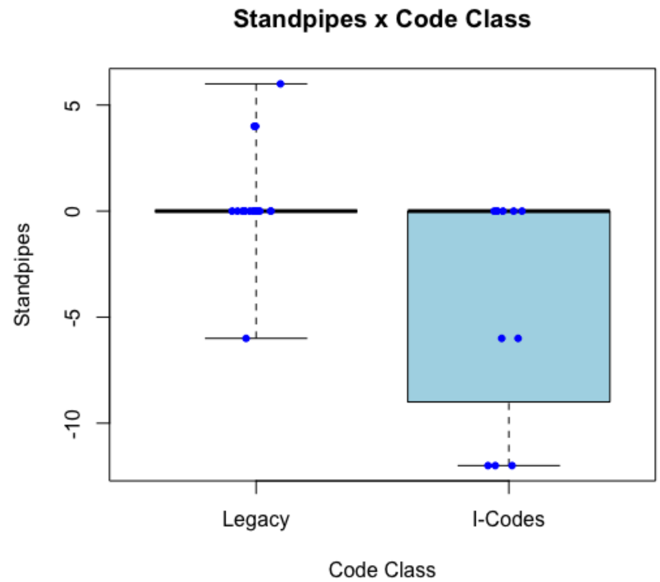
Figure 1. Comparison of Means of Egress Capacity



Conversely, the standpipe score decreased significantly with the adoption of the I-Codes; scores declined from an average of 0.60 to an average score of -4.4. This decrease can be seen in Figure 2, *Comparison of Standpipes*.

[1]The bottom and top of the box are the 25th and 75th percentile (the lower and upper quartiles, respectively), and the band near the middle of the box is the 50th percentile (the median). The whiskers at the edge of the plot represent the maximum and minimum values in the data set.

Figure 2. Comparison of Standpipes



While not found to be statistically significant, it is notable that there were several other safety parameters that declined by appreciable amounts with the adoption of the I-Codes. Additional data may help further clarify if these declines are statistically significant. These declines are further detailed in Table 11, *Comparison of Other Declining Safety Scores*.

Table 11. Comparison of Other Declining Safety Scores

Safety Score	Average Legacy Codes	Average I-Codes	Percent Change
Building Area	9.70	-3.20	-132.8%
Compartmentation	12.40	11.40	-8.1%
Tenant and Dwelling Unit Separations	0.23	0.18	-20.0%
Smoke Control	2.60	1.70	-34.5%
Maximum Exit Access Travel Distance	11.60	8.10	-30.1%

Additionally, there were several other safety parameters that increased by appreciable amounts with the adoption of the I-Codes. These were not found to be statistically significant, but additional data may help further clarify this observation. These increases are further detailed in Table 12, *Comparison of Other Increasing Safety Scores*.

Table 12. Comparison of Other Increasing Safety Scores

Safety Score	Average Legacy Codes	Average I-Codes	Percent Change
Building Height	1.65	2.55	54.7%
Corridor Walls	-0.50	0.00	100.0%
Automatic Fire Detection	-5.23	-1.45	72.2%
Fire Alarm Systems	0.86	4.91	468.4%
Elevator Control	-0.13	2.00	1700.0%
Means of Egress Control Lighting	1.36	2.27	66.7%
Automatic Sprinklers	-0.18	2.91	1700.0%

The contrast of these increases and decreases are indications of the changes in structural tradeoffs with the adoption of the I-codes. In particular, the tradeoffs illustrate the decline of passive building features such as compartmentation, tenant / dwelling separation, and travel distances compared with the increased reliance of active building features such as automatic fire detection, fire alarm systems, and automatic sprinklers.

Finally, while not found to be statistically significant, it is notable that **all** aggregate safety scores declined by appreciable amounts with the adoption of the I-Codes. Average fire safety scores decreased by 23.4%, average means of egress scores decreased by 18.4%, and general safety scores decreased by 13.2%. These declines are further detailed in Table 13, *Comparison of Aggregate Safety Scores*; Figure 3, *Comparison of Fire Safety Scores by Code Class*; Figure 4, *Comparison of Means of Egress Scores by Code Class*; and Figure 5, *Comparison of General Safety Scores by Code Class*.

Table 13. Comparison of Aggregate Safety Scores

Safety Score	Average Legacy Codes	Average I-Codes	Percent Change
Fire Safety (FS)	23.98	18.34	-23.4%
Means of Egress (ME)	40.81	33.32	-18.4%
General Safety (GS)	41.62	36.13	-13.2%

Figure 3. Comparison of Fire Safety Scores by Code Class

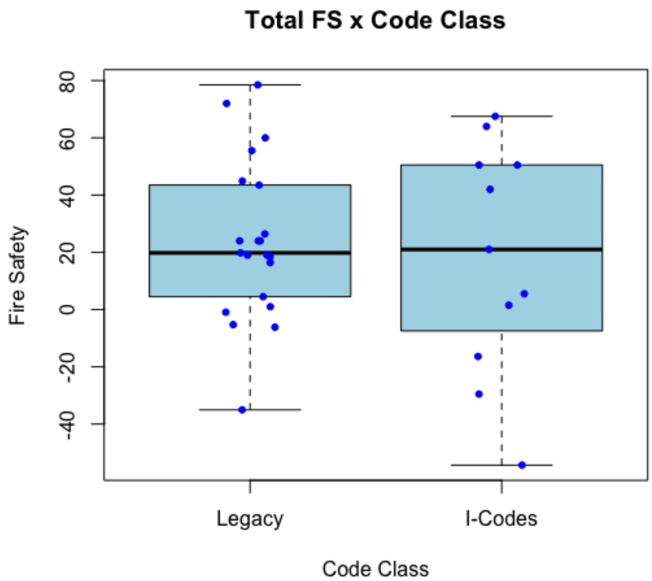


Figure 4. Comparison of Means of Egress Scores by Code Class

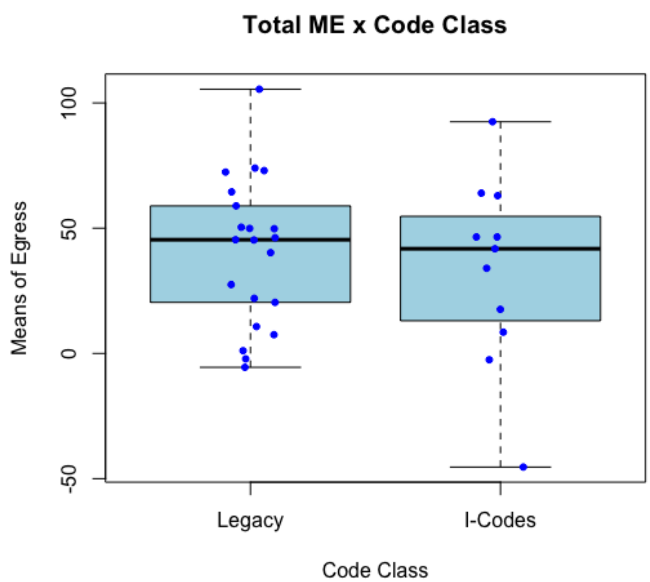
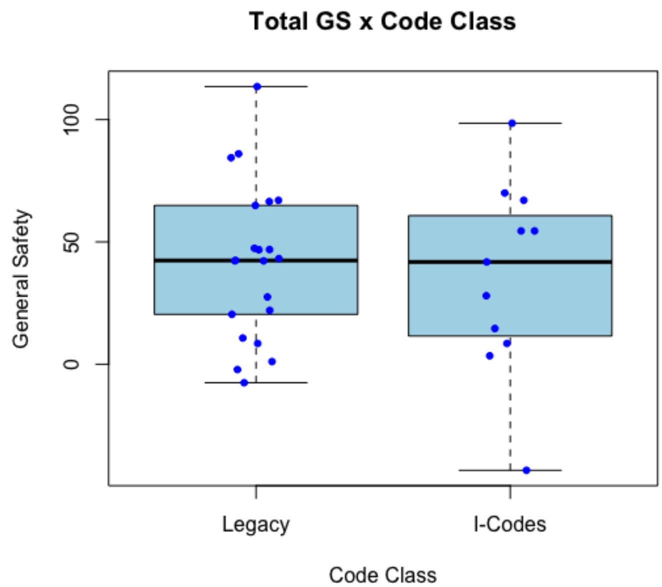


Figure 5. Comparison of General Safety Scores by Code Class



A complete description of each of the safety parameters and their impact on the aggregate safety scores can be seen in the Appendix in Table 14, *Comparison of Legacy and I-Codes Fire Safety Scores*; Table 15, *Comparison of Legacy and I-Codes Means of Egress Safety Scores*; and Table 16, *Comparison of Legacy and I-Codes General Safety Scores*.

Further Study

Additional data would allow for the isolation of specific variables and their influence on population data as well as more in-depth analysis of the impacts of specific code changes on building safety scores. In particular, occupancy type has a disproportionate effect on the calculation of safety parameters as well as a minimum passing score. Additional data would allow for isolation of the effects of code changes within a given occupancy type.

A larger data set would also allow a more detailed analysis of safety features tradeoffs. This tradeoff analysis could be conducted by comparing, for example, the relative scores of passive and active features as a percentage of the building safety score over time. This analysis could highlight the balance of active and passive features and their evolution with different updates of the IEBC standards.

Conclusions

Based on the initial data sample, as previously detailed in the Summary of Data Collected, the adoption of the I-Codes does appear to have had a statistically significant impact to the safety parameters of buildings built post adoption of the code. In particular, means of egress capacity safety scores increased and the standpipe safety score decreased.

Additionally, there were notable changes in other safety parameters that indicate a shift of structural tradeoffs with the adoption of the I-Codes. In particular, the tradeoffs of the decline of passive building features such as compartmentation, tenant / dwelling separation, and travel distances compared with the increased reliance of active building features such as automatic fire detection, fire alarm systems, and automatic sprinklers. More data is required to determine which of these changes are statistically significant.

All the aggregate building safety scores – fire safety, means of egress, and general safety – decreased with the adoption of the I-Codes. With further data, it may be possible to further determine if this decline was statistically significant and the root causes of these decreases. Additional data would also allow for better isolation of specific variables, such as occupancy type, on the overall population scores.

Finally, the NASFM Foundation Risk Evaluation MATRIX™ tool is a significant aid in the measurement of building safety parameters and provides a foundation for the collection and analysis of the evolution of the building code and its impact on occupant and building safety.

APPENDIX

Table 14. Comparison of Legacy and I-Codes Fire Safety Scores

IEBC Code Section	Safety Parameter	Average Fire Safety Score (FS) Legacy Codes	Avg. Fire Safety Score (FS) I-Codes	Percent Change	Significant
1401.6.1	Building Height	1.65	2.55	54.70%	
1401.6.2	Building Area	9.66	-3.16	-132.77%	
1401.6.3	Compartmentation	12.36	11.36	-8.09%	
1401.6.4	Tenant and Dwelling Unit Separations	0.23	0.18	-20.00%	
1401.6.5	Corridor Walls	-0.50	0.00	100.00%	
1401.6.6	Vertical Openings	1.82	1.64	-10.00%	
1401.6.7	HVAC Systems	1.36	1.36	0.00%	
1401.6.8	Automatic Fire Detection	-5.23	-1.45	72.17%	
1401.6.9	Fire Alarm Systems	0.86	4.91	468.42%	
1401.6.10	Smoke Control	NA	NA	NA	
1401.6.11	Means of Egress Capacity	NA	NA	NA	
1401.6.12	Dead Ends	NA	NA	NA	
1401.6.13	Maximum Exit Access Travel Distance	NA	NA	NA	
1401.6.14	Elevator Control	-0.13	2.00	1700.00%	
1401.6.15	Means of Egress Emergency Lighting	NA	NA	NA	
1401.6.16	Mixed Occupancies	1.19	1.36	14.55%	
1401.6.17	Automatic Sprinklers	-0.18	2.91	1700.00%	
1401.6.18	Standpipes	0.60	-4.36	-827.27%	*
1401.6.19	Incidental Uses	0.00	0.00	-	
1401.6.20	Smoke Compartmentation	NA	NA	-	
1401.6.21.1	Patient Ability for Self-preservation	NA	NA	-	
1401.6.21.2	Patient Concentration	NA	NA	-	
1401.6.21.2	Attendant-to-patient Ratio	NA	NA	-	
Total Fire Safety Score		**23.98**	**18.38**	**-23.35%**	

Table 15. Comparison of Legacy and I-Codes Means of Egress Safety Scores

IEBC Code Section	Safety Parameter	Avg. Means of Egress Score (ME) Legacy Codes	Avg. Means of Egress Score (ME) I-Codes	Percent Change	Significant
1401.6.1	Building Height	1.65	2.55	54.70%	
1401.6.2	Building Area	9.66	-3.16	-132.77%	
1401.6.3	Compartmentation	12.36	11.36	-8.09%	
1401.6.4	Tenant and Dwelling Unit Separations	0.23	0.18	-20.00%	
1401.6.5	Corridor Walls	-0.50	0.00	100.00%	
1401.6.6	Vertical Openings	1.82	1.64	-10.00%	
1401.6.7	HVAC Systems	1.36	1.36	0.00%	
1401.6.8	Automatic Fire Detection	-5.23	-1.45	72.17%	
1401.6.9	Fire Alarm Systems	0.86	4.91	468.42%	
1401.6.10	Smoke Control	2.64	1.73	-34.48%	
1401.6.11	Means of Egress Capacity	0.32	4.00	1166.67%	*
1401.6.12	Dead Ends	2.00	2.00	0.00%	
1401.6.13	Maximum Exit Access Travel Distance	11.61	8.12	-30.08%	
1401.6.14	Elevator Control	-0.13	2.00	1700.00%	
1401.6.15	Means of Egress Emergency Lighting	1.36	2.27	66.67%	
1401.6.16	Mixed Occupancies	NA	NA	-	
1401.6.17	Automatic Sprinklers	-0.09	1.46	1700.00%	
1401.6.18	Standpipes	0.60	-4.36	-827.27%	*
1401.6.19	Incidental Uses	0.00	0.00	-	
1401.6.20	Smoke Compartmentation	-	-	-	
1401.6.21.1	Patient Ability for Self-preservation	-	-	-	
1401.6.21.2	Patient Concentration	-	-	-	
1401.6.21.2	Attendant-to-patient Ratio	-	-	-	
Total Means of Egress Safety Score		**40.82**	**33.32**	**-18.36%**	

Table 16. Comparison of Legacy and I-Codes General Safety Scores

IEBC Code Section	Safety Parameter	Avg. General Safety (GS) Legacy Codes	Avg. General Safety(GS) I-Codes	Percent Change	Significant
1401.6.1	Building Height	1.65	2.55	54.70%	
1401.6.2	Building Area	9.66	-3.16	-132.77%	
1401.6.3	Compartmentation	12.36	11.36	-8.09%	
1401.6.4	Tenant and Dwelling Unit Separations	0.23	0.18	-20.00%	
1401.6.5	Corridor Walls	-0.50	0.00	100.00%	
1401.6.6	Vertical Openings	1.82	1.64	-10.00%	
1401.6.7	HVAC Systems	1.36	1.36	0.00%	
1401.6.8	Automatic Fire Detection	-5.23	-1.45	72.17%	
1401.6.9	Fire Alarm Systems	0.86	4.91	468.42%	
1401.6.10	Smoke Control	2.64	1.73	-34.48%	
1401.6.11	Means of Egress Capacity	0.32	4.00	1166.67%	*
1401.6.12	Dead Ends	2.00	2.00	0.00%	
1401.6.13	Maximum Exit Access Travel Distance	11.61	8.12	-30.08%	
1401.6.14	Elevator Control	-0.13	2.00	1700.00%	
1401.6.15	Means of Egress Emergency Lighting	1.36	2.27	66.67%	
1401.6.16	Mixed Occupancies	1.19	1.36	14.55%	
1401.6.17	Automatic Sprinklers	-0.18	2.91	1700.00%	
1401.6.18	Standpipes	0.60	-4.36	-827.27%	*
1401.6.19	Incidental Uses	0.00	0.00	-	
1401.6.20	Smoke Compartmentation	-	-	-	
1401.6.21.1	Patient Ability for Self-preservation	-	-	-	
1401.6.21.2	Patient Concentration	-	-	-	
1401.6.21.2	Attendant-to-patient Ratio	-	-	-	
Total General Safety Score		**41.62**	**36.14**	**-13.19%**	

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Dembsey, N., Meacham, B., & Wang, H. (n.d.). *A Literature Review of Sprinkler Trade-offs.* Worcester Polytechnic Institute, Fire Protection Engineering.

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