



NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

**PROTECTING PEOPLE OVER THINGS:
INTEGRATING SOCIAL VULNERABILITY
INTO FIRE DEPARTMENT RISK ASSESSMENTS**

by

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December 2023

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REPORT DOCUMENTATION PAGE			<i>Form Approved OMB No. 0704-0188</i>	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington, DC, 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE December 2023	3. REPORT TYPE AND DATES COVERED Master's thesis	
4. TITLE AND SUBTITLE PROTECTING PEOPLE OVER THINGS: INTEGRATING SOCIAL VULNERABILITY INTO FIRE DEPARTMENT RISK ASSESSMENTS			5. FUNDING NUMBERS	
6. AUTHOR(S) Thomas L. LaBelle				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release. Distribution is unlimited.			12b. DISTRIBUTION CODE A	
13. ABSTRACT (maximum 200 words) With finite resources, fire departments strategically allocate their assets to protect lives and property. This allocation encompasses proactive and reactive measures based on risk assessments which favor long-term evaluations. This also means the unique vulnerabilities of residents are often neglected. This thesis reviews risk assessment processes, asking if modern methods equitably consider residents' vulnerabilities. The research investigates use of social vulnerability indexes in risk assessments, seeking more equitable fire service responses. A literature review, conceptual model development, and data examination of three Prince William County, Virginia census tracts provides insight into each community's risk. Using this examination, the author created a model for envisioning risk elements and a tool for risk analysis. Findings reveal the insufficiency of indexes alone for shaping resource deployment; as indexes flag risks, but fall short of explaining the "why" behind the results. Nuanced, area-specific risk elements emerged, which are capable of steering policy, as well as distinctly forming resource assignments, which an index alone could not achieve. Contemporary techniques enlighten equal response distribution yet falter at delivering an equitable response system. The analysis process shows a possible way to fill this void by considering the residents' distinctive vulnerabilities and fostering a fire service that recognizes each community's unique vulnerabilities.				
14. SUBJECT TERMS social vulnerability, vulnerability indices, fire department risk assessment			15. NUMBER OF PAGES 97	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UU	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18

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**PROTECTING PEOPLE OVER THINGS: INTEGRATING SOCIAL
VULNERABILITY INTO FIRE DEPARTMENT RISK ASSESSMENTS**

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Submitted in partial fulfillment of the
requirements for the degree of

**MASTER OF ARTS IN SECURITY STUDIES
(HOMELAND SECURITY AND DEFENSE)**

from the

**NAVAL POSTGRADUATE SCHOOL
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ABSTRACT

With finite resources, fire departments strategically allocate their assets to protect lives and property. This allocation encompasses proactive and reactive measures based on risk assessments which favor long-term evaluations. This also means the unique vulnerabilities of residents are often neglected. This thesis reviews risk assessment processes, asking if modern methods equitably consider residents' vulnerabilities. The research investigates use of social vulnerability indexes in risk assessments, seeking more equitable fire service responses. A literature review, conceptual model development, and data examination of three Prince William County, Virginia census tracts provides insight into each community's risk. Using this examination, the author created a model for envisioning risk elements and a tool for risk analysis. Findings reveal the insufficiency of indexes alone for shaping resource deployment; as indexes flag risks, but fall short of explaining the "why" behind the results. Nuanced, area-specific risk elements emerged, which are capable of steering policy, as well as distinctly forming resource assignments, which an index alone could not achieve. Contemporary techniques enlighten equal response distribution yet falter at delivering an equitable response system. The analysis process shows a possible way to fill this void by considering the residents' distinctive vulnerabilities and fostering a fire service that recognizes each community's unique vulnerabilities.

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LIST OF ACRONYMS AND ABBREVIATIONS

BRIC	Baseline Resilience Indicators for Communities
CDC	Centers for Disease Control
CFAI	Commission on Fire Accreditation International
CPSE	Center for Public Safety Excellence
EMS	Emergency Management Services
FEMA	Federal Emergency Management Administration
FSEC	Fire Service Emergency Cover
GIS	Geospatial Information Systems
MBQ	Marine Base Quantico
NAPSG	National Alliance for Public Safety GIS
NFPA	National Fire Protection Association
NIST	National Institute for Science and Technology
NRI	National Risk Index from FEMA
SAFER	Staffing for Adequate Fire and Emergency Response
SoVI	Social Vulnerability Index (from the University of South Carolina's Hazards Vulnerability Institute)
SVI	Social Vulnerability Index (from FEMA)
UK	United Kingdom
USFA	United States Fire Administration
VLI	Vulnerable Localities Index

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EXECUTIVE SUMMARY

As with any government effort, there are limited resources available for fire departments to meet their missions of protecting life and property. Resources can include fire apparatus and fire stations crews to respond to emergencies. Resources can also be more proactive, such as fire inspectors and crews providing fire safety training in an effort to stop an emergency from happening or limiting its impact. Regardless of whether the resource allocation is focused on response or prevention, decisions must be made on where, how much, and which resources to make available to the community.

Most fire departments will perform some sort of risk assessment to guide resource decisions. These risk assessments can range from intuition, experience for calls/demand, and even more complex mathematical formulas. The most common risk assessments are long-term in nature. They consider building-types systems to predict how a building would burn and how many firefighters and what types of trucks would be needed. They assess road networks and hydrant locations to calculate how long it would take to get to a fire, which stations are closest, and if enough water is available to address the probable size of the fire. Each is a valid element for consideration and changes little over time. The most common element of risk assessment is long-term in nature; risk elements like building types, road networks, and hydrant systems are all examples. These longer-term items impact risk assessments; for example, the construction type (wood or concrete) of a building will affect how fast a building will burn, the number of firefighters to send, and what types of trucks are needed. How long it will take to get to a fire and which stations are closest, based on road networks? Is there enough water available to address the probable size of the fire? Each is a valid element for consideration and changes little over time.

The next part of risk assessment is short-term in nature: events such as actual calls and their propensity within an area, or community events or natural disasters, which are frequent enough to be considered for departmental planning. Each of these short-term elements provides some insight into the work that the fire department might face, and this also helps plan for resource deployments. But what about the people in those buildings?

How do we account for the unique risks they might face? How do we account for their vulnerability?

BACKGROUND

I have spent my entire adult life working in the fire service. I know the men and women I work with are committed to the mission of protecting lives, property, and the environment. But as a chief officer, I also know that we do not fully analyze risk within our own communities. Our fire services focus on ensuring that our resources are deployed equally across our communities, which has been the norm for numerous years. But we must ask ourselves if this equal service is in fact equitable service to our residents. If our goal is to allow people to get back to a normal life after an emergency, then understanding their vulnerabilities will help ensure that our responses—before, during, and after the fire—are equitable in nature.

The focus of this paper is to determine how fire departments might take into consideration the social vulnerability of residents when performing risk assessments. I ask the question: What are the indicators and metrics of social vulnerability in a community, and how could they be integrated into fire service risk assessment models? I hope that through this research, fire service leaders can begin to be more proactive in their consideration of social vulnerability and social equity in emergency responses.

RESEARCH DESIGN

The methods of analysis for this paper include both a literature review and a data analysis experiment. The literature review provides insight into fire department risk analysis methods, including a review of current gaps in analysis and a review of practices in the United Kingdom. A review of the literature on both risk analysis and social vulnerability concepts is included. Based on these readings, a conceptual model of fire department risk analysis was created. This model is based on the duration (long, moderate, and short) of the various elements that impact risk. This model also provides examples of resource allocation decisions connected to these elements.

Based on this conceptual model, a process for analysis was created. To aid in the use of this framework, specific tools and a repeatable step-by-step process were developed. This process was then utilized in a real-life evaluation of census tracts within Prince William County, VA. This real-world example provided insight into the value of the analysis tools created and, ultimately, a validation of this simple method which could be used by any agency wishing to look at social vulnerability or other similar data sets.

Additionally, this paper is informed by the author's personal experience. I have served for over 30 years within the fire service overseeing planning, response, and prevention. I also volunteer with an organization that assists in evaluating fire department planning and resource deployment.

FINDINGS

The research found that the Social Vulnerability Index (SVI) is not sufficient for making policy decisions on resource deployment. Although it can point to an area of vulnerability, it cannot inform the decision-maker why the area is vulnerable. The type of vulnerability can also vary based on geographic area analyzed. Looking at too broad an area will dilute the value of the index or its contextual data for decision-making.

By reviewing the variables within the SVI, I was able to find specific risk elements within smaller geographic areas of our community. This information provided greater context, a context that was shown to influence policy decisions and resource allocation in a way that the index scoring alone could not provide.

CONCLUSION

Current methods of fire department risk analysis focus on short, moderate, and long-term elements of risk. These current methods of risk analysis do provide insight into providing an equal response to all residents, but not an equitable response based on social vulnerabilities. Applying an index as a whole can help generally prioritize areas, but it cannot drive specific fire department resource decisions. This thesis provides a process for analysis to account for the unique risks that residents face to inform those resource decisions.

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ACKNOWLEDGMENTS

It was inconceivable at the beginning of this academic journey all that would occur in such a short time span. After reaching what I believed to be the pinnacle of my career and being accepted into this program, I could not believe much more change could occur. Then, in 2022, three major changes happened: my wife was diagnosed with—and successfully battled—cancer, my children moved out and began successful careers, and I began a new career leading an amazing fire department in the greater National Capital Region. I write this simply to say that without much help, I would not be finishing this program within the allotted timeframe, and I have many people to thank.

Through all of this turmoil, the staff at CHDS was more than supportive. From administrative staff to the amazing professors and instructional staff: every time a hurdle appeared, they simply helped me understand how to get over, around or under it. I would not have been able to continue on this journey without the support of each of these wonderful people. Each class allowed me to learn more about my industry's role in homeland security, as well as, perhaps more importantly, the homeland security enterprise roles of every member of the Cohort 2203/04. I know we will not all stay in touch, but each of you touched my life and I am better for it.

As with everyone within this program, support from one's place of employment is paramount to success. I need specifically to thank Chief Alec Oughton of the Aurora Colorado Fire Department. Alec was my chief in the metro Richmond, Virginia region, and his support goes beyond that of a good supervisor to the roles of coach and mentor in my life. I also need to thank Mr. Chris Shorter, the county executive of Prince William County, Virginia. In May 2023, I became the fire chief in this wonderful community he leads. It would have been simple for him to ask me to delay finishing this program, and make my new department my sole focus. Although appropriate, it was not what Mr. Shorter expected. His leadership and support in ensuring I finish this program speaks volumes about his leadership and expectations within our community.

I cannot possibly convey in mere words the depth of support from my family. These last few years have taken attention away from my amazing daughter, Rebecca, and son, Michael, each of whom are successful leaders in their own spheres. I also want to thank my mother and father, Kathleen and Lt. David LaBelle (Ret.) for my commitment to public service. I find it especially difficult to convey appropriate thanks for my wife, Debbie LaBelle. Her unwavering belief in me often defied common sense. She has been, and remains, committed to my journey. Her steadfast presence by my side is the only reason for any of my successes.

I. INTRODUCTION

Fire departments across the United States must determine how to use their limited resources to protect citizens and businesses from the negative impacts for fire and medical emergencies. Determining the policies and resource allocations to keep a community safe requires insight into the community the risks residents face, and the possible impacts of disaster. How fire departments can best determine the risks faced and how to minimize impact is the focus of this thesis.

When planning to allocate programs and resources, fire departments consider the types and severity of risks within a community.¹ After identifying risks, departments can identify multiple options for developing policies and services to assist in specific risk mitigation. Fire departments typically divide their services to address such dangers into two areas: minimizing risks and mitigating emergencies. Various efforts by fire departments to minimize risk try to be proactive: they seek to eliminate the hazard, or limit its impact, through preventive methods such as code enforcement, fire prevention, and community education. After an event occurs, mitigation efforts typically include emergency medical response and fire suppression.

For most communities, the decision to have a fire department is born out of a general desire to protect against the ravages of fire. However, modern fire departments provide numerous services, including emergency medicine, hazardous material response, water rescue, and wildland firefighting. However, the types of services provided should be based on the risks a community faces. Fire departments must decide what activities need to be performed to deliver the services their community needs. They must also decide how to carry out those activities and how to allocate resources in each activity. When planning to allocate resources, fire departments consider the types and severity of risks within a

¹ Clinton Haverkamp, *Understanding Community Risk Assessment* (Emmitsburg, MD: National Fire Academy, 2020), <https://usfa.bibliovation.com/app/work/250719>; John A. Stouffer, *Community Risk Assessment: A Guide for Conducting a Community Risk Assessment*, Version 1.5 (Warrenton, VA: Vision 20/20, 2016), <https://riskassessment.strategicfire.org/>; and Metropolitan Chiefs Association, *Fire Service Deployment: Assessing Community Vulnerability* (Washington, DC: Metropolitan Chiefs Association, 2019), <https://www.nfpa.org/-/media/Files/Membership/member-sections/Metro-Chiefs/UrbanFireVulnerability.ashx>.

community.² After identifying risks, departments should assign a value to each of their risks to prioritize which risks need to be addressed first. Through this process of risk identification and risk ranking, a department could identify multiple options for what activities should be used to mitigate those risks.

The risk analysis methods used by fire departments rarely consider the social vulnerability of the residents in the assessed geographic area. The method of risk identification and ranking may also not take into account the impacts of an event (fire or EMS call) on the citizens in harm's way. For example, a fire department may look at two homes within their community: each is of equal size, and each has a similarly sized family. But if one family is more vulnerable (due to things like socioeconomics, ability to speak the native language, or perhaps differently abled and utilizing a wheelchair) to the impact of the loss than the other family, the fire department might not take that into account when performing a risk assessment to determine the types of proactive or reactive service delivery. For example, they may not plan for more firefighters that will be needed to rescue someone confined to a wheelchair or the need to provide Spanish based public education material in an area where English is not the primary language. Vulnerabilities within a community do have an impact on resources and should be considered.

Hurricane Katrina is a prime example of how different communities experienced dissimilar aftereffects due to socioeconomic disparities.³ The Category 5 Atlantic hurricane hit New Orleans, LA and surrounding areas in August 2005, and the socioeconomically vulnerable areas saw more significant amounts of death, injury, and disease, as well as greater overall destruction.⁴ In fact, the Federal Emergency Management Agency (FEMA) and the United States Fire Administration (USFA) both have in their policies encouragement for fire departments to consider social vulnerability

² Haverkamp, *Understanding Community Risk Assessment*; Stouffer, *Community Risk Assessment*; and Metropolitan Chiefs Association, *Fire Service Deployment: Assessing Community Vulnerability*.

³ Donald L. Neuert, "Bridging the Gap: To What Extent Do Socioeconomic Barriers Impede Response to Emerging Public Health Threats?" (master's thesis, Naval Postgraduate School, 2017), 24,42, <https://hdl.handle.net/10945/53023>.

⁴ Neuert, "Bridging the Gap," 31.

when creating risk assessments. But even if a fire department chose to include vulnerability, how might they include that information in their risk assessments?

A. PROBLEM

Standard fire department risk modeling involves evaluating the impact (positive or negative) of long-term elements, such as building construction, road networks and water systems. These items impact risk in various ways: the materials used in building construction can aid in fire spread or slow its progress; the existence of a water system with hydrants will allow for sprinkler systems and the hydrants; road networks influence the types of calls (highways with large trucks as opposed to smaller streets) and roadways can impact how quickly a fire apparatus can arrive to mitigate a call.

Fire departments include short-term elements, such as fires and EMS calls, in risk modeling. These short-term events (e.g., the age of a building or road infrastructure emergencies) can give insight into what types of risks a community might face. Although there is no guarantee of future activity, past emergencies can help predict future emergencies. Also, short-term events, like festivals, can be planned for by analyzing the risks associated with such events.

Moderate-term elements include how the building is being used (warehouse or apartment building), who is in the building (shoppers or residents), socioeconomics, and demographics. Employment can also play a role in risk and vulnerability, but is less easy to account for in planning. Nonetheless, it is a good example of what makes planning for moderate-term risks so difficult. People only live in a community for so long, or business and building use might change. It is difficult to plan for the temporary and ever-changing nature of these moderate-term elements.

In an effort to quantify various indicators of resiliency and vulnerability, many organizations have created frameworks for group indicators and provided a numerical evaluation. These frameworks are referred to as indices and can be used to help measure

risk within a community.⁵ The National Institute of Science and Technology (NIST) has a list of over fifty indices that may prove suitable as a tool for adding social vulnerability into fire department's might use for risk analysis.⁶ However, how a fire department might choose an index is unclear as is how a department might conduct a systematic review of these indices to analyze their community for social vulnerability.

Various studies have identified the inadequacies of utilizing simplistic indices to determine risk, and each has called for a more nuanced insight into risk for planning. Research has looked at the value of various types of vulnerability indices to provide a context for policy planning. This study has sought to examine the value of using such indices to clarify risk within a community, and provides a sample process that fire departments can use to acquire value from such a review.

B. RESEARCH QUESTION

What are the indicators and metrics of social vulnerability in a community, and how could they be integrated into fire service risk assessment models?

C. RESEARCH DESIGN OVERVIEW

The methods of analysis for this paper included both a literature review, development of a conceptual model, and data analysis. The literature review provided insight into fire department risk analysis methods, current gaps in analysis, and practices in the United Kingdom. It also included general risk analysis concepts and social vulnerability. Based on these readings, a conceptual model of risk fire department risk analysis was created. This model addressed the various elements that impact risk over different time durations (long, moderate, and short) It also provided some examples of resource allocation decisions connected to these elements.

⁵ Jarrod Loerzel and Maria Dillard, "An Analysis of an Inventory of Community Resilience Frameworks," *Journal of Research of the National Institute of Standards and Technology* 126 (October 21, 2021): 1, <https://doi.org/10.6028/jres.126.031>.

⁶ Loerzel and Dillard, "An Analysis of an Inventory of Community Resilience Frameworks," 1.

A process for analysis was then created and applied to Prince William County, Virginia. This real-world example provided insight into how social vulnerability data could be integrated into fire service risk assessment. The process is a repeatable process that could be applied to other jurisdictions to inform resource decisions.

D. CHAPTER OVERVIEW

Chapter II provides a review of the literature regarding concepts of vulnerability, risk analysis, social vulnerability, fire department risk measurement, and concepts in fire department resource allocation. Chapter III provides insight into the development of concepts linking temporal elements in fire department resource planning, including the creation of modeling and frameworks for use. Then, Chapter IV provides an analysis process to Prince William County, Virginia. Chapter V provides a review of the findings from this research effort, and finally, Chapter VI contains the author's conclusions.

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II. LITERATURE REVIEW

This chapter is an academic examination of what constitutes risk and vulnerability, as well as debating the best methods to analyze and convey risk for decision-making. The review also identifies general indicators and metrics of risk, and provides insight into how fire departments use various measurements to help inform their allocation of reactive and proactive resources.

This literature review parsed processes and guidelines for deciding methods for risk analysis specifically within the United States, Canada and the United Kingdom. Additionally, a focus on fire department risk analysis was reviewed. This research delved into current risk analysis processes and identified current gaps within risk analysis in general and fire departments specifically.

A. FIRE DEPARTMENT ANALYSIS

There are several models that fire departments can use for risk analysis and resource deployment. The National Fire Protection Association (NFPA) utilizes a panel of experts and a consensus process of open input and voting to create its standard on risk assessments for fire departments.⁷ The not-for-profit Commission on Fire Accreditation International also has a program for an in-depth review of risk and response.⁸ There are also free resources from the not-for-profit Vision 20/20 and the Urban Fire Forum.⁹ In Europe, there are also similar models for identifying risk to determine resource deployments.¹⁰

⁷ “NFPA 1300: Standard on Community Risk Assessment and Community Risk Reduction Plan Development,” National Fire Protection Association, accessed January 30, 2023, <https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=1300>.

⁸ “Accreditation Overview,” Center for Public Safety Excellence, October 10, 2023, <https://www.cpse.org/accreditation/>.

⁹ Metropolitan Chiefs Association, *Fire Service Deployment: Assessing Community Vulnerability*; Stouffer, *Community Risk Assessment*.

¹⁰ Philippe Chevalier et al., “Locating Fire-Stations: An Integrated Approach for Belgium,” *LIDAM Discussion Papers CORE*, LIDAM Discussion Papers CORE, February 1, 2010, <https://ideas.repec.org/p/cor/louvco/2010008.html>; E. Higgins et al., “Understanding Community Fire Risk—A Spatial Model for Targeting Fire Prevention Activities,” *Fire Safety Journal* 62 (November 2013): 20–29, <https://doi.org/10.1016/j.firesaf.2013.02.006>.

In all cases, a similar format is used. The identification of hazards within the community, the delineation of hazards based on type (fire hazard vs. an EMS hazard, for example). The history of calls within an area and the utilization of resources to determine the type and quality needed to either proactively (prevention) or reactively (response) address the issue.

Fire Department Analysis in North America

The NFPA, Commission on Fire Accreditation International (CFAI) and Vision 20/20 models are the most commonly used in the United States. Each model focuses on data for risk analysis and resource deployment. The NFPA utilizes a panel of experts and a consensus process of open input and voting to create its standard on risk assessments for fire departments.¹¹ The not-for-profit CFAI has also developed a program for an in-depth review of risk and response.¹² There are free resources from the not-for-profit company Vision 20/20 and the Urban Fire Forum.¹³ In Europe, there are also similar models for identifying risk to determine resource deployments.¹⁴

In all cases, more nuanced evaluation of vulnerability (as opposed to risk) is omitted. For example, the models created by Vision 20/20 and Center for Public Safety Excellence (CPSE) utilize a low/medium/high matrix for evaluating risk.¹⁵ Additionally, the evaluation of risk for all modeling in the United States is based on evaluating things such as building stock and building use by the public. In his master's thesis on fire service risk assessments, Clinton Haverkamp provided an excellent comparison of these various models.¹⁶

¹¹ National Fire Protection Association, "NFPA 1300."

¹² Center for Public Safety Excellence, "Accreditation Overview."

¹³ Metropolitan Chiefs Association, *Fire Service Deployment: Assessing Community Vulnerability*; Stouffer, *Community Risk Assessment*.

¹⁴ Chevalier et al., "Locating Fire-Stations"; Higgins et al., "Understanding Community Fire Risk—A Spatial Model for Targeting Fire Prevention Activities."

¹⁵ Commission on Public Safety Excellence, *Community Risk Assessment: Standard of Cover*, 6th ed. (Chantilly, VA: Commission on Public Safety Excellence, 2016); Stouffer, *Community Risk Assessment*.

¹⁶ Haverkamp, *Understanding Community Risk Assessment*, 22.

In all cases, a similar format is utilized. The identification of hazards within the community, the delineation of hazards based on type (fire hazard vs. and EMS hazard for example.) The history of calls within an area and the utilization of resources to determine the type and quality needed to either proactively (prevention) or reactively (response) address the issue.

These models also direct departments to look at issues such as road network and travel times of fire and EMS units, as well as the existence of fire suppression systems and hydrants. Although each of the referenced models recognizes the need for communities to consider such things as the vulnerability of the citizens impacted, none gives a methodology for determining that vulnerability nor how to incorporate it into the modeling.

Fire departments across the globe use a smorgasbord of models for risk analysis and resource deployment, so there is no common model upon which to compare data. The NFPA, the CFAI, Vision 20/20, the Urban Fire Forum, and similar European models are recognized standards. These methodologies typically identify and categorize hazards, consider the history of emergency calls and resource utilization, and focus on handling issues both proactively and reactively. However, these models often overlook a nuanced consideration of vulnerability beyond a simple risk evaluation. Geospatial tools are extensively used for visualizing and analyzing problems, with FEMA offering numerous Geospatial Information Systems (GIS) resources for local governments. Nevertheless, while these models acknowledge the need to account for citizen vulnerability, they lack a defined mechanism to assess and incorporate it into the schemes.

There is a lot of emphasis on utilizing geospatial (mapping) tools to visualize problems for analysis.¹⁷ In addition, the FEMA Geospatial Resource Center provides multiple GIS resources that agencies might utilize.¹⁸ The Geospatial Resource Center uses a standard ARC GIS format to make information available for local governments. FEMA also provides an index of indices in its National Resiliency Index (NRI) model, with the

¹⁷ Todd T Tuggle, “Spatiotemporal Modeling of Community Risk” (master’s thesis, Monterey CA, Naval Postgraduate School, 2016); Higgins et al., “Understanding Community Fire Risk—A Spatial Model for Targeting Fire Prevention Activities.”

¹⁸ “FEMA Geospatial Resource Center,” accessed October 10, 2023, <https://gis-fema.hub.arcgis.com/>.

compilation of multiple risk and social based indices.¹⁹ And as mentioned above, the USFA also offers a GIS based resource for analysis based on the Centers for Disease Control (CDC)’s SVI.²⁰

B. FIRE DEPARTMENT USE OF VULNERABILITY INFORMATION

Even with an understanding of vulnerability as a risk analysis data point, it is limited in its use in the United States. There are several American models that outline limited methods for folding vulnerability into the scope of risk analysis. These include the *Community Risk Assessment Model* from Vision 20/20, the *Standard of Cover* model provided by the Commission of Public Safety Excellence, and several documents by the NFPA.²¹

NFPA 551 provided direction in the creation of predictive models, both quantitative and qualitative, but does not take into account the impacts on individuals. Therefore, vulnerability indices do not fold into any metric. Additionally, NFPA 1300 provided direction on identifying risk hazards within the community, but did not provide suggestions on recognizing variables in vulnerability within different segments of the community.²²

The Community Risk Reduction model recognized the value of quantifying risk and a sub-community level. However, it did not give specific suggestions on how to quantify the risks, nor how to use them to adjust the risk model.²³ The model went even further, creating a matrix for quantifying levels of vulnerability to adversity, but did not provide any insight into providing context or quantification of vulnerability.²⁴

¹⁹ “Community Resilience | National Risk Index,” Federal Emergency Management Agency, accessed July 13, 2023, <https://hazards.fema.gov/nri/community-resilience>.

²⁰ “Tool for Accessing Data on Fire Risk and Vulnerability,” *New U.S. Fire Administration Tool for Accessing Data on Fire Risk and Vulnerability* (blog), July 13, 2023, <https://www.usfa.fema.gov/blog/tool-for-accessing-data-on-fire-risk-and-vulnerability/>.

²¹ National Fire Protection Association, “NFPA 1300”; Haverkamp, *Understanding Community Risk Assessment*; Stouffer, *Community Risk Assessment*.

²² National Fire Protection Association, *NFPA 511 Evaluation of Fire Risk Assessments*, 2022nd ed. (Quincy, MA: National Fire Protection Association, n.d.); National Fire Protection Association, “NFPA 1300.”

²³ Stouffer, *Community Risk Assessment*, 11.

²⁴ Stouffer, *Community Risk Assessment*, 15.

FEMA provided an online tool that looks at risk indices based on the University of South Carolina’s Social Vulnerability Index (SoVI)—which is trademarked and different from FEMA’s SVI standards—and Baseline Resilience Indicators for Communities (BRIC) modeling, but only for natural disasters, which is based on counties rather than subsets of a community.²⁵ Additionally, in June 2023, the USFA created a GIS database using a rating scale to rank vulnerability to home fires based on the number of home fire deaths and the CDC’s SVI.²⁶

One standard for determining the risk used by many fire service organizations within the United States, and particularly by Department of Defense fire departments, is the CPSE. The CPSE is a not-for-profit organization that provides direction on becoming an accredited agency under their standard. This standard for risk assessment requires agencies to review the risks within their community-based on types of buildings and occupancy types. It also directs agencies to review the impact of a fire or event at a particular venue, with a focus on how it would impact the resources of the fire department. And finally, it asks the agency seeking accreditation what the impact of the loss of property on the community.

As an example, in a theoretical community, a grocery store might not be a high risk for loss of life, but it would be a large fire, as the store doesn’t have a sprinkler/suppression system. It would require over half of fire suppression resources (apparatus and personnel) and therefore have a significant impact on the fire department. Finally, the loss of tax revenue for the community from sales could be calculated. This model does not take into account impacts beyond the obvious (e.g., loss of employment, loss of access to healthy food, or loss of local monetary support from the grocery store) or provide a specific method to do so, but allows the fire department to consider such things.

²⁵ Federal Emergency Management Agency, “Community Resilience | National Risk Index.”

²⁶ “CDC/ATSDR SVI 2020 Documentation,” Agency for Toxic Substances and Disease Registry, accessed July 13, 2023, https://www.atsdr.cdc.gov/placeandhealth/svi/documentation/pdf/SVI2020Documentation_08.05.22.pdf.

Fire Department Analysis in the United Kingdom

In the United Kingdom (UK), there is a national standard for risk assessments in place since the early 2000s.²⁷ Since 2018, there has also been a focused standardization of fire brigade organization and oversight within the “Home Office.”²⁸ Much of this approach was brought about via issues of equity, both within the workforce and how fire brigades treated citizens within the UK. Figure 1 is an example of the current framework offered by the National Fire Chiefs’ Council, which shows that the evaluation of equality of impact based on items of vulnerability is disconnected from the risk analysis process itself.

In two separate studies, a connection was made between vulnerability and the number of fires experienced. In a report by Chainey, the author looked at the UK’s Vulnerable Localities Index (normally used for crime analytics) and determined a high correlation between high scores on the Vulnerable Localities Index (VLI) and higher fire rates within communities.²⁹ Separately, a review of fires and areas where Red Cross provided help saw similar correlations. In their article, Evan Lue and John P. Wilson point to the relationship between increased use of Red Cross services within a community in areas with greater fire.³⁰ Lue and Wilson suggested that those most vulnerable in our community also need the help of the Red Cross more often after a fire, and as such there appears to be a correlation between fire experience and vulnerability.

Figure 1 is from the UK’s National Fire Chief Council and shows that the evaluation of equality of impact based on items of vulnerability is disconnected from the risk analysis process.

²⁷ Congressional Research Service, *European Approaches to Homeland Security and Counterterrorism*, CRS Report No. RL33573 (Washington, DC: Congressional Research Service, 2006), https://www.everycrsreport.com/reports/RL33573.html#_Toc234314395.

²⁸ British Home Office, ed., *Fire and Rescue National Framework for England* (London, UK: British Home Office, 2018).

²⁹ Spencer Chainey, “Using the Vulnerable Localities Index to Identify Priority Areas for Targeting Fire Safety Services,” *Fire Safety Journal* 62 (November 2013): 30–36, <https://doi.org/10.1016/j.firesaf.2013.03.013>.

³⁰ Evan Lue and John P. Wilson, “Mapping Fires and American Red Cross Aid Using Demographic Indicators of Vulnerability,” *Disasters* 41, no. 2 (2017): 409–26, <https://doi.org/10.1111/disa.12198>.



Figure 1. UK National Fire Chiefs Council Risk Management Planning Framework³¹

It is also worthy of note that the systems for analysis discussed in this chapter tend to focus on the risks connected to long-term risk elements. Things such as building type, use/occupancy, road networks and water supply tend to stay static over time. The building of fire stations and staffing of those stations based on these long-term realities makes sense. However, communities change, and these weaker temporal items can impact resources needed. One study from England looked at the changing demographics within an area of Merseyside, and how the community changed, so did the needs within that community.³² Similar changes occur throughout our communities, changing the vulnerabilities and risks at the same time.

³¹ Source: National Fire Chief Council, “NFCC – Components of a CRMP,” July 2021, <https://www.ukfrs.com/media/1916>.

³² M. Taylor et al., “Population Trends and Fire Prevention in Merseyside UK,” *Fire Technology* 57, no. 4 (July 2021): 1783–1802, <https://doi.org/10.1007/s10694-020-01083-w>.

In the UK, the local fire service has been nationalized, and there are country-wide standards of approach. The first is the Fire Service Emergency Cover (FSEC), which is similar to the United States “standard of the cover.” This is an electronic resource, or toolkit, to help local agencies collect historical fire information, as well as building information to determine fire risks. It is not mandated to be used, and does not look at the resiliency or vulnerability of those protected. There is a national requirement to create an “Integrated Risk Management Plan.” This plan is also focused on historical data and building types. In both cases, resources are limited to analyzing areas of 3,000 or more people, making subcommunities difficult to target.³³

In 2013, Merseyside Fire and Rescue in the UK began to use “customer insight” to pinpoint where individuals were more vulnerable to the impacts of fire. Utilizing causal connections to fire death and injury, such as smoking or those over age 65, the fire brigade pinpointed those at greatest risk. Unlike the other resources, such as the FSEC, this focused on people and their vulnerabilities, rather than the resources of the community alone.³⁴

Since 2005, the UK’s fire service has undergone a continual nationalization in practice and policy. In 2016, it was organized under their “Home Office” in a move that intended to create more consistency and professionalism within the service.³⁵ Part of this process has been to better coordinate proactive responses to community needs. The fire service has increased the VLI use by the fire service has been seen. Like other indices in this report, the VLI provides insight into vulnerability based on socioeconomic, crime, and poverty to focus efforts on public safety.

There is clearly a desire from the various agencies and bodies to provide risk analysis models to the United States Fire Services, which include some type of vulnerability assessment within fire department risk assessments. Just as clearly, there is

³³ Higgins et al., “Understanding Community Fire Risk—A Spatial Model for Targeting Fire Prevention Activities.”

³⁴ Haverkamp, *Understanding Community Risk Assessment*.

³⁵ “Fire and Rescue Policy to Move to the Home Office,” GOV.UK, accessed May 18, 2023, <https://www.gov.uk/government/news/fire-and-rescue-policy-to-move-to-the-home-office>.

little direction on how to do so within the United States, but the use of indices within the UK might serve as a direction.

C. RESOURCE ALLOCATION MODELS

In each of the models referenced in the previous section, there are express expectations that the identified risks will provide insight into one of two categories: proactive/preventive or reactive/response resources being applied. However, definitive policies and services are not prescribed, as fire departments vary in size and resources based on the communities they serve. In the case of England's fire brigades, national guidance requires them to consider societal risk factors in their fire planning, both proactive and reactive.³⁶

There is, however, literature which provided examples of how vulnerability contextual information might be considered, particularly for proactive activities. One study proposed the use of social vulnerability data to direct the activities of the London Fire Brigade and the National Health Service to combine efforts in prevention activities.³⁷ Another study in England looked at the activities of the Merseyside Fire Brigade and its use of social vulnerability identification to work directly with vulnerable populations.³⁸ In both cases, as well as other research, there is a recognition that these efforts may include multiple agencies to address, which can create hurdles to success.³⁹

Within the United States, there was also research into connections between policy decisions and activities. In his review of geospatial modeling, Todd T. Tuggle referenced several possible, proactive policies that can be driven by a more nuanced understanding of

³⁶ British Home Office, *Fire and Rescue National Framework for England*, 6.

³⁷ Karen Lowton et al., "Can Fire and Rescue Services and the National Health Service Work Together to Improve the Safety and Wellbeing of Vulnerable Older People? Design of a Proof of Concept Study," *BMC Health Services Research* 10 (2010): 327, <https://doi.org/10.1186/1472-6963-10-327>.

³⁸ David A. Purser, "Effects of Pre-Fire Age and Health Status on Vulnerability to Incapacitation and Death from Exposure to Carbon Monoxide and Smoke Irritants in Rosepark Fire Incident Victims: Effects of Pre-Fire Age and Health Status on Fire Victims," *Fire and Materials* 41, no. 5 (August 2017): 555–69, <https://doi.org/10.1002/fam.2393>.

³⁹ Kristin Halvorsen, Petter G. Almklov, and Gudveig Gjørund, "Fire Safety for Vulnerable Groups: The Challenges of Cross-Sector Collaboration in Norwegian Municipalities," *Fire Safety Journal* 92 (September 2017): 1–8, <https://doi.org/10.1016/j.firesaf.2017.05.001>.

risk.⁴⁰ Additionally, Paul L. Miller pointed to the need to understand the vulnerabilities within a community, not simply to respond, but to connect with that community to help it develop its own resiliency.⁴¹

The models explored in the literature outline expectations for the use of identified risks in shaping proactive/preventive or reactive/response resources, with considerations varying based on the size and resources of a given fire department. The UK's fire brigades are required to consider societal risk factors in both their proactive and reactive fire planning. Multiple studies provided examples of the use of social vulnerability data in planning prevention activities, with one suggestion of the collaboration of the London Fire Brigade and the National Health Service, while another cited the Merseyside Fire Brigade's tactics for dealing with vulnerable populations.

These initiatives often involved multi-agency collaborations, which could present challenges. In the United States, research was being conducted to find a correlation between policy decisions and activities. Tuggle's review of geospatial modeling suggested that few proactive policies are informed by an in-depth understanding of risk, while Miller stressed the importance of comprehending community vulnerabilities to enhance resilience, not just for response purposes.⁴²

⁴⁰ Tuggle, "Spatiotemporal Modeling of Community Risk," 60.

⁴¹ Paul L. Miller, "Preparing Minority Populations for Emergencies: Connecting to Build a More Resilient Community" (Thesis, Monterey, California: Naval Postgraduate School, 2012), 11, <https://calhoun.nps.edu/handle/10945/27871>.

⁴² Tuggle, "Spatiotemporal Modeling of Community Risk"; Miller, "Preparing Minority Populations for Emergencies."

D. RISK ANALYSIS

The literature revealed a consistent concern for ensuring sufficient inclusion of data sets when creating risk analysis and indices.⁴³ MacKenzie held that any effort to create an index of risk requires a quantitative study, not just a qualitative one.⁴⁴ The literature reflected a general disdain for most current matrixes that policymakers use. Hubbard and MacKenzie both suggested that risk analysis often uses categorical descriptors such as “high to low” or “red, yellow, and green” to indicate levels of risk.⁴⁵ At the same time, scholars recognized the need to translate real-world numbers, which might be too large to fathom, into more manageable numbers for analysis.⁴⁶ All agreed that regardless of the translation of numbers, solid data sets are the source for all categories.⁴⁷

The literature further discussed the value of various indices or matrixes. Cameron MacKenzie’s article on risk noted the ubiquitous nature of risk indices. However, he also decried the lack of deeper data in creating these decision-making models.⁴⁸ Douglas Hubbard suggested using empirical data to identify the impact of loss or probability of exceedance rather than a simple categorical index, such as red, yellow, and green.⁴⁹ MacKenzie further elaborated that risk indices attempt to address a standard set of goals:

⁴³ Cameron A. MacKenzie, “Summarizing Risk Using Risk Measures and Risk Indices,” *Risk Analysis* 34, no. 12 (2014): 2143–62, <https://doi.org/10.1111/risa.12220>; Douglas W. Hubbard, *The Failure of Risk Management: Why It’s Broken and How to Fix It*, 2nd ed. (Hoboken, NJ: John Wiley & Sons, Incorporated, 2020); Luis Anthony (Tony) Cox Jr., “What’s Wrong with Risk Matrices?,” *Risk Analysis: An International Journal* 28, no. 2 (April 2008): 497–512, <https://doi.org/10.1111/j.1539-6924.2008.01030.x>; John E. Thomas, Daniel A. Eisenberg, and Thomas P. Seager, “Holistic Infrastructure Resilience Research Requires Multiple Perspectives, Not Just Multiple Disciplines,” *Infrastructures* 3, no. 3 (2018): 1–18, <https://doi.org/10.3390/infrastructures3030030>; Louis Anthony (Tony) Cox, Jr., “Evaluating and Improving Risk Formulas for Allocating Limited Budgets to Expensive Risk-Reduction Opportunities,” *Risk Analysis: An International Journal* 32, no. 7 (July 2012): 1244–52, <https://doi.org/10.1111/j.1539-6924.2011.01735.x>; and Neuert, “Bridging the Gap.”

⁴⁴ MacKenzie, “Summarizing Risk Using Risk Measures and Risk Indices,” 3.

⁴⁵ MacKenzie, “Summarizing Risk Using Risk Measures and Risk Indices,” 6; Hubbard, *The Failure of Risk Management*, 54.

⁴⁶ MacKenzie, “Summarizing Risk Using Risk Measures and Risk Indices,” 20.

⁴⁷ MacKenzie, “Summarizing Risk Using Risk Measures and Risk Indices,” 26; Hubbard, *The Failure of Risk Management*, 54.

⁴⁸ MacKenzie, “Summarizing Risk Using Risk Measures and Risk Indices,” 4.

⁴⁹ Hubbard, *The Failure of Risk Management*, 64.

communicate the level of risk, compare different risks, identify the most serious threat, translate how risk changes over time, measure the effectiveness of risk-reduction strategies, and recommend actions for a given level of risk.⁵⁰

Tony Cox also argued that evaluating risk indices for risk analysis should occur with care. Given the simplicity of matrixes, context and explanations need to be provided.⁵¹ Several authors, mainly Cox, worried that most matrixes are of little to questionable use given the limited data sets. The question is, how do we improve or substitute matrixes for decision-makers?

Much of the literature conveyed concerns that simple risk matrixes do not provide enough context for sound decision-making. MacKenzie argued that using numerical rather than categorical indices (red, yellow, green, for example) is preferable, as it provides more significant differentiation.⁵² Therefore, Cox and Hubbard argued that given the low quantitative values that inform many of the matrixes, they may be of little value at best and, at worst, lull decision-makers into a false sense of security.⁵³ Cox and Hubbard conceded that although matrixes might not be suitable for deciding where to allocate resources, they can help identify risks.

Cox also argued that simple increases in quantitative assessments will increase the value of risk assessment aids.⁵⁴ Cox and Hubbard said that too many computer programs used to identify risk do not consider the inequality of return on investment. These simplistic risk matrixes are too easy to create and follow; without adding greater context, the data may present too simplistic an answer, creating a false sense of security or value of effort.⁵⁵ All the literature agreed that decision-makers need to place resources where they will receive the best return on their investment in risk mitigation.

⁵⁰ MacKenzie, "Summarizing Risk Using Risk Measures and Risk Indices," 5.

⁵¹ Cox Jr., "What's Wrong with Risk Matrices?," 497.

⁵² MacKenzie, "Summarizing Risk Using Risk Measures and Risk Indices," 21.

⁵³ Hubbard, *The Failure of Risk Management*, 58; Cox Jr., "What's Wrong with Risk Matrices?," 500.

⁵⁴ Cox, Jr., "What's Wrong with Risk Matrices?," 501.

⁵⁵ Cox, Jr., "Evaluating and Improving Risk," 1252.

Experts seemed to agree that indices do not allow an organization to increase the quantitative value of its analysis in order to aid in decision-making. Hubbard suggested the need to substitute more quantitative input into indices or matrixes. He indicated that even educated “guessing” at the probability (not just possibility) of an event occurring could provide more excellent quantitative value.⁵⁶

E. CONTEXT FOR INDICES

Determining which additional data sets might add value is also a subject of much research. An interesting article discusses a holistic approach to risk analysis: the authors argued that understanding resilience requires all four quadrants of an “integral map.” The same authors also said that using only one quadrant, such as infrastructure resilience, and only considering systems (e.g., group exterior) limits the value of the analysis. John E. Thomas, Daniel A. Eisenberg, and Thomas P. Seager suggested identifying and including as many elements as possible within a risk analysis to increase the accuracy and value of the analysis.⁵⁷ Cox and Hubbard suggested expanding data sets in their papers. Still, they relied more on better mathematical modeling than the broader data sets offered by Thomas, Eisenberg, and Seager.⁵⁸ Interestingly, Hubbard also emphasized that using computer programs to model risk did not verify the accuracy of the math, so organizations should test computer model outcomes.⁵⁹ Ultimately greater data sets, such as risk indices, can improve modeling outcomes.

Is Context Enough?

Even with solid and suitable data sets, Cox and Hubbard suggested understanding risk for organizations remains incomplete. Cox and Hubbard suggested that knowing the size of the risk does not indicate how much investment or return on investment one gains by trying to prevent the threat. Not all risks are equal, nor are all outcomes comparable.

⁵⁶ Hubbard, *The Failure of Risk Management*, 64.

⁵⁷ Thomas, Eisenberg, and Seager, “Holistic Infrastructure Resilience Research,” 7.

⁵⁸ Hubbard, *The Failure of Risk Management*; Cox, Jr., “Evaluating and Improving Risk”; Cox Jr., “What’s Wrong with Risk Matrices?”

⁵⁹ Hubbard, *The Failure of Risk Management*, 54.

Finally, address impacts with the greatest return—not simply the most significant risk—should be a focus.⁶⁰

In one article, Cox emphasized that even with a risk analysis, random choices on what issues to address lead to a few gains. Cox warned that “Knowing which risks are largest does not necessarily reveal which risk management interventions will achieve the greatest risk-reduction for a given amount spent, and thus risk sizes may prove deceptive as screening and prioritization tools.”⁶¹

The most obvious risk within a community is not always the issue which should be addressed. Hubbard posited that, above all else, the question asked is “the right question.”⁶² He argued, not unlike Cox and MacKenzie, that identifying what risks to address and at what cost is an organization’s most important focus. Hubbard asserted that a sophisticated system, which is inaccurate and used with confidence, is worse than a simple, but useless, system. He claimed that in the former method, policymakers can commit to the wrong course of action.

The literature consistently called for increasing quantitative analysis and better data sets. Thomas, Eisenberg, and Seager stated that overly defining risks limits the scope of research to those specific items showing resilience.⁶³ This limitation hinders a more holistic approach to an understanding of the resilience of any group or system. They advocated the necessity of an “integral map” to achieve a holistic review of any risk analysis. They further postulated that this integrated approach will address many of the concerns raised by those championing improved quantitative analysis.⁶⁴ The article stated that resilience research must consider the critical factors that dictate human action—that without such inclusion, vulnerability over geographic areas or communities can be challenging to determine.

⁶⁰ Cox, Jr., “Evaluating and Improving Risk,” 1246; Hubbard, *The Failure of Risk Management*, 58.

⁶¹ Cox, Jr., “Evaluating and Improving Risk,” 1246.

⁶² Hubbard, *The Failure of Risk Management*, 56.

⁶³ Thomas, Eisenberg, and Seager, “Holistic Infrastructure Resilience Research.”

⁶⁴ Thomas, Eisenberg, and Seager, “Holistic Infrastructure Resilience Research,” 3.

The reviewed literature highlighted the crucial importance of in-depth data sets in risk analysis, with a prevalent emphasis on quantitative data over qualitative. Contemporary risk-rich matrixes used by policymakers are generally criticized for their simplistic categorical descriptors like “high to low” or “red, yellow, and green.” Notably, scholars like MacKenzie and Hubbard advocated for the transformation of real-world data into more manageable figures for effective risk analysis. However, regardless of how these figures are translated, it is universally agreed that solid data sets serve as the primary basis for all categories.

Experts further discussed the value of various indices or matrixes. MacKenzie noted the prevalence of risk indices, yet criticizing the lack of deeper data in these decision-making models. Hubbard recommended utilizing empirical data to identify probable risks, whereas Tony Cox warned about the simplistic use of risk matrixes without adequate context or careful application. Further exploration within the literature suggested dissatisfaction with conventional risk matrixes due to their inability to provide enough context for sound decision-making.

Both MacKenzie and Hubbard endorsed the use of numerical indices for more accurate differentiation. Cox and Hubbard critiqued the lack of quantitative values in numerous matrixes, asserting they provide minimal strategic value and may create a false sense of security among decision-makers. On recognizing the limitation of these matrixes, Hubbard suggested infusing more quantitative assessments into indices or matrixes, and asserted that even estimating the probability of an event happening can provide greater quantitative value. The essence of multiple data sets in enriching quantitative analysis and aiding decision-making is a constant theme across the scholarly discourse. Moving further, the literature also emphasized the need for holistic analysis in risk studies, asserting that resilience research requires addressing various sociological, ecological, and technical aspects to present a complete picture. This holistic approach is considered beneficial for improving the accuracy of risk assessments and the allocation of resources for risk mitigation.

Much of the research conveyed the need to include data sets to address unequal resource responses to our societies’ socioeconomically and geographically repressed

members. In his research on the impacts of socioeconomic barriers on emergency response, Neuert emphasized research indicating that those with cultural barriers have a history of being underserved during emergencies.⁶⁵ The effect of such obstacles in studies on natural disasters, Hurricane Katrina, one often-cited example, provided supporting evidence.⁶⁶ This research pointed out that governments are not always providing equal protection for all citizens.

Thomas, Eisenberg, and Seager also suggested that a more holistic approach will guarantee the consideration of things such as socioeconomic barriers.⁶⁷ One specific example of the impact of such obstacles comes from Neuert's reference to an American Heart Association study from 2014. The study found vast differences in cardiac-related emergency survival in different communities. Ultimately, those in impoverished communities had a 9.4% survival rate, compared to an over 40% in more affluent neighborhoods.⁶⁸ Using social vulnerability indices to inform risk analysis may be a valid tool, with enough context and analysis.

F. VULNERABILITY

Defining vulnerability is crucial in understanding the purpose of the indices used to measure them. While vulnerability refers to the lack of resiliency, resilience implies a neutral or positive response to adverse events.⁶⁹ The literature on these terms lacked specific definitions, but researchers commonly categorized resilience into individuals, communities, teams, organizations, and systems.⁷⁰ Moreover, the definition of resilience

⁶⁵ Neuert, "Bridging the Gap," 24.

⁶⁶ Neuert, "Bridging the Gap," 42.

⁶⁷ Thomas, Eisenberg, and Seager, "Holistic Infrastructure Resilience Research," 7.

⁶⁸ Neuert, "Bridging the Gap," 43.

⁶⁹ Jill Raycroft, "Realizing Resilience: A Study of Definition, Indicators, and Operationalization" (master's thesis, Naval Postgraduate School, 2021), <https://hdl.handle.net/10945/67172>.

⁷⁰ Thomas Britt and Gargi Sawhney, "Resilience Capacity, Processes and Demonstration at the Employee, Team and Organizational Levels: A Multilevel Perspective," in *Research Handbook on Organizational Resilience*, ed. Edward Powley (Northampton, MA: Edward Elgar Publishing, Inc., 2020), 10–24.

has expanded over time, now encompassing both systems and people.⁷¹ This expansion is evident in FEMA’s definition, which highlighted resilience as the capacity of individuals, communities, businesses, institutions, and governments to adapt, prepare for, withstand, and rapidly recover from disruptions to everyday life. FEMA’s broad definition underscored the comprehensive nature of resilience.⁷² Ultimately, understanding the concepts of resilience and vulnerability allowed for more effective measurement and responses to hazards and disruptions.

How Vulnerability and Resilience Differ

Few scholars agreed on the meaning of the term resilience. Some considered resiliency a status, or personal trait; it can also be viewed as a continually changing state over time. Definitions featured many variations, but most focused on the organization, team, or individual that experiences adversity, which causes a change in status or state.⁷³ Terje Aven helped define the impact of adversity. In his model, any subject is in one of four states before and after hardship: 3) standard, 2) intermediate, 1) intermediate low, and 0) failure.⁷⁴ Based on these states, after adversity occurs, an individual, team, or group will go to one of the four states: the more resilient, the faster the return to state three. Vulnerable individuals or communities will return more slowly to state three than those who are more resilient. Aven contended that, in some cases, the impacted person or group will be so vulnerable that they will return to state zero and never recover. In her master’s thesis, Jill Raycroft’s concepts underpin Aven’s temporal status four-state system. Raycroft argued that resilience exists in a person or community before, during, and after a disaster.⁷⁵

⁷¹ Thomas, Eisenberg, and Seager, “Holistic Infrastructure Resilience Research.”

⁷² “Planning Resilient Communities Fact Sheet,” Federal Emergency Management Agency, 2017, https://www.fema.gov/sites/default/files/documents/fema_planning-resilient-communities_fact-sheet.pdf.

⁷³ Terje Aven, “How Some Types of Risk Assessments Can Support Resilience Analysis and Management,” *Reliability Engineering & System Safety* 167 (November 2017): 536–43, <https://doi.org/10.1016/j.ress.2017.07.005>; Raycroft, “Realizing Resilience”; Britt and Sawhney, “Resilience Capacity, Processes and Demonstration”; Karolidis, Vouzas, and Antonacopoulou, “The Effects of Individual Resilience on Organizational Citizenship Behavior in Conotemporary Public Administration: A Dual Pathway Model,” 247–60.

⁷⁴ Aven, “How Some Types of Risk Assessments,” 538.

⁷⁵ Raycroft, “Realizing Resilience,” 32.

Further, Raycroft stated that “Vulnerability is a lack of access to resources in addition to living within a particular risk-prone area, while resilience is access to resources and the capacity to deal with different levels of risk.”⁷⁶ If Raycroft’s assertions are correct, then identifying those people and areas which are risk-prone is a crucial step for fire departments to address risk accurately.

Resiliency can be measured as the ability of an organization or individual to bounce back to its original state prior to the catastrophe. Since there are many elements which make people resilient, there are also many ways to measure resilience. Resilience can also be contrasted with stability. A system that does not vary greatly, even in the face of adversity, can be considered having stability. Even if a system sees a wide fluctuation, if it returns to its previous status (based on relationships and resources), it is considered resilient. In fact, without a fluctuation in status and a reliance on relationships and resources, no resilience actually occurred.⁷⁷

Fire departments currently utilize risk measurement to determine appropriate policies and services. However, as reviewed before, these measurements are lacking in consideration of vulnerability. Therefore, a more comprehensive understanding of risk is needed to ensure good modeling. In MacKenzie’s 2014 article, he argued, “Risk is best defined as a combination of the probability of an unwanted event occurring and the severity or consequences if that event occurs.”⁷⁸ This combination of probability and severity underpins risk analysis for fire departments.

A more comprehensive approach to the concepts of vulnerability includes viewing resilience as a fluid status or state that changes over time and differs across individuals, communities, teams, organizations, and systems. Terje Aven’s model of resilience, underpinned by four states of adversity, adds dimension to these perspectives. The importance of identifying risk-prone individuals and areas, as suggested by Jill Raycroft,

⁷⁶ Raycroft, “Realizing Resilience,” 38.

⁷⁷ Aaron Wildavsky, *Searching for Safety* (New Brunswick, USA: Social Philosophy and Policy Center, 1988), 78.

⁷⁸ MacKenzie, “Summarizing Risk Using Risk Measures and Risk Indices,” 2144.

underscores the role of resilience in managing various degrees of risk exposure. Fire departments use risk measurements, and must consider both probability and severity of adverse events, to refine their response models. This reinforces the need for a thorough understanding of resilience, vulnerability, and risk, guiding more effective strategies for dealing with hazards and disruptions.

G. SOCIAL VULNERABILITY INDICES

Socioeconomic vulnerability is an often referenced but broadly defined aspect of the literature. A commonly used index in the United States is the SVI, and comes from the CDC. In Neuert's research, SVI is focused on language, culture, and historical trauma barriers.⁷⁹ SoVI is the trademarked name for similar research into social health or resiliency indicators, and originated at the University of South Carolina. However, many agencies use BRIC.⁸⁰ More recent literature reviewed the concept of social infrastructure and its impacts on resilience. The SoVI indicators, for example, looked at the social network within a community and its impact on personal strength.⁸¹ There exist multiple indices which fire departments could use to provide greater context for risk assessment development, but deciding which one is difficult. The United States Fire Administration has started to offer some generic GIS overlays that communities can use based on SVI.⁸²

This lack of specific direction on what indices a fire department might utilize created an opening for research for this thesis. The value of indices as a risk measurement tool is also evaluated. A review of methodology and finding can be found in Chapters III and IV of this thesis. Those chapters review a method for identifying specific indices for

⁷⁹ Neuert, "Bridging the Gap," 29.

⁸⁰ Susan L. Cutter, Christopher G. Burton, and Christopher T. Emrich, "Disaster Resilience Indicators for Benchmarking Baseline Conditions," *Journal of Homeland Security and Emergency Management* 7, no. 1 (2010): 19, <https://doi.org/10.2202/1547-7355.1732>.

⁸¹ Dean Kyne and Daniel P. Aldrich, "Capturing Bonding, Bridging, and Linking Social Capital through Publicly Available Data," *Risk, Hazards & Crisis in Public Policy* 11, no. 1 (2020): 61–86, <https://doi.org/10.1002/rhc3.12183>.

⁸² "New U.S. Fire Administration Tool for Accessing Data on Fire Risk and Vulnerability," U.S. Fire Administration, last modified July 13, 2023, <https://www.usfa.fema.gov/blog/tool-for-accessing-data-on-fire-risk-and-vulnerability/>.

departmental consideration, as well as a method chosen for this thesis to evaluate based on spatiotemporal analysis.

Summary

This literature review provided an examination of key concepts, such as resilience, vulnerability, and risk associated with a fire department's practices of prevention and response. It emphasized the importance of viewing vulnerability as a dynamic status influenced by individual, team, organizational, and community characteristics. Communities in the UK have begun to utilize vulnerability data to better inform risk analysis and drive policies and actions to address those same risks. How fire departments in the United States might also utilize vulnerability data is covered in the next chapter.

Understanding vulnerability and risk informed the strategies for handling hazards and disruptions more effectively. Aven's resilience model, driven by four states of adversity, and Raycroft's advice of identifying risk-prone elements underscored the importance of these terms. Furthermore, in risk measurement, it is crucial to balance the probability and severity of adverse events, a tactic commonly utilized by fire departments to fine-tune their response models.

The review also provided critiques of the oversimplified risk matrixes often used in policy making, and advocated for more comprehensive and in-depth data sets for accurate risk analysis. Tools like numerical indices are favorably viewed for their depth and clarity, provided they are used contextually and carefully. Adding to that, a holistic approach toward risk studies that amalgamates sociological, ecological, and technical aspects is suggested. Holistic analysis fostered a more accurate risk assessment and resource allocation.

The use of risk analysis models—such as the NFPA, the CFAI, and Vision 20/20—by fire departments, despite their benefits, tended to overlook an in-depth evaluation of vulnerability. This review also pointed to the affinity for geospatial tools for risk visualization, although these models sometimes lacked methods to evaluate citizen vulnerability.

The literature indicated how risk knowledge shapes resource allocation in proactive/preventive or reactive/response efforts. However, it underscored that equality of impact based on vulnerability elements is often not properly integrated into risk analysis. The inclusion of vulnerability data in preventive planning was encouraged, leading to more robust and effective strategies. It also underlined the necessity of understanding community vulnerabilities to bolster resilience.

The need for ongoing research to correlate policy decisions with such initiatives is highlighted. Understanding the interplay of resilience, vulnerability, and risk aids in achieving stronger fire prevention and response strategies, and this thesis sought to provide an example of such an approach.

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III. DEVELOPING AN ANALYSIS FRAMEWORK

A. DEVELOPING A CONCEPTUAL MODEL

The goal of this research was to examine how existing social vulnerability measurements could be used by fire departments to inform risk assessment used for proactive and reactive resource decisions. A review of the various models outlined in the Fire Department Analysis section of the Literature Review makes it clear that several models exist to provide risk analysis which could inform fire department decision-making. To provide analysis, it was necessary for the author to create a conceptual model of risk analysis for fire departments. This modeling would allow for comparisons between various types of risk analyses.

Fire department analysis of policy decisions surrounding resource allocations can be framed in many ways. For this research, the risks were conceptualized based on the amount of time they impact the risk. Items are divided into short-term, moderate-term and long-term. Short-term elements (such as experience of actual fires or EMS calls) and long-term elements (like buildings, road networks, station locations) are standard components of risks assessments. However, moderate-term items such as vulnerability are the focus of this thesis.

1. Gap Identification

In an effort to determine how vulnerability might be considered in a fire department's risk analysis, a review of gaps in that analysis process is necessary. By reviewing the various methods available to evaluate risk elements, as well as how fire departments consider these elements, a temporal framework began to take shape. I broke these elements into three sections: short, moderate, and long-term elements.

2. Temporal Elements

The built environment, road networks, houses, apartments and office buildings and factories tend to last a long time. To that end, the policy decisions connected to them also

are long-term decisions. Where fire stations are placed and the services provided are also based on those long-term elements.

Similarly, there are events that exhibit short-term elements that impact fire department policies. These certainly include fire and EMS calls (which are significant but relatively short-lived) but also local events such as a 5K race or farmer's market. These events require planning and resource allocation. Examples of short-term elements impacting policy resources include daily fire and EMS response, an extra ambulance to staff a 5k race and pre-planning of large community events.

Finally, there are other risk implications within our community that consist of moderate-term elements—they are not quick events, but they do not last for 20 years or more. These tend to be based on the people living in the area. For example, do people in the area have access to cars? If not, will pedestrian traffic increase and the chances for people being hit by cars increase as well? For this thesis, the concept of vulnerability of the population is the moderate-term element being considered. Recognizing moderate-term elements of vulnerability and reviewing how we might evaluate these for proactive and or reactive policy decisions is the focus of this effort.

As discussed earlier, fire departments need to conduct risk analysis to determine policies and resource allocations. Dividing these risk elements to be analyzed in a temporal manner provides some framework for analysis. Figure 2 provides a conceptual model of the types of temporal risk elements that can exist in each temporal zone. Because each time span has different impacts and variables, the response of policy and resource choices can, and is, different for each.

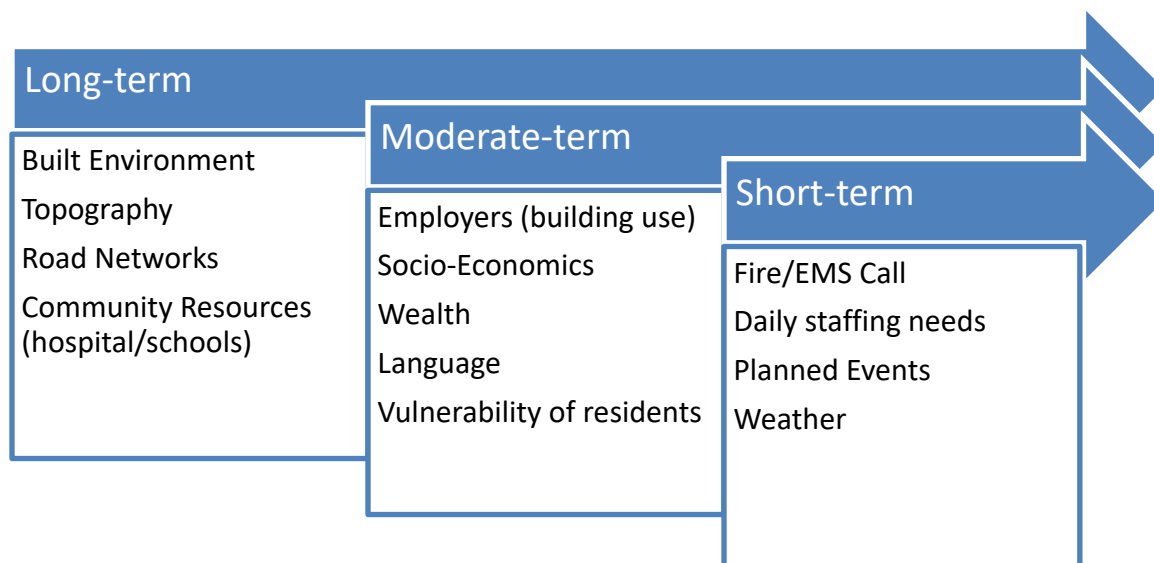


Figure 2. Temporal Risk Elements

As discussed above, for each type of temporal element, fire departments can create policy and resource allocation decisions. These resources (e.g., human, financial, capital) tend to get grouped into two areas. The first and most common are reactive responses, which are applied after an event occurs. For long-term temporal elements (e.g., a growing or declining community), departments might change where fire stations are located, and the type of fire apparatus/services provided from that station. For short-term elements (e.g., calls for service), fire departments can plan both types and quantity of resources with which they will respond.

Fire departments can also supply proactive responses. These might include things like fire safety and building code compliance and fire prevention measures for long-term elements. Proactive approaches for short-term elements could include sending an extra ambulance to cover a high school football game or increasing staffing in an area during rush hour traffic to help with increased traffic concerns. Permit applications would be a good example of a proactive resource application to short-term elements, such as a festival. Examples of proactive and reactive decisions based on temporal elements can be found in Figure 3.

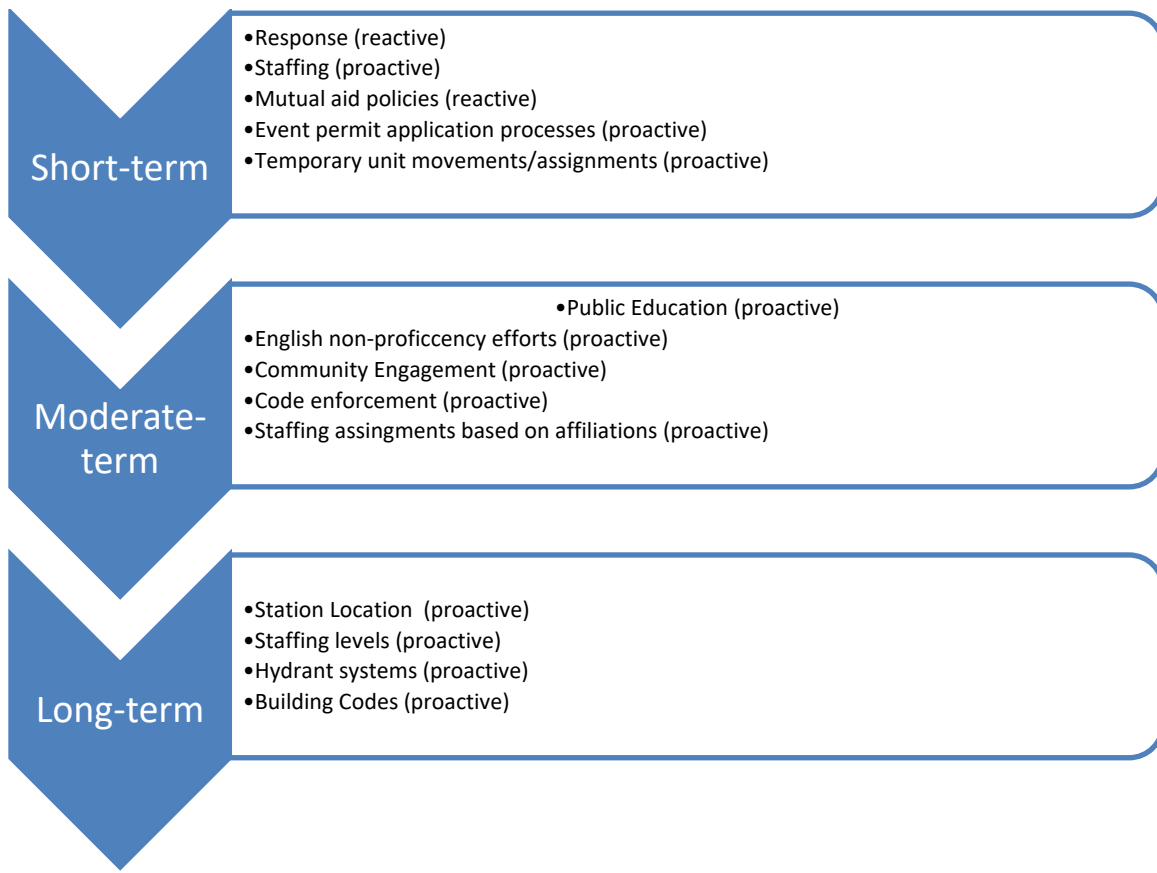


Figure 3. Policy and Resource Considerations Based on Temporal Elements

3. Moderate Temporal Elements Policy Impacts

Moderate-term elements include items such as social vulnerability. As such, it would be helpful if departments could identify moderate-term elements within a risk assessment tool or risk index to utilize for planning. This section will review how an agency can determine which tools might be of use.

There is an abundance of literature on the impacts of both short- and long-term elements on risks and on how a department might supply proactive and reactive planning. The question arises what measurements might be used for moderate-term elements and how might such data be folded into policy planning? This research supposes that using the same spatiotemporal (mapping) modeling of strong and weak temporal events, overlay with a vulnerability or risk indices will provide context to help create policy on proactive approaches to fire and EMS policy.

For example, an index that shows a community with an elevated level of non-English speaking population would be a good area for non-English public education events. Also, that area might be a place to develop specific relationships within the community. However, given the transient nature of residents in any community—these indices point to moderate rather than weak or strong events.

It was first necessary to identify what types of policy decisions fire departments will consider when evaluating risk. Through a review of literature and online resources, federal agencies and national associations created a list of policy decisions. Using the same resources and my experience in fire service planning, these items were then divided into groups based on what types of variables within a community impacted the decision.

These variables were then divided along two axes. The first was based on the longevity of the element. This temporal element grouping was divided into three segments: short-term (emergent nature elements such as fires, EMS calls and weather events) long-term (such as building construction, road and water supply/hydrant networks) and moderate-term. These moderate-term items are based on the current vulnerabilities of the citizens in our community, with realities such as economic and social well-being. The second axis was based on the type of policy decision. Again, with an eye to the temporal nature of the decision, this axis focused on policy decisions that have impacts before (proactive) or after (reactive) and emergency.

Examples of the policy decisions connected to different temporal variable is outlined in Table 1.

Table 1. Policy Consideration Framework for Temporal Elements

Temporal Element	Variables Influencing Risk	Services/Resources	Policy Decisions
Near-term	Fire/EMS Call Staffing Events Weather	Response Staffing Mutual aid policies Application processes Temporary unit movements/ assignments	Where to place temporary units Which skill sets/ personnel to send on a call How to structure mutual aid policies
Moderate-term	Employers Building use Socioeconomics Wealth Language Policy	Public Education Fire and Health English/non-proficiency efforts Community Engagement Code enforcement Staffing assignments	Where to provide fire prevention education, and what kind (school vs. elder center) What languages to use in public safety messages What affiliation considerations to make in staffing
Long-term	Built Environment Topography Road Networks Community Resources (hospital/schools)	Fire/EMS Stations Staffing levels Hydrant systems Building Codes	Where to place stations Where to place hydrants Which building codes to establish where

4. Moderate-Term Analysis Tools

As discussed earlier, long-term and short-term elements are well considered within standard fire department risk analysis. It became necessary to create an analysis tool for considering moderate-term elements, such as vulnerability.

To consider moderate-term elements, it is necessary to identify them in a usable format. Using any moderate-term element measurement resource (i.e., an index), one can look at variables influencing risk and how they might be addressed in both proactive

preventive responses (e.g., code enforcement, fire prevention, unit deployment) and reactive responses (e.g., fire and EMS responses). Although it seems intuitive to the author, a fire department focus should be on proactive prevention rather than response so most of the analysis leans to that arena, as John A. Stouffer advocates.⁸³ Regardless of the index chosen it is necessary to evaluate the index with an eye to making policy choices.

Based on the Policy Consideration Framework found in Table 1, a department analyst could evaluate how an index might impact policy choices. This moderate-term analysis tool is influenced the NAPSG evaluation of vulnerability indices and uses the four lenses of analysis for evaluating moderate-term elements:

Demographics: Items such as age, English as a second language, and non-white communities may all provide insight into vulnerabilities that can impact safety during a fire or emergency incident. For example, advanced age can be an indicator of deteriorating health status. English as a second language could be an indicator that an individual was not educated in U.S. public schools and was not indoctrinated with standard school-age fire prevention training.

Economics: Poverty and wealth are well-identified indicators for resiliency, as are access to health care and living conditions. Items such as the age of residents (below eighteen years of age and over sixty-five years of age) can be a factor in EMS demand and the ability to escape from an active fire. Consideration of percentages of non-white citizens in the tract who may experience different disease processes, and therefore have different EMS outcomes. Homes with limited English proficiency show the need for prevention material in other languages, and a recognition that these individuals may not have received the standard fire prevention education found within the United States's school curricula.

Household Composition: Indicators of crowding (i.e., the number of people per dwelling), rental vs. privately owned housing stock, and overall type of housing stock can also provide insight. Overcrowding puts stress on systems such as the electrical or cooking systems, leading to fires. Home escape is based on the “right” number of people living in

⁸³ Stouffer, *Community Risk Assessment*, 1.

the property and housing's stock age and type impacts fire spread, should a fire start. These can indicate needs for different fire ground operations or resources, increase the need for fire prevention efforts and increased code enforcement efforts.

Employment: Employment and access to employment are not simply indicators of wealth. They help determine daytime residency (assuming unemployed people are more likely to be home during “working hours”). The type of work available within a community also indicates the types of fire (residential or commercial) and the road networks available for fire response movement. Using these four lenses, the author can provide different proactive or reactive policy decisions connected to each of these variables. Although limited in scope for the purposes of this paper, a sample is located in Table 2.

Table 2. Sample Risk Variable Based Policy and Resource Considerations

Variables	Proactive	Reactive
Demographics: Residents above the age of 65 and below the age of 18, the percentage of non-white/minority residents and percentage of people who speak English as a second language or less the well.	Fire Prevention Education: Age, and language appropriate public education material Trip and Fall prevention Basic fire safety education for adults who did not attend U.S. schools	Fire and EMS Response: Daytime population consideration for search and rescue Language barrier/language line training Community-based CPR training.
Economics: The percentage of people living below the poverty line, people at median income, people with a high school or higher education level	Code Enforcement: Older housing stock/lack of smoke alarms Fire Prevention: Language barriers for public education programs/information	Fire Response: Use of space heaters for winter season Property maintenance/fire spread Post-fire housing support
Household Composition: The indicators of crowding (number of people per dwelling), rental vs. privately owned housing stock Overcrowding in homes can be considered in this variable.	Fire Prevention: Fire prevention education focused on rental property Focus on escape plans to address overcrowding.	Fire response: Crowding requirements for rescue resources Rental types (for response levels)
Employment: The unemployment rate within the community should be reviewed	No suggested action.	Fire Response: Daytime occupancy for unemployed Ability to maintain property EMS Response: Access to insurance, reliance on EMS

B. EVALUATION STEPS OVERVIEW

Any fire department risk analysis will be based at a minimum on the geographic area for which the fire department is responsible. However, the response area may be broken down into smaller units. Although it certainly is possible that a total response area

is homogeneous in its makeup and risk elements, it is unlikely, therefore, a smaller geographic area should be considered.

Step 1 of this process involved determining the geographic area to be evaluated.

Step 2 used a SVI to help determine the vulnerability within an area.

Step 3 involved reviewing the index for more contextual information to provide insight on specific risk impacts.

Finally, in Step 4, based on these moderate-term elements (i.e., both the index number and the contextual information), a projected course of action for proactive and reactive policies is suggested.

This is all done via the worksheet created for this thesis. These steps are outlined in Figure 4:

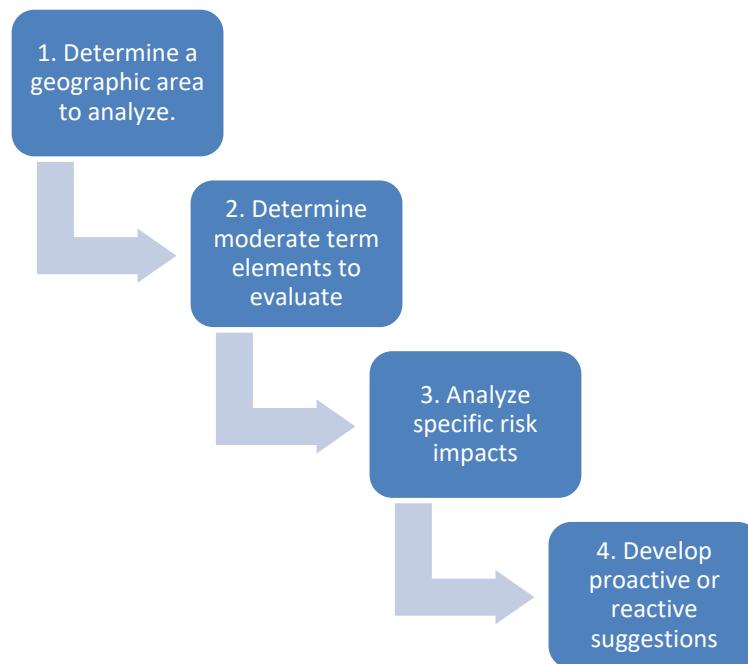


Figure 4. Policy Consideration Framework for Temporal Elements

1. Step 1: Determine a Geographic Area to Analyze

An interpretation of this is provided for context. For each community, a decision needs to be made on the area to be analyzed. The area needs to be large enough to create usable data for agency wide policy or resource allocation changes. Additionally, the area analyzed should not be so large that the index cannot be used to provide more granular detail. For the United States, each community is divided up into census tracts. A census tract is a geographic region defined for taking a census.

These tracts are relatively permanent, but they can, and do, change over time. In the United States, these areas are determined by the U.S. Census Bureau and are relatively homogeneous in terms of population characteristics, economic status, and living conditions. Census tracts usually have between 2,500 and 8,000 residents, and they are used to collect and analyze demographic data.

Initially, a comprehensive list of all census tracts within each respective magisterial district was procured from the Census Bureau website.⁸⁴ Each individual census tract was then assigned a unique sequential number, starting with one and continuing until all tracts had a corresponding assigned number.

The analysis used a random number generator to select one specific tract from each district. Then, the random number generator's range was configured from one to the total number of census tracts within each magisterial district, ensuring an equal opportunity for each tract to be chosen. Finally, the census tracts with assigned numbers that matched the generated random numbers were designated as selected tracts for the study. The study for this paper aims to provide representativeness and inclusivity of the varied communities within each magisterial district, thus maintaining the integrity of the results.

A minimum number of tracts is necessary because the effort is to evaluate the value of using indices based on the addition of contextual data. Prince William County, Virginia, is divided into seven magisterial districts. For that reason, one tract from each district was chosen. For this thesis, the study employed a random selection methodology to determine

⁸⁴ "2020 Census—Census Tract Reference Map," US Census Bureau, accessed October 12, 2023, <https://www.census.gov/geographies/reference-maps/2020/geo/2020pl-maps/2020-census-tract.html>.

the census tracts for research within each magisterial district in Prince William County. For each of the seven census tracts from Prince William County, an original GIS map showing the census tract is depicted.

2. Step 2: Determine Moderate-term Elements to Evaluate

An index for analysis must first be chosen that could be applied to fire department allocation decisions. The following steps were used to narrow down the possible indices for use. A rubric was created to evaluate the indices recognized by NIST. Using the NIST study as a method to focus on specific index attributes, the field of applicable indices was narrowed down.

Based on this narrowing process two indices were chosen, the CDC's SVI and FEMA's NRI. The National Alliance for Public Safety GIS (NAPSG) provides a similar breakdown on its website for five specific resiliency indices.⁸⁵ This NAPSG evaluation was utilized as a quality assurance reference for items from the NIST report.

The next process focused on the aspects of the index chosen. Again, this winnowing focused on determining the values/detractors from various risk evaluation indices and how they might interplay with local fire protection? The NAPSG report was also helpful in identifying specific data that informed the various indices, further helping to narrow down possible index choices.

Two indices were indicated through both of the above processes, the CDC's SVI and FEMA's NRI. The United States Fire Administration, in July 2023, unveiled a tool which uses SVI to assist departments in evaluating fire safety in their communities. For this study, I am only using one index, the CDC's SVI. However, a community could utilize multiple indices to provide insight or context.

⁸⁵ National Alliance for Public Safety GIS, "Overview Compare | Guidance on Risk, Resilience, and Vulnerability Indices," Social Indices Overview Chart, accessed October 4, 2023, <https://experience.arcgis.com/experience/376770c1113943b6b5f6b58ff1c2fb5c/page/Overview-Compare/>.

3. Step 3: Analyze Specific Risk Impacts

To support the analysis process, a worksheet was created for each geographic area considered. This worksheet included:

- An area for a map of the geographic area being analyzed.
- An area to place a basic analysis of fire risk element features obvious to the trained observer from the map. A location for any index number or ranking that might be provided.
- Space was provided to provide contextual insight based on the four lenses of analysis as well as projected proactive and reactive policies. (This is based on Table 2.)
- A series of questions for analysis in Step 4.

This worksheet was used for Census Tracts A, B, and C.

4. Step 4: Develop Proactive or Reactive Suggestions

Utilizing the worksheet and data from above for each geographic area analyzed, the research sought to evaluate the following:

- Are any changes in vulnerability indicated in the level of risk to the community via the SVI number? If so, what suggested actions could be taken to address the risk?
- Are any changes in vulnerability indicated in the level of risk to the community via the contextual information provided by the SVI? If so, what suggested actions could be taken to address the risk?

These simple-seeming questions provide some insight as to what, if any, impact the risk variables play.

What information was I able to glean from the chosen index number? The chosen index number may or may not provide insight into specific actions an agency could take to

amend policy or resource allocations. Determining if that numerical value was enough should help how an index could be used.

What information did the contextual variables of the chosen index provide for policy or resource changes? By looking at the specific variables within the census tracts protected by a fire department, I sought to determine if greater insight into actions could be achieved. This would help determine if an index was enough for an agency to take action.

How did the various census tract analyses compare to each other? By comparing the policy changes found from each of the census tracts, I sought to look for differences in suggested policy changes. Variations in suggested actions can be considered an indicator that the variables in moderate-term analysis speak to the value of individual assessment, rather than the county geographic region as a whole.

IV. APPLYING THE MODEL TO PRINCE WILLIAM COUNTY

A. PRINCE WILLIAM COUNTY BACKGROUND

Prince William County is in the National Capital Region of Virginia, approximately twenty-five miles south of Washington, DC. It is bordered on the north by Fairfax and Loudon Counties; its southern border is Stafford County, its eastern border is the Potomac River, and its western border is rural Fauquier County, Virginia. The county has a population of just under 500,000 residents and is home to both Marine Corps Base Quantico and Manassas National Battlefield Park.

The community supplies a wide range of risks for consideration. It is a “minority-minority” community in that the majority of citizens identified as Asian, Black or Hispanic in the last census and these demographics will continue to grow. As a suburb of urban Washington, DC., there are similar economic challenges as found in any suburb within the United States and other areas of affluence in the western part of the county.

Prince William County is also the employer of this paper’s author and, as such, the author gained information and provided greater context for evaluation of the community as a member of its fire department. The steps for analysis outlined in Chapter III were applied to this community.

1. Step 1: Determine a Geographic Area to Analyze

Initially, I found a comprehensive list of all census tracts within each respective magisterial district from the Census Bureau website, from the most-recent census in 2020. From that government website, I acquired a comprehensive list of census tracts within each of the seven respective county magisterial districts from the Census Bureau website.⁸⁶ Each individual census tract was then assigned a unique sequential number, starting with one and continuing till all tracts had a corresponding assigned number. Then using a random number generator, I chose one census tract for each of the seven magisterial districts.

⁸⁶ US Census Bureau, “2020 Census—Census Tract Reference Map.”

Because the effort is to evaluate the value of using indices based on the addition of contextual data, a minimum number of tracts is necessary. For each of the seven census tracts from Prince William County, an original GIS map showing the census tract is depicted. Then, for each map, the SVI for that census tract is recorded based on the SVI's 0.0 to 1.0 scale. The census tract number connected to each map is also recorded.

2. Step 2: Determine Moderate-term Elements to Evaluate

For this study, based on the steps outlined in Step 2, Part A of this chapter, the CDC's SVI was chosen. The SVI looks at sixteen various indicators of resiliency and vulnerability within a community. It then compiles these indicators into an overall score for a defined area (i.e., the county or census tract). This index provides a rating on a scale of 0 to 1, with 0 being the least vulnerable and 1 being the most vulnerable. This rating is recorded on the worksheet.

For this thesis, the goal was to provide examples of how the contextual information from an index might better inform decision-making. The author chose three of the seven census tracts analyzed. These were chosen to show low (0.0 to 0.33), medium (0.34 to 0.66), and high (0.66 to 1.0) sections of Prince William County based on SVI's 0.0 to 1.0 scale.

3. Step 3: Analyze Specific Risk Impacts

The analysis worksheet was used for each census tract area. This worksheet involved using the Census Bureau's online resources and adding a map of the census tract into the worksheet. Then, the specific SVI numerical rating for that census tract was provided. A brief narrative of the area, hazards, and defining features was also provided.

For each of the four variables (demographics, economics, household composition, and employment) data from the contextual information found within the SVI score for that census tract was provided. Based on this information, a qualitative assessment of possible changes in policy or resource allocations was provided. Examples of these worksheets can be found in the "census tract" section of this thesis.

4. Step 4: Develop Proactive or Reactive Suggestions

This analysis led to a series of possible policy decisions, both reactive and proactive, for fire department consideration. Although this author has evaluated seven census tracts, for comparison, the examples provided (below) are a census tract with a low SVI score of 0.02, a census tract with a medium SVI score of 0.48, and census tract with a high SVI score of 0.94. Using the worksheet outlined in the research design chapter of this paper, the reader can review the basic contextual information used for analysis. Then, I answered the two primary questions for each of these worksheets:

- Are any changes in vulnerability indicated in the level of risk to the community via the SVI number? If so, what suggested actions could be taken to address the risk?
- Are any changes in vulnerability indicated in the level of risk to the community via the contextual information provided by the SVI? If so, what suggested actions could be taken to address the risk?

At the end of this chapter, there will be a comparison of each of the three analyses performed to determine any trends worthy of consideration.

Census Tract A is shown in both Figure 5 and the corresponding Table 3.

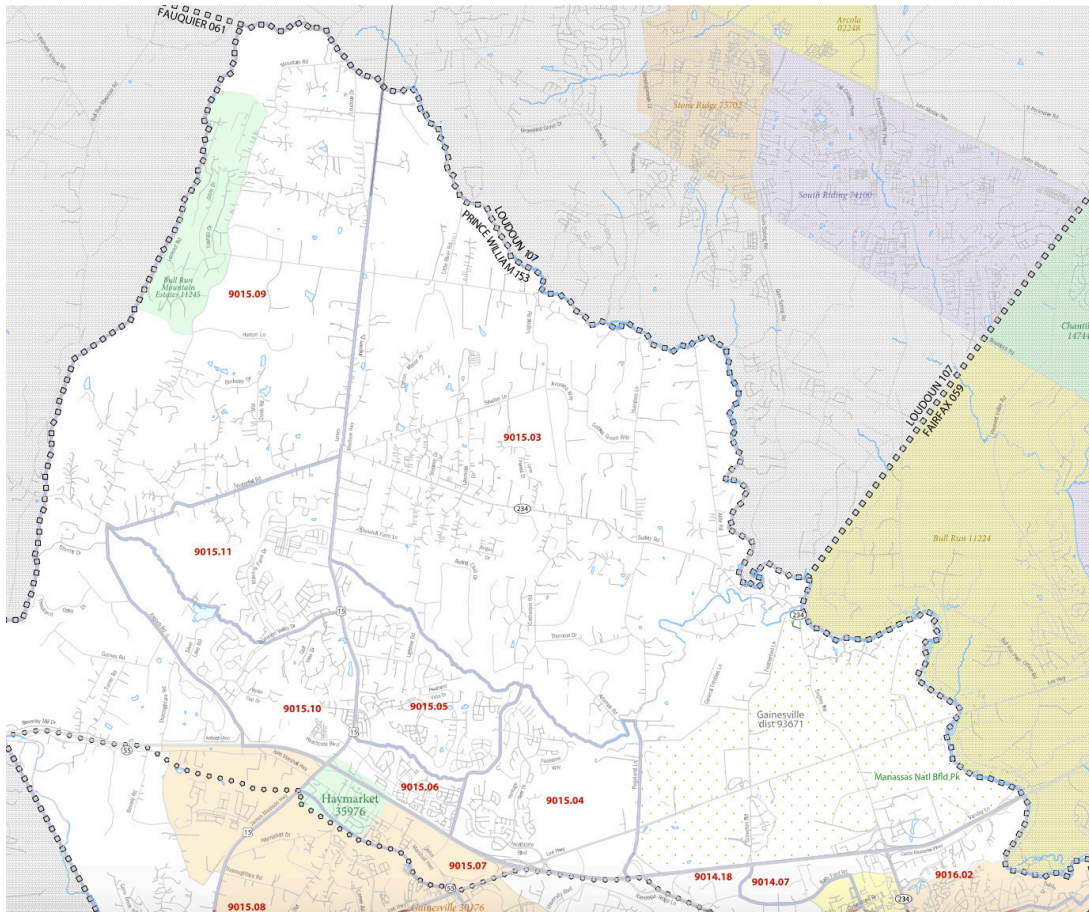


Figure 5. Prince William County Census Tract A (Low SVI Score)⁸⁷

⁸⁷ Source: U.S. Census Bureau, “2020 Census—Census Tract Reference Map.”

Table 3. Prince William County Census Tract A (Low SVI Score) Data⁸⁸

Census Tract # 901503 SVI ranking 0.02	This area within the Gainesville district is predominately single-family homes on large lots. The area is rural and includes part of the Manassas National Battlefield Park. There is no fire station within the census tract and water supply is limited. It is served by stations 15, 22 and 11.		
		Proactive Decisions	Reactive Decisions
Demographics	15.5% are 65+ and 25.7% are under the age of 17. 24.7 are non-white/minority and 0.4% speak English less than well	A large percentage of those over 65 indicates senior-focused public education may be appropriate	The large percentage of those over 65 may indicate decreased property maintenance impacting fire spread and decreased ability to self-rescue
Economics	3.5% below the poverty line; the median income is \$63,172. 4.9% have no high school diploma. No vehicle is available in 0.5% of the homes	No action	No action
Household Composition	7.7% of the homes have a civilian with a disability and 5.3% are single-parent households. There are no multi-unit or mobile homes in the tract. Crowding is occurring in only 0.6% of the homes and there are no group quarters	A focus on fire prevention for people with differing abilities should be considered for this area	Rescue operations should recognize the presences of differently abled individuals
Employment	2.9% Unemployment	No action	No action

⁸⁸ Adapted from “CDC/ATSDR Social Vulnerability Index (SVI),” Agency for Toxic Substances and Disease Registry, last modified July 12, 2023, <https://www.atsdr.cdc.gov/placeandhealth/svi/index.html>.

Census Tract A (#9015.03) had the lowest SVI score with a 0.02 score, indicating that there was very little vulnerability within the census tract. However, an analysis of the moderate-term contextual data indicates a higher presence of senior citizens and disabled people. Policy considerations of senior citizen focused public education and fire and rescue implications from senior's ability to self-evacuate during a fire are shown.

Are any changes in vulnerability indicated in the level of risk to the community via the SVI number? If so, what suggested actions could be taken to address the risk?

No, in of itself this low SVI score does not indicate that any specific issue needs to be addressed to account for vulnerability within the area.

Are any changes in vulnerability indicated in the level of risk to the community via the contextual information provided by the SVI? If so, what suggested actions could be taken to address the risk?

Yes, even though this is a low SVI score area. There is a relatively high number of senior citizens and individuals with disabilities within the area. Consideration of specific fire prevention education in this area should be taken. Reactive actions could include the recognition of higher probability of senior citizens and those differently abled to self-evacuate from home fires. Also, there is a probable need for an increase in EMS resources for the area.

Census Tract B is shown in Figure 6 and the corresponding Table 4.

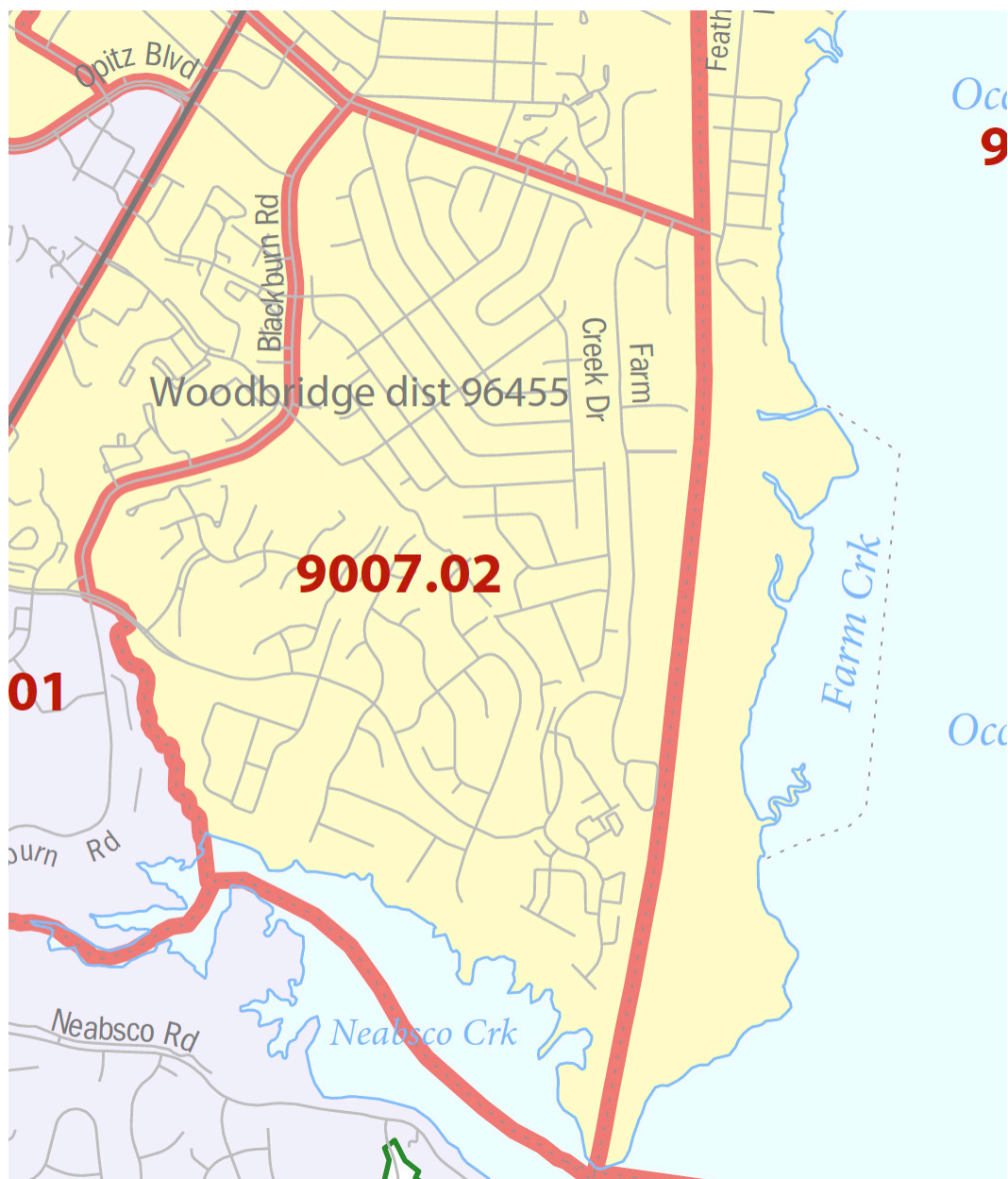


Figure 6. Prince William County Census Tract B (Moderate SVI Score)⁸⁹

⁸⁹ Source: U.S. Census Bureau, “2020 Census—Census Tract Reference Map.”

Table 4. Prince William County Census Tract B (Moderate SVI Score)
Data⁹⁰

Census Tract # 9007.02 SVI Rank.48	This area is predominately 1960s–1980s single-family detached housing stock in the Woodbridge District. The far eastern side is light to mid-level industrial. There is no direct access to the water, and it does not include abutting commercial development on the Rt. 1 Corridor.		
Variables	Insight	Proactive Decisions	Reactive Decisions
Demographics	7.6% are 65+ and 26% are under the age of 17; 69.1% are non-white/minority and 6.9% speak English less than well	Nearly 7% don't speak English well and public education with a non-written focus should be considered	Translation services should be clearly accessible for personnel
Economics	9.6% live below the poverty line, the median income is \$31,337; 17.9% have no high school diploma. No vehicle is available in 0.3% of the homes	The lack of high school diploma may indicate a lack of standard school-based fire prevention training. Basic training should be reinforced within this area	No specific action
Household Composition	8.9% of the homes have a civilian with a disability and 5.1% are single-parent households. There are 301 (11.3%) multi-unit homes and thirty-five (1.3%) mobile homes in the tract. Crowding is occurring in 6.9% of the homes and there are zero group quarters	Specific fire and injury prevention for those with varied abilities should be considered for this area, as well as apartment-occupant specific fire prevention efforts	Disability impacts on rescue operations should be reinforced for first arriving units in this area. Relatively high crowding should also be considered for rescue. Addressing the number of units available on the initial response should be a consideration
Employment	7.1% Unemployment	No action	Possibly high daytime population

⁹⁰ Adapted from Agency for Toxic Substances and Disease Registry, “CDC/ATSDR Social Vulnerability Index (SVI).”

Census Tract B (#9007.02) had a moderate SVI Rank.48, indicating a mid-level of vulnerability on the SVI scale. Although this ranking shows that some vulnerability exists in the area, it gives no specific understanding of what those vulnerabilities might be or the proactive or reactive resources that should be considered. Items such a language proficiency and education all have implications for public education materials appropriate for the area. The high level of people with disabilities within homes and unemployment may indicate that residents are home during daytime hours or unable to evacuate, both of which have implications for how rescue operations would occur during a fire.

Are any changes in vulnerability indicated in the level of risk to the community via the SVI number? If so, what suggested actions could be taken to address the risk?

Yes, an SVI score of 0.48 shows vulnerability within the community and should be considered for planning. The score alone does not provide a context for what actions should be taken.

Are any changes in vulnerability indicated in the level of risk to the community via the contextual information provided by the SVI? If so, what suggested actions could be taken to address the risk?

Yes, there were indicators in three of the four variables, only unemployment showed no possible actions to take. There is a seven percent ESL issue within the community, as well as an estimated eighteen percent language barrier. There is a slight amount of crowding. The data suggested preventive actions that don't rely on a strong ability to read and write English are appropriate. It also indicated that prevention efforts for those with disabilities might be appropriate. Given the percentage of individuals living within apartments, apartment specific fire prevention should also be considered. From a reactive standpoint, consideration of daytime populations given unemployment should be accounted for. Also, the need to support the rescue of those with differing abilities should be accounted for.

Census Tract C is shown in Figure 7 and the corresponding Table 5.

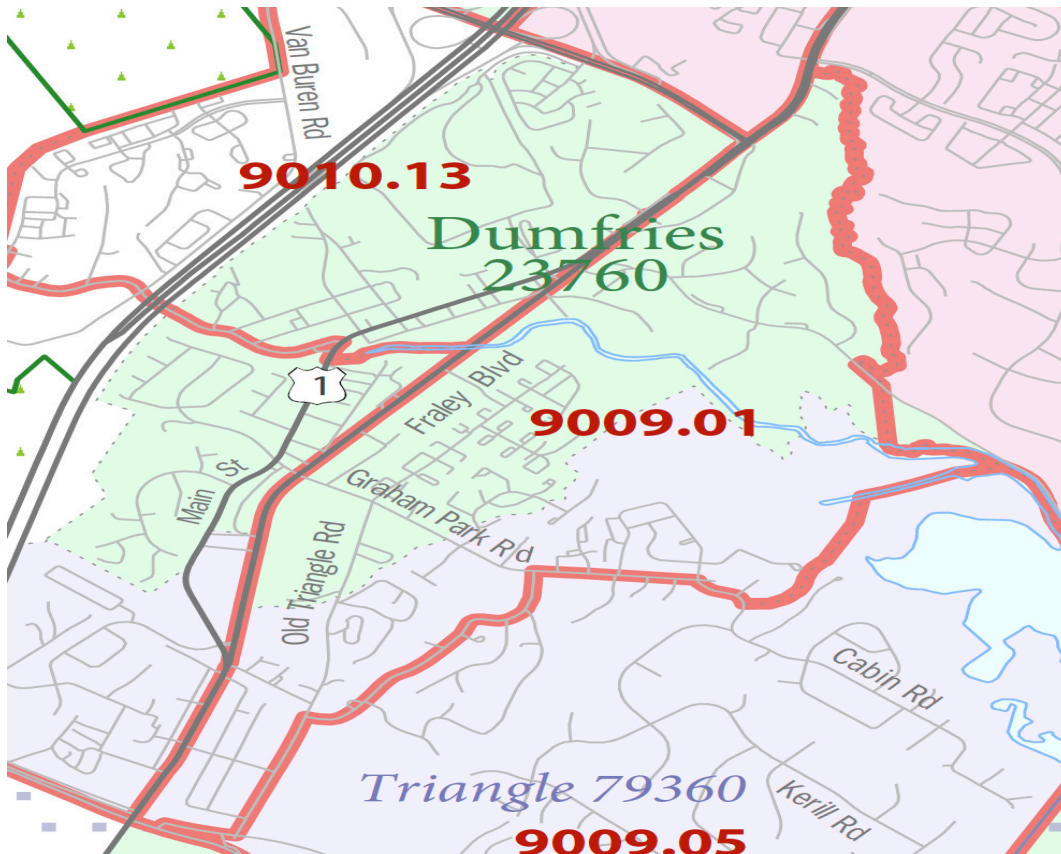


Figure 7. Prince William County Census Tract C (High SVI Score)⁹¹

⁹¹ Source: U.S. Census Bureau, “2020 Census—Census Tract Reference Map.”

Table 5. Prince William Census Tract C (High SVI Score) Data⁹²

Census Tract # 9009.01 SVI ranking 0.94	This area is in the Potomac district and lies between Cherry Hill and Marine Base Quantico (MBQ). It is older housing stock with mostly detached commercial structures along the Rt. 1 corridor. It is served by Station 23 and 3 and has a large number MBQ-adjacent residents.		
		Proactive Decisions	Reactive Decisions
Demographics	3.3% are 65+ and 36% are under the age of 17; 84.2% are non-white/minority and 6.2% speak English less than well	The high youth population should influence our public education outreach. English proficiency should not be assumed	Young population can impact search operations
Economics	23.8% below the poverty line, the median income is \$20,639; 23.7% have no high school diploma. No vehicle is available in 9.9% of the homes	Large population without high school diploma may not have received or normal public education doctrine. Revisiting older programs may be necessary. Low access to cars may require pedestrian safety programs	Higher poverty rate may impact home maintenance and fire behavior
Household Composition	8.4% of the homes have a civilian with a disability. 24.3% are single-parent households. There are 411 (19.7%) multi-unit homes and 162 (7.8%) mobile homes in the tract. Crowding is occurring in 12.7% of the homes and there are 22 (0.4%) group quarters	Apartment focused public education programs	High number of mobile homes should be pre-planned for fire attack. Apartment home operations should also be prepared. High crowding level will hamper operations, increasing initial assignments may be warranted
Employment	7.1% Unemployment	No action	Daytime population may be higher than normal

⁹² Adapted from Agency for Toxic Substances and Disease Registry, “CDC/ATSDR Social Vulnerability Index (SVI).”

Census Tract C (#9009.01) had the highest overall SVI rating of 0.94, nearly the highest ranking of 1. Again, although this ranking would certainly provide an indication that the census tract was of higher risk of negative impacts from fires or other events the fire department responds to, the lack of context makes this vulnerability difficult to plan for. By evaluating the contextual information found within the SVI numbers, policy decisions surrounding these findings. Items such as poverty, youth, lack of access to a vehicle and the types of homes found in the area all speak to both proactive and reactive needs within the community.

Are any changes in vulnerability indicated in the level of risk to the community via the SVI number? If so, what suggested actions could be taken to address the risk?

Yes, the very high vulnerability rating of 0.94 indicates the need to consider vulnerabilities in planning. There is no contextual information to aid in decision-making.

Are any changes in vulnerability indicated in the level of risk to the community via the contextual information provided by the SVI? If so, what suggested actions could be taken to address the risk?

The variables indicate a highly vulnerable community under the SVI system at a 0.94 out of a 0.0 to 1.0 scale. Only in the unemployment section where no substantive policy changes suggested. The lack of English proficiency a post high school education should impact our thoughts on public education material. Also, the higher rate of poverty may impact home maintenance and how fire will spread. Apartments make up a large percentage of the community and should be recognized as possibly having a higher number of residents within what might look like a single-family home.

B. OBSERVATIONS

Although simplistic, this review appears to validate the differentiation of moderate-term elements and the use of lenses to evaluate risk elements. Several specific items worth of mentioning became apparent during this review.

To help evaluate these three samples, a series of questions was used to help determine the value of the tools. For each geographic area analyzed, the research sought to evaluate the following:

What information was gleaned from the chosen index number?

The chosen index number may or may not provide insight into specific actions an agency could take to amend policy or resource allocations. Determining if that numerical value was enough should help how an index could be utilized.

What information did the contextual variables of the chosen index provide for policy or resource changes?

By looking at the specific variables within the census tracts protected by a fire department, I sought to determine if greater insight into actions could be achieved. This would help determine if an index, in and of itself was enough for an agency to take action.

How did the various census tract analyses compare to each other?

By comparing the policy changes found from each of the census tracts, I sought to look for differences in suggested policy changes. Variations in suggested actions can be considered an indicator that the variables in moderate-term analysis speak to the value of individual assessment rather than the county geographic region as a whole.

1. Fallacy of Index Scores

Overall, although Census Tract A had a very low SVI score of only 0.02, it still had specific proactive and reactive policy changes worth considering. Additionally, even the highest-level SVI score found of 0.94 in Census Tract C indicated that some action likely needed to be addressed. That both the highest and lowest scores still needed policy analysis and showed risks speaks to the possible lack of value in the index score alone.

2. Context Impacts Outcomes

It is also worthy of note that each analysis brought about different suggestions when viewed through the four lenses created for this evaluation. That the suggestions were different speaks to the interplay between the various elements of risk. Had the lenses and

elements had no real impact on the risk analysis, no changes in suggested policies or services would be suggested. This also speaks to the value of creating a lens for analysis, rather than just using any index number or value alone. It is worthy of note that the employment lens seems to have little impact on suggested policy with comparison to the other three lenses.

3. Validation of Method

Although not used for this research effort, there are several computer programs and analysis companies in the market that can provide similar, and likely better, evaluations. However, the purpose of this comparison was to see if a simple model for analyzing moderate temporal elements, such as vulnerability, could be achieved. This method did show positive results that any fire department can utilize. Also, this process was designed to see if greater analysis provided any real value. The analysis provided from the contextualized data from the SVI showed there was value in deeper analysis rather than simply utilizing an index number alone.

4. Summary

Ultimately, the model—with its policy consideration framework, variable lenses and moderate-term analysis tools—clearly creates a format for dividing elements into categories for analysis. Just as importantly, the different policies and actions suggested seem to imply that there is a unique value in the moderate-term elements being considered during risk analysis. As stated before, long-term items such as buildings and road networks are well considered in fire department risk, as are short-term elements such as building use, history of calls and events like festivals.

Although the various models for fire department risk analysis spoke to the need for risk analysis surrounding vulnerabilities, they supplied no specific methodology for fire departments to follow. This review shows how possible it is to use a method of choice for vulnerability measurements, whether it is Prince William County or another community.

V. FINDINGS AND RECOMMENDATIONS

The analysis conducted in this research provided several processes and insights into the value of indices in determining the impact of moderate-term elements on risk within a community. It provided a series of simple analysis tools a fire department can utilize for analyzing proactive and reactive policy decisions. It provided a process for evaluation of policy decisions based on temporal variables and finally showed how these methods can be used in a real-life scenario based on Prince William County. Most importantly, they showed that although the CDC's SVI provides some level of insight into a community, digging into smaller geographic areas (such as census tracts) and evaluating the data that created the score provide greater context for analysis for proactive and reactive policies and resource deployment.

A. FINDINGS

This paper sought to determine how a fire department might consider the vulnerability of its residents when preparing policy or resource deployment for reactive and proactive actions. To that end, the following research questions were developed and answered.

How can we look at risk evaluations and determine that a vulnerable population exists?

Standard risk evaluations for fire departments do encourage the review of community vulnerability and resiliency. These same standards do not provide specific direction on how to garner vulnerability information nor what to do with that information if you had it to analyze. However, there are over 50 indices recognized by NIST and a litany of research pointing to others.

Ultimately, this paper could show that indices alone are not sufficient for determining resource deployment. By reviewing the analysis census tracts, one can see that the index number does not provide any real insight into addressing vulnerabilities and may in fact have analysts overlook some vulnerabilities. In accordance with the literature on the

subject, greater context is needed for decision-making. However, indices contain variables that provide greater contextual data that may provide value for an analysis.

What are the values/detractors of various risk evaluation systems (matrixes, indices, etc.), and how do they interplay with local fire protection?

The literature review made clear that indices and matrixes were poor analytical tools. Several authors decry the simplistic nature of these systems. However, they also recognized that the context to be found within these systems might provide information worthy of analysis for decision-making.

How do we address a vulnerability (pre-, during, and post-incident?)

Fire departments can use inherent knowledge of communities to analyze how to apply proactive and reactive response to risks within the community. However, a more analytical approach will require a defined and repeatable set of data and analysis. The methodology in this thesis allowed for the use of social vulnerability variables to provide a more in-depth analysis for policy/decision-making about responses.

What systems already exist? And do they meet the demands of a sound evaluation system?

Although systems existed for risk analysis from organizations such as Vision 20/20, the National Fire Protection Association and the Commission on Fire Accreditation International, these systems all provide systematic approaches to evaluation of short, moderate and long-term variables for risk analysis. They also encourage the evaluation of moderate-term variable such as vulnerability, yet they do not provide nor suggest a specific process for such evaluation. The methods and analysis outlined in this thesis provided a suggested way of identifying an index as well as breaking the index down into its component variables, allowing for more contextualized analysis.

What might a better system look like?

This thesis provides a repeatable process that fire departments can use to evaluate various indices for their own communities. Determining what an index actually measures, and how those variables interplay with your fire department's mission, is a valuable step

in selecting an index. Additionally, this thesis lays out a process for using the variables within an index to provide insight into a community's specific vulnerabilities at a census tract level.

B. RECOMMENDATIONS

1. Choose a Small Geographic Area to Measure

It is necessary to determine the level of granularity of the geographic area that will be analyzed. For most fire departments that have more than one station it is common to divide the community into smaller response areas—often referred to first due areas (as units from a particular station within the geographic zone are expected to be “first due” to that area.)

Narrowing this area for analysis not only provides greater insight, it also lowers the loss of specific contextual data through the amalgamation of data from too large an area. Many indices only measure at the county level. However, as shown in the analysis in this paper, smaller geographic areas provide greater granularity in evaluations. In any case, the use of a census tract provides a standardized form or area for use.

2. Choose an Index for Its Variables

A fire agency should be cognizant of what an index is measuring. By choosing an index based on its variables, a department can gain valuable contextual data to inform decisions. Agencies need to take the time to research what exists within each index to determine if those unique variables will provide insight into policy making. Other agencies within a community, such as public health or social services, may already use some vulnerability index, and can help a fire department in determining what an index actually measures.

3. Use a Standardized Analysis

For this research, a standard analysis worksheet ensured consistent evaluation for each census tract. Although a different worksheet could be created, the standard format made comparing census tracts straightforward. Also, by determining the variables

which would be considered (demographics, economics, household composition, and unemployment), consistent evaluation was maintained from one census tract to the next.

As shown in Chapter IV, through the use of the standard processes outlined in this paper, a fire department can provide simple yet insightful analysis of vulnerabilities within a community. Once an index is chosen, its variable breaks down into specific lenses, and as a geographic area of analysis is determined, the analysis itself will be fairly intuitive. Even this example analysis will provide actionable items for a fire department to consider.

VI. CONCLUSION

Fire departments need to provide more in-depth, contextualized assessments of risks and impacts of hazards within their communities. Quantifying the social vulnerability within the community can assist in determining the possibility of disparate impacts of various hazards, most notably fire and emergency medical incidents. Most fire department's risk analysis methods, both within the United States and abroad, fixate on long-term elements such as water supply and road networks. Although sufficient systems of analysis encourage fire departments to consider vulnerability factors, they offer no transparent methodology for factoring these risks into planning for proactive or reactive resource deployments, such as fire prevention or the number of units in an area.

Ultimately, the literature outlined the need for greater context when determining risk and simultaneously recognized that indices are not quite the tool, as they lack the specific sub-context that provides good risk analysis. The literature also pointed to the need for vulnerability measurements with emergency responses—citing examples such as Hurricane Katrina—that describe disparate impacts of emergencies on the socially vulnerable. The same reviews also pointed to several systems, within the United States and abroad that look at risk, and suggest looking at social vulnerability, but do not provide a pathway forward to that analysis.

This paper provides a process, but not a definitive process, for choosing an index, showing the contextual data for analysis, and creating a consistent format for that analysis. It is simplistic, but in that simplicity is an approachable path for any fire department. As such, fire departments can and should use such tools to better inform decision-making on the use of proactive and reactive resources.

The Department of Homeland Security, FEMA and the USFA have all encouraged municipalities to start considering the vulnerability of protected populations within our planning processes. In July 2023, the USFA even unveiled a new interactive website that combined fire loss of life and the CDC's SVI for counties. However, this paper seems to

show that communities need to take the time to delve into the context of an index like the SVI to garner real information for action.

The federal government may also want to consider the role of indices in determining grant funding, such as the SAFER Act or Fire Act grant series. By linking funds to such analysis, it will increase the consideration of vulnerability to fire department planning, and through the grants, funding such vulnerability informed efforts. It should be noted that the analysis I performed within this research paper required no sophisticated software and is repeatable by any fire department.

Finally, although the international not-for-profit, Commission on Public Safety Accreditation references the need for consideration of vulnerabilities, it provides no specific format for such analysis. Including even a rudimentary process, such as what is found in this paper can be done by any community seeking accredited status.

A. ANSWERING THE RESEARCH QUESTION

The standard mathematical model for assessing risk is

$$\text{Risk} = \text{Hazard} * \text{Vulnerability} * \text{Mitigation or Consequence}^{93}$$

1. Equitable, Not Equal Response

As such, risk is not simply the impact of a hazard on a community, but also the vulnerability of that community to withstand the disequilibrium of the event and the ability of the responsible organization to mitigate the consequence. To that end, fire department models for planning to avoid and reduce risk have focused on hazard removal (fire prevention) and consequence management (fire suppression) but not on determining vulnerability for possible mitigation. The one exception could be the use of hazard classifications. Still, in those cases, the fire service is considering the hazard of the resource lost (building or service) rather than the vulnerability of people.⁹⁴

⁹³ Cox Jr., “What’s Wrong with Risk Matrices?,” 498.

⁹⁴ Stouffer, *Community Risk Assessment*; National Fire Protection Association, “NFPA 1300”; Metropolitan Chiefs Association, *Fire Service Deployment: Assessing Community Vulnerability*.

Although fire departments have authority in many areas of fire prevention and suppression, they are not necessarily agencies focused on building resilience. Regardless of whether a community has a resiliency development mandate, understanding the resilience within a community should play a role in fire department risk evaluations. Fire departments should also consider that a focus on prevention and mitigation management will be flawed if it assumes all citizens have an equal level of vulnerability. This flaw will be from the lack of including vulnerabilities within a community's risk assessment. Without a full comprehension of risk, policy decisions could be negatively impacted. Again, the basic risk equation is:

$$\text{Risk} = \text{Hazard} * \text{Vulnerability} * \text{Mitigation or Consequence}^{95}$$

If we assume that the hazard of fire is equal for different citizens and our fire service deployment is therefore equal to all citizens, then the only remaining factor to address in analyzing risk is the vulnerability of those impacted by the hazard. By providing contextual data found within risk indices, we can better quantify the “consequence” section of the above equation. The fire services’ focus on hazard prevention and mitigation has provided an equal level of service for all, but the lack of context within the risk equation hinders the provision of equitable service levels for all.

2. Measuring Coverage for the Fire Service

Fire Departments need to determine where to put resources to address emergencies within a community. We must consider the vulnerability of those impacted by fires and emergencies. Those with lower resilience are more vulnerable to the negative impacts of the disaster, and addressing that vulnerability can be a valuable tool for fire protection policy.

Adding how resilient a sub-community is within our larger community into our risk assessments will allow us to better determine where resources should go before and after an event. The impact of a fire can be different for everyone, but how do we assess that impact? By looking toward resiliency, and creating solutions to help people in the

⁹⁵ Cox Jr., “What’s Wrong with Risk Matrices?,” 498.

community achieve that. In her 2012 article in *Fire Engineering*, FDNY Deputy Commissioner Kat Thompson discusses that the number of metrics for fire department success do not consider the actual impact on those served rather than focusing on equality in response.⁹⁶

We can, of course, use many approaches to limit the impact of catastrophic events, such as a fire. Engineering buildings to withstand fire (concrete vs. wood) or adding sprinklers to stop a fire from spreading will all create stability as the adversity is limited. Codes that limit the spread of fire should they occur, and fire prevention education all create stability through the limitation of adversity from the start. Each of these provides for a “safer” community and should be considered.

The idea of risk mitigation (making things safer) and improved mitigation (making people more resilient). It is not a new concept. It is worthy of note, however, that experts like Aaron Wildavsky have argued that a certain amount of stress on a system will make it more resilient as it becomes necessary for that system to develop resiliency rather than hoping to exist in a safe world free of adversity. That fact that adversity cannot be removed from the world, Wildavsky argues, is the reason for a focus on resilience rather than simply making the world safer.⁹⁷

Mitigation lies between this idea of safety and resilience. It recognizes that adversity will occur, and that people and systems will need to have some level of resiliency. Mitigation seeks to limit the impact of adversity so that resiliency, though present, doesn’t need to be fully utilized. If we are to determine where resources should go based on the ability to return quickly to the status quo, then mitigation based on resiliency should be a factor in resource deployment.

⁹⁶ Kat Sonia Thomson, “Fire Department Performance Management: Is Public Policy on the Map?,” *Fire Engineering* (London, United Kingdom: Clarion Events, Ltd., August 2012).

⁹⁷ Wildavsky, *Searching for Safety*, 83.

3. Applying the Concepts

The analysis of the Prince William County data provided insight into the many roles that the fire department plays in our community. Not unlike other fire departments, we are an “all hazards” agency, meaning that we are not limited to fire response. Additionally, our agency should consider working with other agencies, such as Prince William County Social Services or the Area Office on Aging to see if a shared understanding of vulnerabilities and resource deployment from all agencies could bring about better results for citizens. For examples, the fire department’s recognition of a vulnerable elderly population may be better served by the Area Office on Aging using their programs rather than a fire department response.

Like any variable in a complex system such as risk analysis, there are numerous variables to consider, and perhaps too many for most agencies. An index appears to provide a way for an organization to hone in on specific variables based on what an index is trying to measure.

As stated earlier the United States Fire Administration has encouraged fire departments to use the CDC’s SVI index through its web portal.⁹⁸ This index is focused specifically on vulnerabilities rather than risk and likely has value for communities. However, this paper suggests that it is only through an analysis of the elements within the index, not the index itself, that will provide the greatest value.

Additionally, NAPSG provides insight into several GIS centered indices that can be used. NAPSG’s focus specifically on GIS public safety also provides a breakdown on different variables that can be considered.⁹⁹ NAPSG looks into both resilience and vulnerability through the lens of demographics, economics, household composition, employment, transportation, community health, community resiliency and the environment.

⁹⁸ USFA Infogram, “Tool for Accessing Data.”

⁹⁹ “Overview Compare | Guidance on Risk, Resilience, and Vulnerability Indices”; National Alliance for Public Safety GIS, “Variables Compare | Guidance on Risk, Resilience, and Vulnerability Indices,” accessed October 8, 2023, <https://experience.arcgis.com/experience/376770c1113943b6b5f6b58ff1c2fb5c/page/Variables-Compare/>.

To be clear, these variables exist to some extent in any index, but they vary in existence or intensity based on the index. A fire agency should be cognizant of what the index is measuring and to what extent. Again, analysis rather than simple overlay is necessary.

Although not used for this paper, I also found other resources from our state's health department that might provide some insight for EMS response. This is all to say that the use of contextualized data is a tool that should be used for analysis, and these indices provide that opportunity. Using publicly available datasets, along with a rubric for analysis as shown, an agency can utilize these resources to provide a more complete assessment of risks within their community and determine appropriate resource allocations based on those risks.

As federal agencies continue to advocate for inclusion of vulnerability data into public safety risk analysis, it will be necessary for local agencies, such as fire departments, to adapt. Ultimately, for most local agencies, the ability to identify specific risk variables of vulnerability (or any other moderate-term element) will be limited simply by the time it will take to research individual variables. However, indexes provide a unified location of these variables. As such, even if the index ranking in and of itself is of little value for this style of analysis, it is still valuable as a way for fire departments to find variables they can consider for analysis.

B. LIMITATIONS

The method has several limitations. The first is the validity of this predictive analysis can only truly be proven by looking at the historical accuracy years from now. Looking at calls for service and see if they do in fact fit into the projected vulnerabilities of the citizens in any given area. This means that only tracking of resiliency will provide the true value of this predictive modeling. This modeling method also is based on the individuals living in a community at a particular time. Community changes, like gentrification, can make the SVI utilized less accurate over time.

Using existing GIS data available to the county, seven census tracts were chosen for comparison based on a random sample to help improve the chances in vulnerabilities

and risks to be evaluated. This GIS mapping provides a “snapshot” singular moment in time based on the data within the commercially available ArcGIS software, developed by Ersi. It should be recognized that various datasets are encompassed within the software and although updates occur regularly, there is a lag in data within the systems.

Another detractor may be perceived as the ability for communities to utilize this level of technology. Two of the three resources (SVI and NRI) are available publicly at no cost, and most communities utilize GIS. This ubiquitous nature of GIS systems and the no cost indices means any fire department will have access to these resources. The Esri Community Analyst is a proprietary system and is considered by many to be the “state-of-the-art” in this arena and may not be readily available for all. Ultimately, the CDC’s SVI model was chosen as the test for the analysis.

Interpretation requires human engagement with the content of indices, not only the numerical output of indices. The research in this thesis sought to determine how a fire department can continue to refine risk analysis to improve how it applies proactive and reactive resources. As suggested in the literature, there is an inherent simplicity in using the numerical values within an index.

It should also be noted that the items within the SVI are, as outlined in the methods section, of moderate temporal consistency; that is, they are not temporary, but they don’t last for as long as some of the other risk measurements. This means that a fire department doesn’t need to check constantly to ensure the height of a building remains the same, but they will need to see if the SVI changes over time. Items like gentrification or economic shifts in society can all impact the SVI for a given area.

C. RECOMMENDATIONS FOR FUTURE RESEARCH

The analysis model and tools created for analysis can apply to most any fire department when they review various indices or metrics. Although not applied to this research, there are other indices that any organization might consider. Fire Departments may also be well served by talking to other agencies and organizations within their community to determine what other indices exist and might be applied. As the use of geospatial information grows, these tools will become even more useful over time.

Ultimately, to determine if the measurements and policies have value, a longitudinal study would need to occur. Only through comparative analysis that shows the impacts of fires on people in the long-term will our industry be able to determine the value of proactive and reactive response. Such a study could look at the long-term success of students who had fires in their home (with and without displacement from the home). Items such as the rate of fires within communities, traced over time with and without interventions, would also add value to understanding if the methods suggested in this thesis hold any long-term policy value.

Finally, the process outlined in this thesis only provides insight into how vulnerabilities within our communities might be incorporated into risk analysis for fire departments. It does not address the vulnerabilities themselves. Research into how the fire service can help, whether to eliminate vulnerabilities or increase resiliency, is an incredibly important public service and worthy of research.

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