

Testing the Validity of 2D and 3D Design Information for Pre-Incident Emergency Response Plans

NCOSHERC

Research Presentation Meeting

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Presentation Agenda

- Executive Summary
- Introduction
- Research Needs
- Research Questions and Hypotheses
- Methods
- Results
- Conclusions and Future Work

Executive Summary

- Simulated emergency plans were conducted with 108 firefighters to explore perceptions of how various formats of building design visualizations affect pre-incident emergency response planning.
- Firefighters were provided with one of four visualizations of the ECU Student Center: (1) a street view image, (2) two-dimensional computer aided design drawings (CAD), (3) three-dimensional navigable imagery, and (4) a first-person game-based environment.
- Participants were randomly assigned to a singular format using a randomized design and were asked to explore the information to build an understanding of the layout and internal configuration of the facility.

Executive Summary

- ANOVA tests suggest that the format of visualization improved firefighters' concepts of navigation, layout and configuration, and division connectivity.
- Results suggest navigable imagery and game-based environments improve concepts of navigation, layout and configuration, and division connectivity.
- Result suggests that 2D CAD is the most difficult format of visualization to use.
- The practical implication is that the format of visualization may enable firefighters to train remotely on building navigation and potentially improve the effectiveness of rescue activities and patient and firefighter survivability.

Introduction – US Fire Problem

- Every 23 seconds, a fire department in the United States responds to a fire somewhere in the nation.
- Between 2011 and 2015, fire fighters nationwide responded to 37,910 fires at industrial or manufacturing properties each year.
 - Annual losses from these fires estimated at 16 civilian deaths, 273 civilian injures, and \$1.2 billion in direct property damage.
- In 2022, fire fighters responded to 1,450 structure fires in warehouses.
 - \$283 million in direct property damage, two civilian deaths, and 16 civilian injuries.

Introduction – Wayne Auto Salvage

Wayne Auto Salvage fatalities – 11/06/98

- Sidney Jones, 29 – Chief of the Thoroughfare VFD
- Robbie Blizzard, 24 – Arrington VFD and Goldsboro FD



Introduction

- Emergency action plans (EAP's) are internal documents that contain procedures for emergency reporting, evacuation, accountability, and more.
- EAP's are essential for emergency preparedness and business continuity in emergency events.
- Coordination between emergency services and industry has reduced response times, increased operational efficiency, and has the potential to improve search and rescue operations.

Research Needs

- Improvement of EAP's
- Testing the provision of 2D CAD, 3D Navigable Imagery, and 3D game-based visualizations for pre-plans and emergency response.
- This is the first research to implement the use of a mixture of 2D CAD, 3D navigable imagery, and 3D game-based visualizations in a controlled quasi-experimental study to evaluate the feasibility and practicality of these formats of information on pre-incident planning and emergency response activities.

Research Questions and Hypotheses

- Research Questions

1. How is the design information useful for understanding the layout and interior configuration of buildings?
2. How can 2D CAD, 3D navigable imagery, and game-based visualizations be used for pre-incident planning and emergency response activities?
3. How can these visualizations be improved?

Research Questions and Hypotheses

- Research Hypotheses

- Ho1: The format of visualization does not affect firefighters' perceptions of potential conceptualization of navigational aspects of buildings.
- Ho2: The format of visualization does not affect firefighters' perceptions of potential conceptualization of building layout and configuration.
- Ho3: The format of visualization does not affect firefighters' perceptions of potential conceptualization of division connectivity.

Research Methods

- Conducted in 3 Phases
 - Phase 1: Site selection and 3D Matterport imagery.
 - Phase 2: Development of Unity game-based environment.
 - Phase 3: Quasi-experimental testing and analysis.

Research Methods – Phase 1: Site Selection

- 220,000 sq ft multiuse space including retail, restaurant, study, and entertainment.
- Multiple divisions and intricate layout of rooms, hallways, and equipment chases.
- 2D computer aided design drawings (2D CAD) and 3D Autodesk Revit building information models (3D BIM) were available.



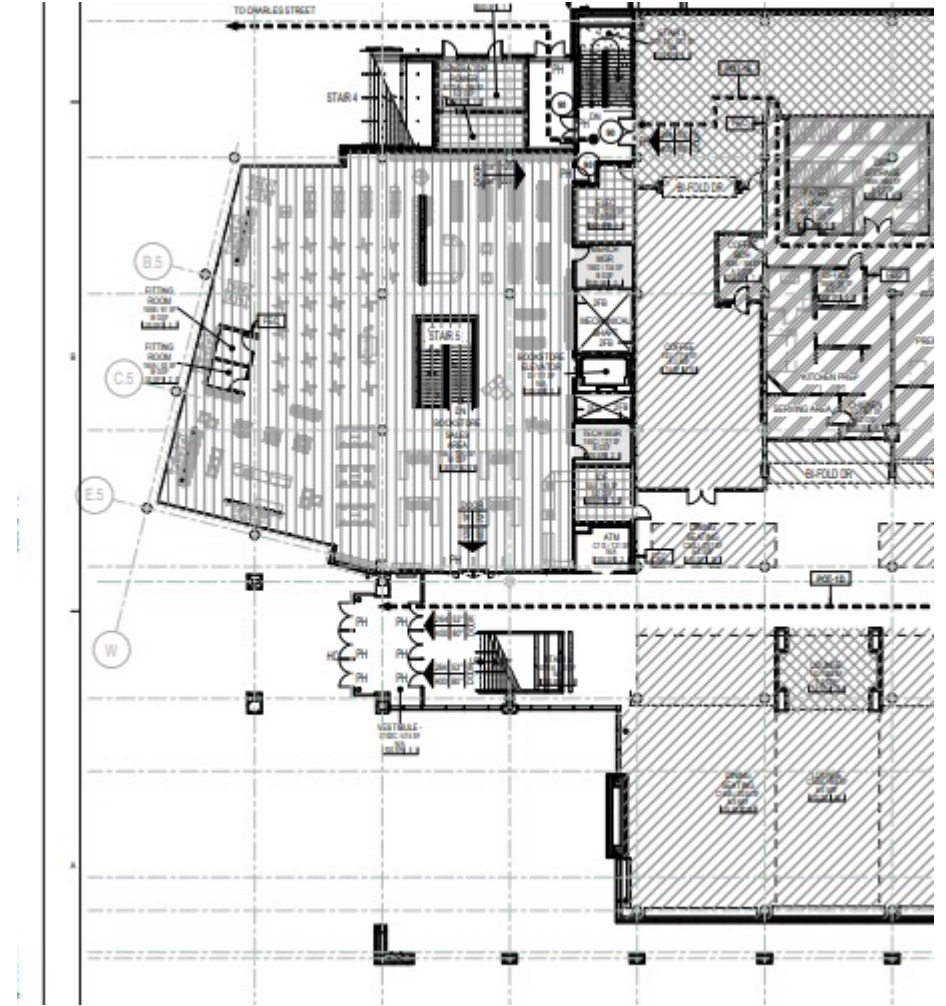
ECU Main Campus Student Center, 10th St., Greenville, NC

Research Methods – Phase 1: Site Selection

- 2D CAD



Autodesk
Rendering



1st Floor Detail Example

Research Methods – Phase 1: Matterport

- 3D Matterport System



Pro 2
Camera



Tripod



iPad

Research Methods – Phase 2: Unity Game

- 3D Game Based Environment

Autodesk Revit – BIM
Model (.fbx)

Maya - Missing
Elements



Unity Environment #350 L.O.D.



Adobe Designer – Textures, Patterns and Colors



Unity Export to Desktop Shortcut



Unity Environment

Research Methods – Phase 3: Research Design

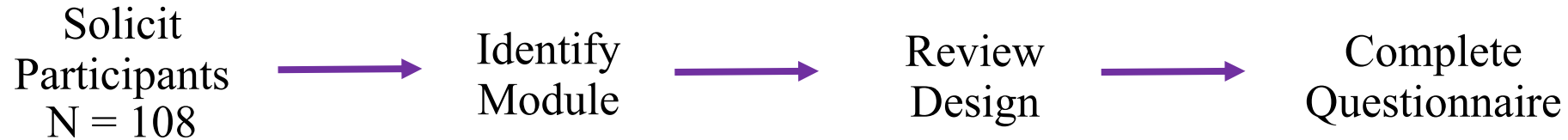


Table 1: Randomized Experimental Design

Randomized Design	Visualization Format (Research Module)			
	2D CAD	Matterport	Unity	Streetview Image
108 Participants	N = 27	N = 27	N = 27	N = 27

Research Methods – Phase 3: Testing

- Questionnaire for Hypothesis Testing

1. The design information visualizes navigational aspects of the building.
2. The design information helped me understand the building layout and interior configuration of the facility.
3. The design information helped me understand the connectivity of the various floors of the building.

Question 1: Do you agree or disagree with the following statement? (Circle One)						
Statement: “The design information visualizes navigational aspects of the building”						
Strongly Disagree	Disagree	Somewhat Disagree	Neither Disagree nor Agree	Somewhat Agree	Agree	Strongly Agree
(1)	(2)	(3)	(4)	(5)	(6)	(7)

Survey Excerpt

Research Methods – Phase 3: Testing

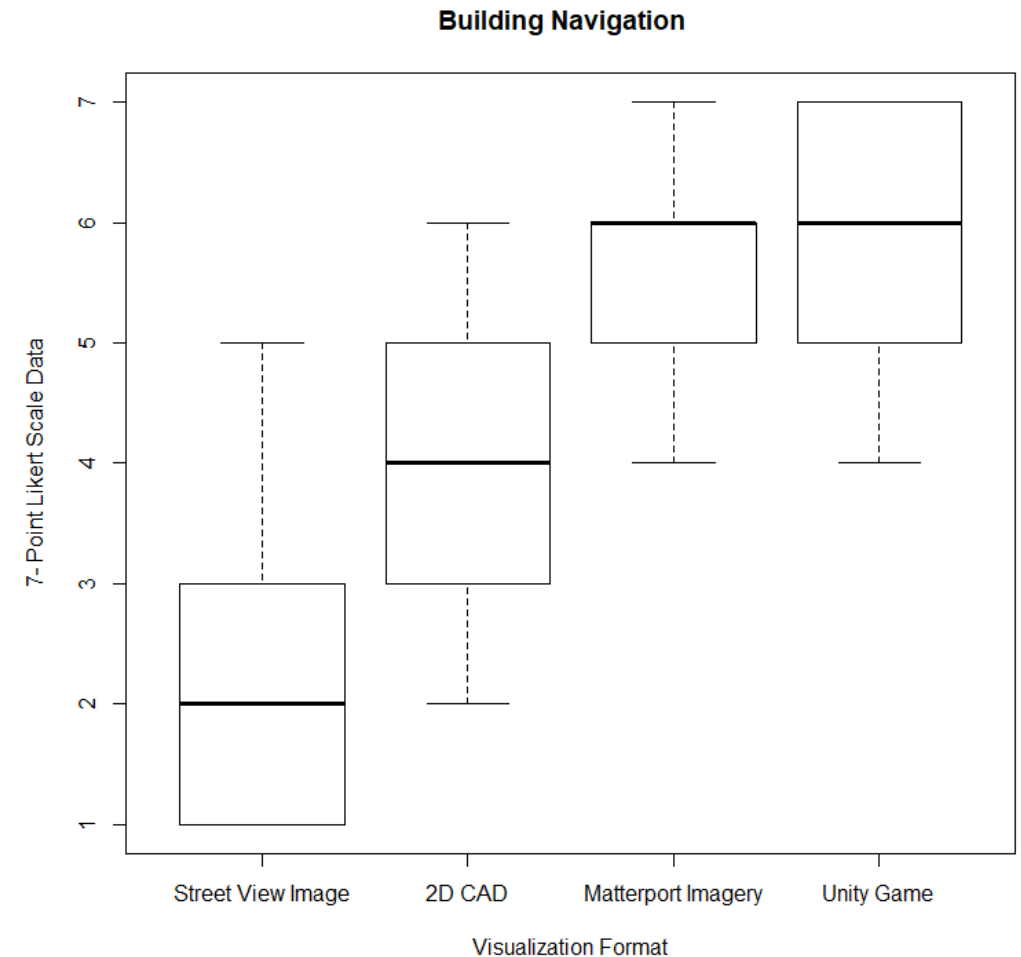
- Questionnaire for Exploratory Analysis
 4. This design information is easy to use.
 5. The design information is interactive.
 6. I was comfortable with the design information.
 7. The design information could be used to facilitate pre incident planning.

Results – Hypothesis Testing

- ANOVA Analysis (Q1): Concept of Building Navigation

Table 2: ANOVA Results Across all Study Participants for Question 1

Visualization Format	Sample Size	Mean Likert Response	<i>F</i>	<i>p</i>
Street View Image	27	2.1481	66.75	0.000*
2D CAD	27	4.1851		
Matterport Imagery	27	5.7407		
Unity Game	27	6.0370		



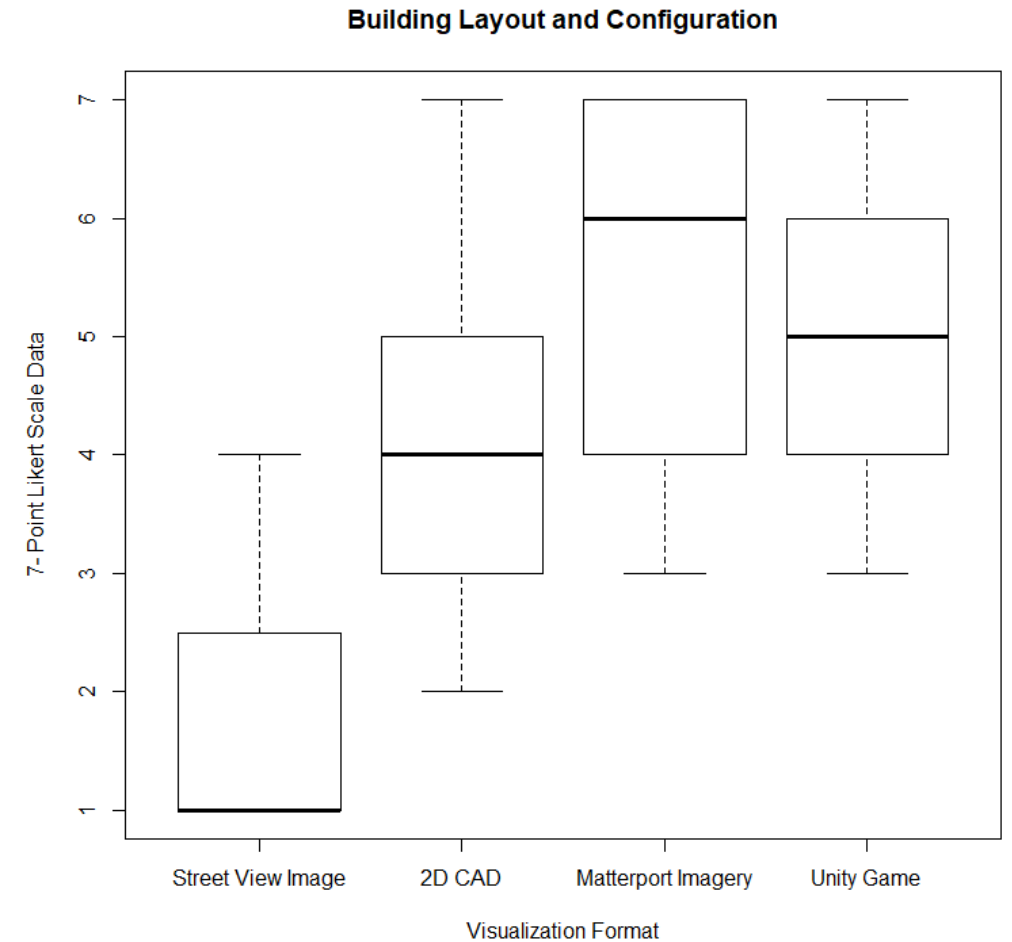
Likert Data for Visualization Format Across all Study Participants for Question 1

Results – Hypothesis Testing

- ANOVA Analysis (Q2): Concept of Building Layout and Configuration

Table 3: ANOVA Results Across all Study Participants for Question 2

Visualization Format	Sample Size	Mean (HR_{index})	F	p
Street View Image	27	1.0455	46.29	0.000*
2D CAD	27	3.8518		
Matterport Imagery	27	5.4814		
Unity Game	27	4.8888		



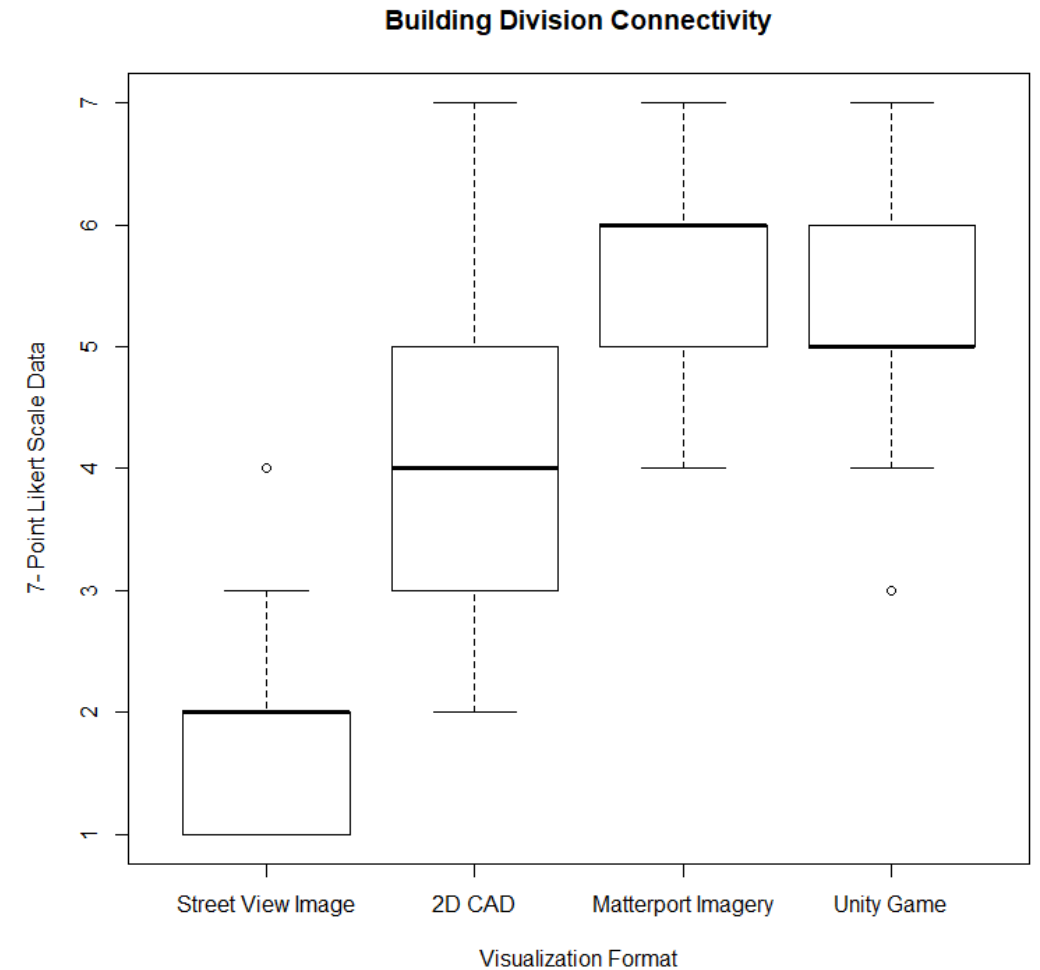
Likert Data for Visualization Format Across all Study Participants for Question 2

Results – Hypothesis Testing

- ANOVA Analysis (Q3): Concept of Building Division Connectivity

Table 4: ANOVA Results Across all Study Participants for Question 3

Visualization Format	Sample Size	Mean (HR_{index})	F	p
Street View Image	27	1.8518	39.66	0.000*
2D CAD	27	3.9629		
Matterport Imagery	27	5.5925		
Unity Game	27	5.1111		

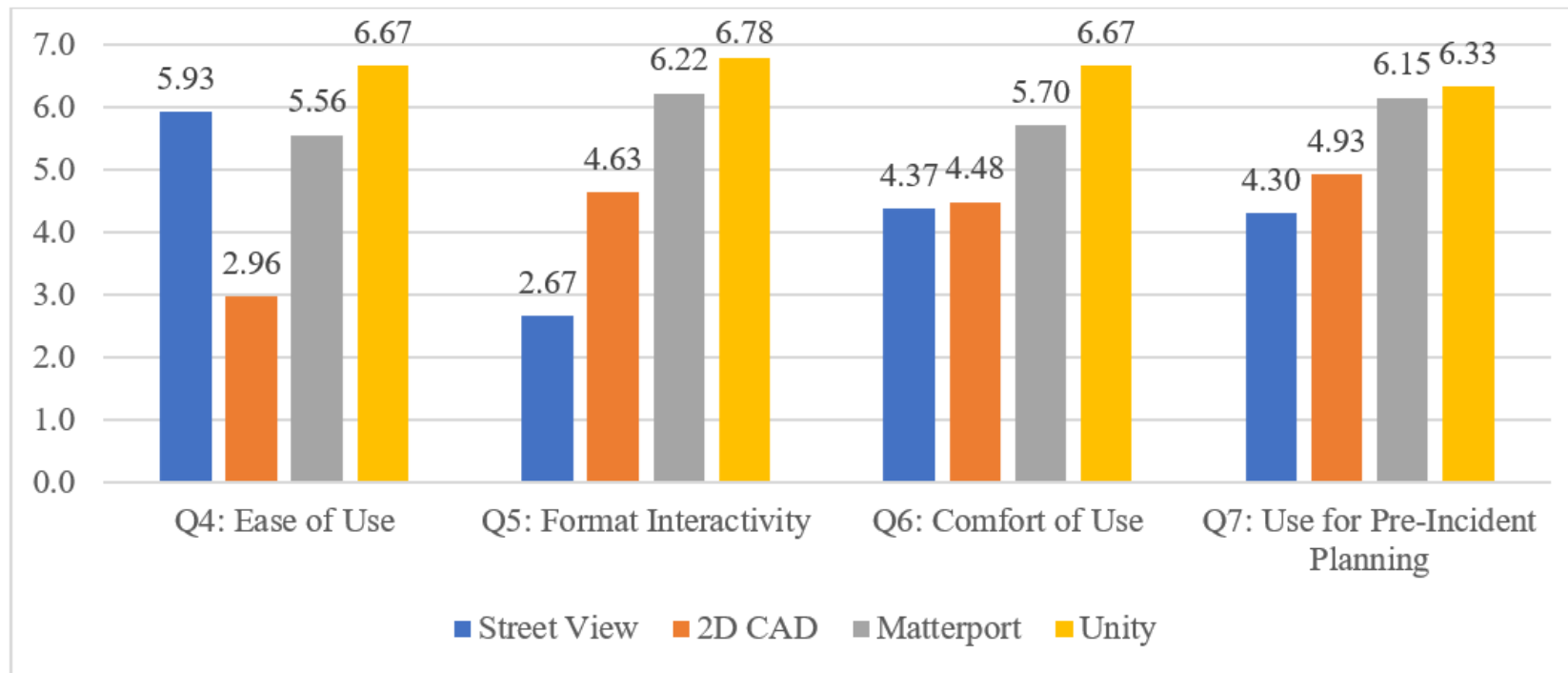


Likert Data for Visualization Format Across all Study Participants for Question 3

Results – Exploratory Analysis

- Mean Likert Survey Responses for Questions 4-7.

Table 5: Bar Chart of Mean Survey Responses by Visualization Format (Q4-Q7)



Results – Open-Ended Questions

- Participant Responses to Open-Ended Questions.
 1. What specifically about the design information was useful for you to understand the layout and interior configuration of the building?
 2. How do you think the design information can be improved to help you better understand the layout and interior configuration of the building?
 3. How do you think the design information can be best used for pre-incident planning?
 4. How do you think the design information can be best used during an active response?

Conclusions

- Likert scale data indicate that participants agreed that the Matterport and the Unity environments improved firefighters' concepts of building navigational and layout and configuration.
- Likert scale data indicates that firefighters agreed that the Matterport improved the concept of division connectivity.
- Overall, these results suggest the provision of Matterport and Unity environments should increase firefighters' knowledge of the structure and may lead to improved search and rescue times.

Conclusions

- Results indicate that participants “*Neither agree nor disagree*” that the 2D CAD format of visualization improved firefighters’ concept of building navigation, layout and configuration, and division connection.
- Responses indicate that participants either “*Disagreed*” or “*Somewhat disagreed*” that the 2D CAD format was easy to use.
 - This could be the steep learning curve associated with 2D CAD formats of visualization which have been found to be tedious for obtaining spatial information.
 - 2D CAD Training could be provided to firefighters to increase this skill.

Future Plans

- Submitting the project as a manuscript to Safety Science journal.
- Submit a grant application to the NIOSH R01 or R21 program.

Career Development

- This project required a detailed proposal outlining the relevant research, research plan, and funding needs which increased the PI's proposal development skills.
- This award provided the PI the opportunity to dedicate more time and resources to this project to ensure its successful completion.
- This project award has provided evidence of successful project success and completion that can be used to seed larger research grant funding opportunities such as the NIOSH R01 and R21 programs.

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