The Potential for Artificial Intelligence and Machine Learning Technologies in the Fire Service

Research presented in partial fulfillment

of the requirements for the

Executive Fire Officer Program

by

Steven Chandler Jr

National Fire Academy

April 2024

Abstract

The problem that the following generic qualitative inquiry study examined, is that the fire service has historically been slow to adapt to change and take proactive advantage of technological advancements. Firefighter fatalities and near-miss incidents have been documented despite practices and technology that could prevent such events. This generic qualitative research study incorporated structured interviews with 11 participants. Analysis of the data revealed a lack of knowledge of the participants in the area of artificial intelligence and machine learning but also demonstrated a willingness to embrace these technologies for a variety of uses throughout the industry. Potential uses, obstacles to integration, and ethical issues were identified as themes within the collected data.

Acknowledgments

This research paper represents the culmination of efforts to both understand and learn the research process and produce a document that will add to the collective knowledge of the fire service. I could not have completed this study without the support of the National Fire Academy staff, Columbia Southern University staff, and the Amherst Fire Department Administration. I would like to specifically thank Chief W. Tim Nelson for his support of this effort. Dr. Misti Kill also deserves an enormous thank you for her patience, support, and editorial recommendations throughout this research. Finally, I would like to thank my beautiful wife Emily Chandler, and my boys Ethan, Wyatt, and Ben. All of my professional efforts have a cost of my time and attention that is paid for by you. I could never have completed this endeavor without your love, support, and understanding.

Contents

CHAPTER 1. INTRODUCTION

Background

The fire service has traditionally been very slow to embrace changes in technology and equipment. A virtuous history of honor and tradition is stained by risky strategies invoked under a mantra of "that's the way we always did it." Firefighters themselves often poke fun at this ethos with sayings like "100 years of tradition unimpeded by progress," and "two things firefighters hate, change, and the way things are." However, these tongue-in-cheek maxims shine the spotlight on a long track record of fire service resistance to adapt to an ever-changing environment.

This organizational reluctance to accept change results in issues like the marginalization of new tactics all the way to the complete snubbing of new tools and technology. Despite this resistance, some changes have found acceptance through engineered solutions. Firefighters who refused or forgot to activate personal alert safety systems (PASS devices) now find them integrated with their breathing apparatus. This engineered change requires PASS device use any time a firefighter is "on-air." Vehicle black boxes and audible alarms have pushed the fire service toward acceptance of a culture where seat belt usage is required when the vehicle is in motion. The problem with relying on engineered solutions is that they are not able to be implemented quickly. Capital request items have lifespans of decades, allowing many smaller, or underfunded departments to operate without certain safety benefits until long after they become industry norms. Other tools, like self-contained breathing apparatus (SCBA), accountability systems, and thermal imagers have born witness to the tragedies in Worcester MA 1999 [thermal imagers] and Charleston, SC 2007 [accountability system] where they were available but either not utilized, or underutilized (National Institute for Occupational Safety and Health, 2018;

National Institute for Occupational Safety and Health, 2018b). A full examination of the causes and enabling factors that created the industry's resistance to change is beyond the scope of this paper, but history has demonstrated that the fire service does not typically adopt change quickly. Even in the face of tragedy, resistance can be commonplace.

The International City/County Management Association (ICMA) and Center for Public Safety Excellence (CPSE) produced a white paper in 2020 listing seven critical areas the fire service must focus on to ensure relevance and sustainability in the next thirty years. Although it is important to recognize that technology and robust use of data account for 28.6% of their recommendations, it is arguably more important to realize that the paper itself was created to address two critical themes. These themes are laid out in the co-chair statement, which discusses the fire service's need for immediate action to address current issues, as well as the need to create a culture that can “adapt and respond to rapid changes” (Bruegman & Martel, 2020, p. 3).

Significance of the Study

Artificial Intelligence (AI) and Machine Learning (ML) are cutting-edge technologies that offer immense benefits to a wide variety of societal issues, public safety concerns, and governmental operations. The hope for a brighter future provided by this technology is threatened by concerns over the ethics and legal pitfalls of machine-driven decision-making. In the Harvard School of Engineering’s second report of a 100-year study of artificial intelligence titled “Gathering Strength, Gathering Storms,” the many ways in which AI and ML are enriching lives and improving the world are presented against potential risks and dangers are investigated (Littman, et al., 2022). Some of the key takeaways from the Harvard study included the need for the assurance of ethical usage and creation of artificial intelligence systems before they become commonplace. If the development of the technology is to outpace the social acceptance and regulation of these tools, a great potential exists for negative outcomes. A second point of this publication is the need to utilize AI to aid human decision-making, not replace it. Viewing AI as a partner in decision-making, not a one-size-fits-all answer to problems great and small is necessary to ensure the ethical usage of this technology (Littman, et al., 2022). AI will help to supplement human decisions through the rapid presentation and evaluation of data, but it will not replace the human element of recognizing the more subtle effects of that decision (Littman, et al., 2022).

Up until now, the vast majority of AI and ML utilized in the fire service have been applied in the domain of fire prevention engineering. The ability of AI and ML to identify the interaction of multiple variables, not require destructive testing, and create large databases that can be applied to real-life observations; made it a near-perfect method for helping to design building egresses. Additionally, it has been able to identify the elements of egress pathways that most affect the safe evacuation of a structure (Zhou, et al., 2023). Studies regarding heat transfer through building elements (Bakas & Kontolean, 2023), smart detection of fire sources in tunnels (Wu, et al., 2021), and the grouping of AI and ML types in fire engineering and sciences (Naser, 2021) are just some of the examples of the existing usage of this technology to help decrease the incidence of fire injury and death. Although the goal of no fire risk is admirable, it is also unrealistic. The shortfall of these studies is that they all involve prevention, but do not address any of the safety issues associated with response and extinguishment of fires in the modern fire service.

The National Institute of Standards and Technology (NIST) is currently developing AI-powered tools to help in the arena of fire suppression. The first iteration “P-flash” was a predictive model for flashover within a known space (Todd, 2021). The newest model “Flashnet” has expanded that predictive ability to structures of unknown size and layout with a 92.1% accuracy (Tam, et al., 2022). The Portland Oregon fire department has begun a program to utilize AI to help decrease 911 call volume by identifying and deferring non-emergent calls outside of the 911 system. These two applications of AI and MI represent the start of a shift toward the utilization of this technology within the response realm of the fire service. The following capstone paper will help to identify and make recommendations toward ways that some of the “next steps,” many of which are noted in the previously referenced studies. Bringing AI and ML into fire service response efforts will help improve firefighter and civilian safety while also demonstrating the ability of the fire service to be a responsive profession that can adapt to a changing environment.

Problem Statement

The problem that the following generic qualitative inquiry study examined, is that the fire service has historically been slow to adapt to change and take proactive advantage of technological advancements. Artificial intelligence and machine learning are here now and rapidly changing the world we live in. The resistance and slow adoption of technology causes unnecessary risk to firefighters and the civilians whom they protect because opportunities to incorporate the latest data and fastest processes are overlooked in favor of anecdotal evidence which may be limited by personal experience and incomplete evaluation. The reluctance of those working in fire to adopt new technology is not a new concept. Popular fire-related magazines, such as FireRescue1 and Fire Engineering have both printed articles focusing on this point (Finazzo, 2017; DeVane, 2017). Additionally, a general societal reluctance to technology use and a resistance to change holistically has also been the focus of academic research (Sinkovics, Stottinger, Schlegelmilch, & Sundaresan, 2002; Warrick, 2023). Moving forward in the field, a best practice may be that decision-making is based less on anecdotal evidence and replaced by properly vetted scientific data and testing. This type of paradigm shift has already occurred in related fields like emergency medical services (EMS) which has demonstrated success with a research-based approach to change, and for the fire service, better understanding and embracing artificial intelligence and machine learning to enhance the efficiency of service delivery could be an essential progressive step.

Purpose Statement

The purpose of the following research was to expand the status of artificial intelligence and machine learning usage in the response side of the fire service. As noted previously, the existing literature indicated that a general resistance to change is not uncommon throughout society (Warrick, 2023). Fire industry executives and individuals involved in research and development were interviewed to gather a qualitative data set that could help identify the factors listed above. Department leaders of various sizes, and from career and volunteer/paid on-call departments were targeted for data collection. Leaders of departments that had AI-based programs and those that had considered but failed to initiate AI-based programs were also sought. Data collection was focused specifically on technology related to AI and ML. Caution was taken to maintain focus on the areas listed above and prevent drifting into the larger issue of the factors that lead to the organizational culture that prevents mobility and integration of new concepts as this issue is beyond the scope of the research.

Research Questions

The following research attempted to answer the following questions.

1. In what way may the implementation of AI/MI technology offer a safer future for the fire service?
2. What obstacles currently exist, and what future obstacles may arise that prevent the integration of AI/ML technology within the fire service?
3. What actions can fire service executives take to enable their departments, and the fire service as a whole to begin integrating AI/ML technology?

Summary

Chapter 1 provided a foundational background outlining the reluctance that has historically been experienced in the fire service to adapt to change. Chapter 1 also highlighted the importance of the need to better understand and utilize AI/ML to advance the field. Moving forward, in Chapter 2, the paper will include a review of the existing peer-reviewed literature on this issue. A brief description of the basic types of machine learning that currently exist will be provided to help the reader better understand the potential benefits and limitations of the usage of AI/ML in its current form. This will be followed in Chapter 3 by providing the specific methodology utilized for research, in addition to an overview of the data collection methods. Finally, the results will be provided in Chapter 4, followed by an analysis of the data, recommendations for immediate actions, and potential future areas of study in Chapter 5.

CHAPTER 2: LITERATURE REVIEW

Introduction

To evaluate the ability of a large organization such as the fire service, in an attempt to embrace new technology, would require that the technology is well-defined, has the current usage assessed, and has the potential impacts holistically evaluated. As a result, reviewing the literature surrounding the topic of AI usage in the fire service identified areas of usage in prevention, and dispatching where this technology has been introduced and embraced; however, when shifting focus to the response side of the fire service a much less forward-thinking view was revealed. Although there are some examples of AI systems being used to identify wildfires from sensors that are monitoring large areas, there is little to no research or implementation of AI/ML at the tactical level.

Existing Literature

Definitions of AI and ML

A full investigation of artificial intelligence and machine learning was well outside the scope of this research; however, a basic understanding of the types of AI and ML platforms that exist was necessary to evaluate the potential benefit to the fire service. Bakas and Kontoleon (2023) defined AI as "the ability of computers to emulate the cognitive process." The authors took the generally held position that machine learning is a subset of artificial intelligence, which was also supported by Mauri and Damiani (2022), who noted that ML is currently the most well-developed subfield of AI, which aids in enhanced decision-making processes. ML is divided into unsupervised, semi-supervised, supervised, and reinforced learning (Bakas & Kontoleon, 2023).

Naser (2021) defined AI as the ability of a system to demonstrate human behaviors (reasoning, problem-solving, planning, etc.) and ML as the ability of a machine or system to make predictions without explicit programming. This interpretation still views ML as a statistical processing system that is a lesser form of full AI. Naser (2021) continued the research and divided ML into three categories as opposed to four. His breakdown of supervised, unsupervised, and semi-supervised learning, all of which represent statistical evaluation techniques, utilize the results of their calculations to create data sets that then guide outcomes. Each form of ML has different benefits and requirements based on the available data and the desired form of outcome data (Naser, 2021). Semi-supervised learning, like artificial neural networks and convolutional neural networks, allows large amounts of input data to be reduced to small numbers of outputs that then "reward" the system for following previously designed algorithms (Naser, 2021). Ultimately Naser's three ML forms can be summarized in the following way: supervised learning is utilized to map existing data and look for patterns; unsupervised learning takes data and looks for underlying structure; and semi-supervised learning takes large amounts of inputs with limited outputs and predicts future possibilities all while searching for patterns and underlying structure (Naser, 2021).

It is also important to recognize the distinction of ML as a subset of AI as Bakas and Kontoleon (2023) noted. The existing research is full of technological examples of the execution of ML tactics without achieving full AI systems. Machine learning that identifies patterns and helps organizational decision-makers implement more efficient solutions falls short of the lofty goal set for artificial intelligence. AI systems that learn and evolve to the potential imagined in studies like gathering strength and gathering storms do not yet appear to be available; however, according to environmental management literature, such as that conducted by Haq et al (2022) and Kaginalkar, Kumar, Gargava, & Niyogi (2021), technology, such as AI and ML, have improved the assessment of environmental factor analysis. This limitation in the current execution of AI is likely to prove to be the limiting factor in the current ability of the fire service to identify and embrace this technology at this stage (Littman, et al, 2022).

Adoption of AI and ML

Bakas and Kontoleon (2023) accomplished two distinct results in their 2023 meta-narrative review of AI applications. In addition to identifying a use for AI to create an organizational study that attempted to organize and summarize existing AI research to create a starting point for future research on AI in the fire engineering field, the authors looked specifically at heat transfer in building elements (Bakas & Kontoleon, 2023). Although they were successful in meeting some of the recommendations set forth by Littman, et al. (2022) in their attempt to integrate existing AI ability into future planning, they failed to further examine and take advantage of AI's ability to self-learn and self-motivate. This narrow focus has the unintended effect of making much of the data and findings applicable only in the narrow field of engineering and building construction. Expanding their research to broader areas of the fire service is difficult, if not impossible. Many of the studies discussed in this review of literature feature a similar narrow focus (Wu, et al, 2021, Zhou, et al, 2023, Tam, et al, 2022). The studies attempted to incorporate aspects of AI and ML into existing technology but were unable to expand their focus into autonomous processes. This is likely due to the lack of fully AI-capable systems as identified by Littman, et al. (2023). Naser (2021) also concluded that ML and AI have existing validated algorithms that present a starting point for those interested in expanding the fire engineering sciences.

Current Usage

Prevention and Engineering

Naser (2021) explored how these new processes (AI/ML) could be used not only to evaluate new data (uncovering new patterns) but also to reevaluate old data for previously unseen information. MI can be used to “recycle and maximize findings of past fire tests” (Naser, 2021, p.2743). The ability of MI to accomplish this without the need for destructive testing has made it an ideal tool for evaluating old data a second time, as well as compiling old data from multiple resources to learn new things that can be integrated into new technologies. This process was used by Khan, et al. (2023) as they evaluated the interstitial space of buildings as a space for fire involvement to go undetected. Using the results of previous studies on fire spread and flashover progression the authors were able to create a large database of information revealing the relationship between room size, heat release rates (HRR), contents, and time to flashover. This data then was utilized to make recommendations on how to use and space detectors, and sprinkler heads in these interstitial areas, as well as how to use the internet of things (IoT) to supplement detector activation to reduce time to water on fire through sprinkler application (Khan, et al., 2023).

Zhou, et al. (2023), and Tam, et al. (2022), used ML to run simulations in an attempt to identify the optimal conditions for high-rise evacuation based on building design, and for flashover prediction based on floorplan layout. Up until the Tam, et al. and Zhou, et al. research was conducted, these topics had been restricted by a lack of applicable analytical data. Although Zhou, et al, identified many studies on the evacuation process, they were unable to identify data accounting for the effect of building design on egress effectiveness. Both authors were able to utilize ML to run simulations and observe the effects of changes in building design on egress effectiveness, and time to flashover. Zhou, et al. (2023) identified that obtaining this data without destructive testing would not have been possible prior to the availability of ML algorithms.

Another use of ML for the fire service was completed by Wu, et al. (2020) and represents one of the few utilizations of this technology with direct application to the response side. The authors studied fire events in tunnels and looked to find a way to send appropriate resources faster and with a better understanding of the fire size based on AI sensor evaluation of data collected in the tunnel. Using algorithmic evaluation of video data and three metrics (fire location, heat release rate, and outlet ventilation velocity) the authors were able to demonstrate the necessary sensor for real-world functionality of a smart tunnel system. This system would produce valuable intelligence for responding fire apparatus regarding the type of materials burning, and the size and spread of fire conditions within the tunnel (Wu, et al., 2020).

Dispatch

Dispatch is a demonstrably “response” side metric within this review of the emergency response continuum. The dispatch of apparatus is the first link in the fire service response to any type of incident. Effective and accurate information can help responders make well-informed, quality decisions, or can start the responding units down a path that allows the emergency to grow unchecked. Information provided to officers by law enforcement dispatchers has been found to play a significant role in decisions made by responders on the scene of incidents and changes in dispatching terms can lead to a reduction in certain types of arrests (Lum, et al., 2020). A successful program in Denmark demonstrated how an AI system of automatic speech recognition (ASR) software was able to increase prehospital stroke recognition, especially in female and younger patients (Scholz, et al., 2022). A similar study by Blomberg, et al., (2021) was able to alert dispatchers in suspected cases of cardiac arrest more effectively than dispatchers alone. Although neither of these studies resulted in improved patient outcomes (they were both retrospective studies where a machine learning algorithm was utilized) they both represent more effective recognition of critical incidents (stroke and cardiac arrest) which has the potential to increase first arriving responder's effectiveness. The Peng et al., (2023), research also supported the findings and further demonstrated how early detection of hemorrhage in trauma care can increase treatment and survivability.

Synthesis of the Existing Literature

Machine learning as a subset of full artificial intelligence based systems is becoming more and more common in many aspects of fire and emergency services. As a means to evaluate past and current data ML provides a unique ability to build data sets by running simulations that would previously have required large quantities of destructive testing. Additionally, much of this information is impossible to gather in real-life events as it is not possible to put live subjects into the types of environments these algorithms are attempting to evaluate; however, as technology continues to progress, Todd (2021) noted that organizations like the National Institute of Standards and Testing (NIST) can continue to utilize “big data” to simulate fire conditions and create tools and tactics that will be more effective for use by firefighters.

Reviewing the existing literature demonstrated that early recognition and awareness of critical call events helps to put responders on a more effective path to mitigating an emergency (Scholz, et al., 2022, Blomberg, et al., 2021). Additionally, the research depicted that AI/ML has demonstrated an ability to aid in the early detection task and dispatchers effectively and efficiently to the potential for these critical events (Lum, et al, 2020).

The largest gap in the AI/ML research exists on the tactical side of the emergency response continuum. Although retrospective data analysis has led to alerting systems for dispatchers and better-engineered buildings and fire detection systems, there is little to no research regarding AI/ML-based systems that can be utilized by fire response units for on-scene decision-making.

Summary

Review of the literature available on the topic of AI and ML usage in the fire service has identified a large gap on the response side of the fire service industry. The areas of fire prevention and engineering, as well as dispatch seem to be embracing the benefits of machine learning for both data analysis and design efficiency. Programs that aid in strategy and tactics on the fireground do not appear in the research and reinforce the belief of an organizational culture that is unable to embrace the types of changes necessary to help the fire service adapt to a changing world. The all-hazards expectations of the public require a fire service that can capitalize on technology and big data to provide efficient and effective service across a wide range of disciplines. The fire service should be demanding to see more opportunities to incorporate AI/ML tools into strategic and tactical decision making.

CHAPTER 3: METHODOLOGY

Introduction

Chapter 3 will lay out the methodology of this research. First, the research design will be defined and explained. The participant population will then be defined, and the instrument utilized for data collection presented. Next, the research process will be reviewed, and ethical considerations will be stated and addressed. This chapter will close with a review of the process thus far.

Research Design

The study was designed using a generic qualitative inquiry approach. A qualitative approach was chosen as the methodology because the goal of the research was to understand how decision-makers within the fire field have made the decision to use or not use AI/ML technology. Quantitative and mixed-method approaches were not utilized for the research as the intent was to understand the AI/ML usage and/or opinions, perceptions, and lived experiences of those in decision-making roles. A quantitative study of how many departments had considered an AI product, or how many organizations utilize AI/ML technology at some level, would inform the researcher of how far this technology has currently expanded, but this type of data collection does not provide insight into the obstacles that must be overcome for the technology to take on a larger role in the response side of the fire service.

A generic qualitative inquiry was chosen as the best path to understanding the obstacles to, and potential of, AI/ML usage as the lived experiences, opinions, and perceptions of participants are best analyzed through this type of analysis. Percy (2015), and Kostere and Kostere (2022), described the ability of generic qualitative inquiry to evaluate the content of issues and the feelings associated with experiences. Percy et al (2015) differentiated this general inquiry from other types of qualitative research. Case studies dive into the specific details of an event or incident. Phenomenology investigates how attitudes and opinions occur around an incident or experience. Ethnography describes how individuals' feelings and beliefs help to define their culture (Percy, et al, 2015). The closest alternative to the generic qualitative inquiry would have been a qualitative grounded theory or phenomenological approach. Grounded theory would allow data collected to develop a theory of the decision-making process over time; however, the following study could not extend the time frame to gather this type of data. Taking all the considerations into account, a generic qualitative inquiry was the approach that achieved the stated goals. The generic qualitative inquiry is flexible enough to capitalize on the benefits of many of the previously mentioned forms of qualitative research without being tied to restrictions and time requirements inherent in their specificity.

Population and Sample Size

The population of the following study was restricted to chief-level officers who had operational decision-making capacity. Initially, it was thought that executive chief-level candidates would be the best candidates from which to gather data. As the methodology of the research came into focus, it became clear that in larger organizations the fire chief may have less to do with operational decision-making and the tasks may fall to the assistant, battalion, or deputy chief-level officers. Firefighters, lieutenants, and captains, although often essential in helping direct operational purchases and changes in strategy and tactics, were not included in the study due to their limited or complete inability to make budgetary planning decisions.

The goal of the study was to collect data across the fire service, for this reason, it was important to gather data from paid on-call/volunteer, and career force departments of all sizes. A minimum sample size of 10 interviews was desired (Kostere & Kostere, 2022). Two categories of department (Paid On-call/Volunteer and Career) and five categories of size (10 members or less, 11 to 49 members, 50 to 99 members, 100 to 149 members, and 150+ members) were sought for participation. The following study attempted to identify at least one department of each type, within each size department type category. Departments meeting each of the ten category possibilities were identified and contacted seeking participation from chief officers with operational decision-making abilities.

The pragmatic worldview guided the candidate selection process in this study; Creswell (2018, p.10) describes pragmatism as having "freedom of choice," meaning the researcher is not locked into a single system of philosophy but rather investigates the world as it is practically. Identifying potential candidates specifically required the researcher to abandon the concept of utilizing only the executive chief officer of each department as the real-world duties of this position are often more political and administratively oriented than operational. The result is that the following study included participants from all chief levels. Eleven participants were identified with participants from two departments in the paid on-call/volunteer, 11-49 member category.

Instrument(s)

The interview questions listed below represent the data collection instrument utilized for the research. Questions were developed with a focus on the problem and purpose statements of the study.

Interview Questions

1. Please introduce yourself. Describe your position, department, and experience.
    - Facilitators
        - How many years in position
        - Responsibilities of current role
        - Size of population your department serves.
        - Call volume per year
        - EMS as well or Fire/Rescue alone
        - Call, Volunteer, or Combination
2. Please describe your level of understanding/familiarity with artificial intelligence and machine learning
3. What is your opinion about the potential for Artificial Intelligence/Machine Learning in the fire service?
    - Facilitators
        - Does your department/community do any data analysis for planning or operational decision-making?
        - Does your department (or the larger municipal government you work for) utilize AI/ML technology for any part of your operations?
        - Does your community or organization have a policy on AI/ML technology?
4. What, if any, are the challenges or issues with bringing AI/ML technology into the fire service?
    - Do you believe there are ethical concerns (if so, please explain)?

- Do these concerns extend throughout municipal government, or do we have specific concerns in emergency services (if they exist, please explain why you feel this way)?

5. Are you aware of any AI/ML-based tools currently marketed to the fire service, if so can you discuss/describe them?
    - If yes, which ones did you consider? Please describe what the product does and how you believe it would aid your department.
    - If yes, did your department consider using this product, why or why not?
6. What concerns do you see with the integration of AI/ML into the fire service?
7. If an AI/ML product existed that addressed a need in your organization, would you consider utilizing it, please explain why or why not?
    - Examples: Technology that could alert you to the type of materials on site and make resource allocation recommendations, or drone technology that could position itself to evaluate survivable areas of a burning structure.
    - What concerns would you have with this type of technology?
    - Other than cost, what factors would affect your decision to utilize such technology?
8. What role does education and training have in the integration of technology (specifically AI/ML) in the fire service?
9. How much does public perception influence your capital spending and budgeting?
    - Do you measure public perception (surveys, online feedback, etc) or do you infer public opinion through public comments/word of mouth?
    - If you felt the public had concerns about this technology, do you think those concerns can be addressed? Should they need to be addressed?

10. Currently there are examples of technology using artificial intelligence that monitors for smoke from wildfires, there is AI software that helps divert 911 calls of a non-emergent nature, and extensive usage of AI/ML in building design and egress access. What do you think is an area of the fire service that could benefit from AI/ML technology?
11. Do you have any additional comments or information about this topic that you would like to share?

The 11 questions are listed and designed to stand on their own, however; the “facilitators” were placed by the questions to help begin a discussion or offer a uniform and unbiased train of thought if the participant was struggling to answer a question. In order to ensure the trustworthiness of the interview questions as a research instrument, it was reviewed by three separate individuals in the field of fire and emergency services. The first individual holds a doctoral degree in public administration and policy. This individual also has experience as an executive chief of a large urban department, and a senior director of research and policy at a large fire chief’s association. The other individuals who were able to “field test” the instrument are industry professionals at the executive chief and battalion chief level from medium and small departments on the east coast. Their feedback was reviewed and incorporated into the interview instrument before the collection of any data.

Research Process

The rank of participants in this research was such that they were able to give permission themselves for participation by their department in this study. Chief officer permission would have been necessary had the participants been of lower rank; however, all participants included in the study held chief ranks. The researcher contacted potential participants who met the research inclusion criteria via email or phone. Inclusion criteria included being a chief-level officer with at least one year in the current position. This ensured that all participants had been through a minimum of one complete fiscal cycle. Candidates who desired to become study participants signed an informed consent (Appendix A) which provided the contact information of the researcher, an overview of the research topic, design, and intent, and stated that participant identities, and any identifiable information provided, would be kept strictly confidential. The informed consent additionally stated that all opinions and statements that could potentially be linked back to an individual participant would be presented in a way that protected the identity of the individual.

After acquiring consent, the participants were scheduled for a virtual interview at a day and time convenient for them. The participants were advised to choose a time when they could speak freely and privately without fear that their opinions may be overheard by coworkers or subordinates. Virtual appointments were set for forty-five (45) minutes to ensure sufficient time to answer the interview questions completely and explore any tangential subjects that the participants brought to the data collection process. The virtual interviews were recorded and transcribed to allow for a complete evaluation of the data collected. The virtual format was chosen due to the cost restrictions of finding interview participants from the varied size and type departments noted above. Travel across the country was not feasible and consistency required that the interviews be conducted uniformly. A virtual format allowed the participants the comfort of a secure environment to complete the interview without requiring the researcher to travel to their location.

Upon completion of the recorded interview session, the recordings were transcribed and shared with the participant for member checking to ensure the accuracy of the transcription.

Once participants indicated that the intent of their comments was reflected in the transcripts, data analysis occurred. Transcripts were reviewed thoroughly and coded to allow for thematic identification. Themes were then analyzed and presented in the manuscript (Kostere & Kostere, 2022).

Ethical Considerations

Ethical considerations and concerns of bias and transparency were paramount throughout all phases of this qualitative research inquiry. The researcher has no known financial or personal investment in any kind of technology or product that has been discussed in the paper. Field testing of the data collection instrument helped to eliminate any potential bias in the format of the questions, or the way the interview was conducted. The researcher also did not stand to gain from fire service investment in any particular technology or product. Additionally, all efforts were made to conceal any personal identifying information provided by the study participants including opinions or statements of departmental processes and procedures that could be traced back to an individual chief officer. Informed consent agreements were signed by all study participants and a clear explanation of the goals of this research was presented to every interview candidate prior to participating in the interview process. Finally, coercion of participants did not occur in this research, as the researcher had no authority over any of the participants and no gain was promised to participants, beyond the shared knowledge of the research findings. All data related to the research is stored in a locked cabinet and will be destroyed after one-years' time.

Summary

The generic qualitative inquiry study utilized an interview-style data collection instrument obtained via a virtual meeting platform. Data was collected from ten categories of fire departments based on size and employee type as listed above with 11 total participants. The interview tool was validated and field-tested by professionals within the fire service field. Sessions were recorded and confirmed with the participants to ensure the accuracy of their intent. Ethical issues were considered and addressed with privacy of participant response information becoming the largest area of attention. Data was reviewed and coded for thematic identification to allow those themes to be presented on the following pages.

CHAPTER 4: STUDY RESULTS

Chapter 4 will present the results of the generic qualitative inquiry study. First, a discussion of the participants' demographics will refresh the reader on who participated in the interviews. A description of the size and make-up of the participant's department is also provided. Finally, a summary of the results will lead the reader to Chapter 5, where the results will be interpreted for deeper meaning.

Introduction – Demographics of the Participants

The study involved 11 chief-level officers from departments of varying sizes and employment types. Although all participants possessed the rank of "chief" in some variation, four held the rank of chief as the executive head of the department. Three of the participants held the rank of assistant chief, and one each held the deputy chief, division chief, and battalion chief ranks. The departments were broken up by size and labor type. Five of the departments represented were career departments, and six were paid-on-call or fully volunteer. Additionally, one career and one paid-on-call/volunteer participant were interviewed from each of the five department sizes. The sizes were broken up as follows. 10 members or less, 11-49 members, 50 – 99 members, 100-149 members, and 150 + members. The participant breakdown is represented below in Table 1.

Table 1

Participant Identification

Number of Members	Career		Paid On Call/Volunteer	
	Participant	# Members	Participant	# Members
10 or less	A	9	B	8

11 - 49	C	47	D1/D2	12/24
50 - 99	E	92	F	60
100 - 149	G	117	H	110
150 +	I	450	J	190

A second department in the paid-on-call/volunteer group of 11-49 members was available and because a determination was made that an additional interview could aid in the confidence of the data saturation without skewing the results, the interview was conducted. The goal of the dispersion of participants across the range of department types and sizes was to ensure that a full sampling of the fire service was conducted. Additionally, as no direct correlations were being drawn between department size or make-up and responses, the additional data from the extra interview was determined to have no negative or weighted impact on the findings. The two participants in this category have been distinguished by adding a 1 and 2 after the aligning participant letters. The participants were made up of eight males (A, B, C, D1, E, F, G, H) and three females (D2, I, J) with between 16- and 34- years in the fire service and a minimum of 1-year in their current rank.

Research Results

After the interviews were completed, the transcripts were created by the Zoom software and then edited for accuracy. The transcripts were sent to the participants for their review for accuracy as well. Upon confirmation of transcript accuracy, coding was then completed using QDA Miner Lite software and the responses were reviewed and coded resulting in the following themes related to the original three research questions. The themes presented below were identified as a result of the interviews and will be analyzed further in Chapter 5 to examine how the themes addressed the overarching research questions.

Theme 1: Lack of Knowledge/Familiarity with AI/ML

The first theme that was universal to all participants and repeated itself throughout other areas of the data collection process was the lack of perceived knowledge of the topic of AI/ML by all interviewees. Participants almost unanimously listed their current knowledge of AI/ML as none or very little, although many then contradicted themselves by later discussing areas of their lives where they interact with AI features on popular search engines or social media platforms. After describing an understanding of AI/ML as “rudimentary at best” Participant C later stated,

> I was looking for stuff on gear and their effects for a grant. Basically, how do I find some more information that I want for this grant? How do I formulate that? It was an interesting way to try and use it (AI/ML) for me, a little bit of help from the search engines’ format.

Participant J described their understanding as “just dabbling in it now,” this was the most advanced description of understanding that any of the participants used for themselves. Interviewees also brought their lack of knowledge forward when asked other questions relating to their opinions on integrating AI/ML. Participant D2 was asked about their opinion on the potential for AI in the fire service and stated, “I don't know a whole lot about it, I guess that question is kind of hard to answer.”

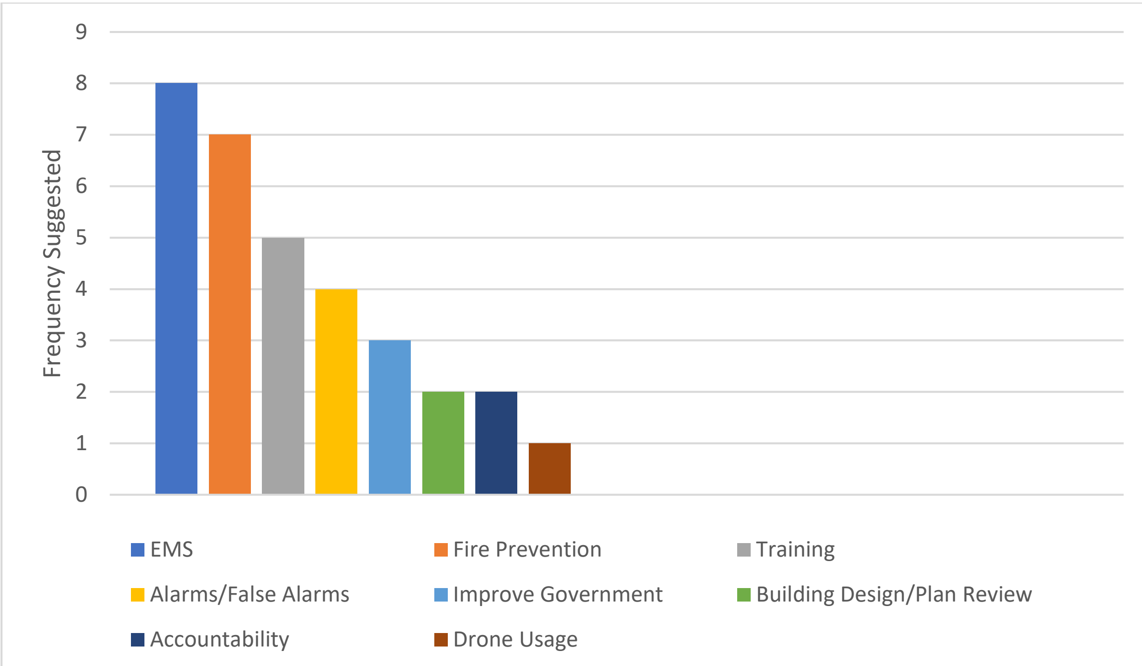
Another area where this “lack of knowledge of AI/ML presented itself was in the response to the question regarding current products marketed to the fire service utilizing AI/ML. 6 of the 11 respondents stated that they were unaware of any products currently marketed to the fire service that utilize AI or ML technology. Participant G stated “I remember that there is a company teaching at our seminar in April and I can find the name if I look, but I don't recall it, so no, I do not know of any. If I were to tell you something I would be lying." Even those who believed they knew of products were unsure of how or if it was integrated into their existing technology. Participant H stated, "we have a drone program, and it is kind of an antiquated airframe, but you know as that technology has improved, maybe some AI is coming into play with drone operations." Participant F shared a similar statement "I understand that the hot mapping is kind of an AI component but yeah, we haven't really thought about or dealt with it." Finally, participant B stated "I've seen some of the robots that the state fire marshal's office or the state police have access to. While they are not artificial intelligence, I guess they are machinery that is capable of accessing AI."

Theme 2: Potential Uses of AI/ML

All participants (11 of 11) noted some level of value/usage for AI/ML. Looking into the way that implementation of AI/ML technology may create a safer future for the fire service resulted in an exploration of the participant's view of the potential areas where this technology can be applied. The results are displayed in Figure 2. EMS and Fire Prevention were listed most frequently as potential uses for this technology with both topics appearing in five of the 11 interviews. The remaining potential uses were training, aiding fire alarms/addressing false alarms, improving government, building design/plan review, fireground accountability, and finally drone programs (Figure 1). Subthemes with four or more participants supporting/noting the item are provided in more detail below.

Figure 1

Suggested Uses of AI/ML in the Fire Service



EMS Data

AI/ML usage for EMS data was noted most frequently by the participants (8 of 11). Participant A stated, “AI could benefit us a little bit more, actually working in the field on the EMS side” while Participant I stated, “when it comes to healthcare, for sure, what an AI interface could potentially due for drug dosages and pumps.” Participant C took the example a step further stating,

> You got Sgarbossa’s criteria or some other thing that pops up, that we weren't so good at, or when it turns itself on the middle of a call because something happened, it could catch something valuable. It has this criterion; the check boxes are checked off. AI is just a faster version of this.

Fire Prevention Data

Participants also noted the potential for AI/ML usage in fire prevention data (7 of 11). Participant G referred to AI's potential for fire prevention by saying "I can see one day fire inspections being a virtual thing. Now the fire inspector has to drive 10 min or longer to a building to walk around it. I can imagine that there is a headset or something in the future that we will be able to wear." Participants A, F, and D2 all mentioned pre-planning with Participant A stating, "I like the fact that it could assist with pre-plans, that's one of the areas for me, in my department, where I don't have the time to go out and check all those buildings." Participant F stated,

> When we're looking at fire prevention, there's something we could do there with some of our more heavily populated structures, like our Walmart's, or our hotels. Our high occupancy fire areas where we could use AI to model what people potentially will do in that situation in a fire, or an active shooter situation. We could use this to try to pre-plan for some of that stuff. I think AI could really help with that.

Training Data

Training was another area that respondents believed could be improved by AI/ML at 16.1% of the suggested uses while addressing alarms/false alarms completed the last of the top four suggestions at 12.9%. Participant H stated, "it can correlate into some of our training for engineers and pump operators dealing with calculations, and friction loss." While Participant I stated,

> It can definitely be used as a tool when it comes down to training. Historically we have done that with simulations during a captains test, or promotional exam. The

ability of a simulation to take out the potential for injury and allow that scenario to go any way you want it to is exciting.

Many of the suggestions for training included the term "virtual reality" (or VR) with three out of the five suggestions for training including this term associated with some type of scenario.

Alarms/False Alarms Data

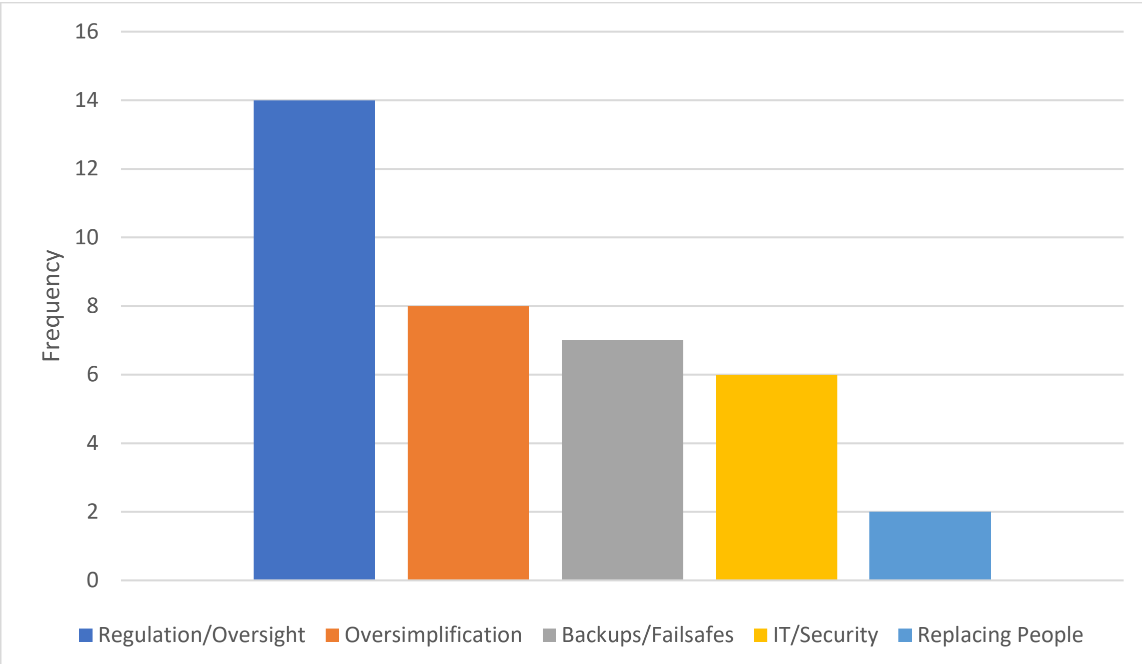
Addressing the alarms/false alarms was listed more frequently with the fire prevention suggestion listed above. Participants C, D2, G, and J all referenced the potential of AI/ML to be effective in this arena. Participant G discussed the ability of AI to support the interaction of alarms and other systems stating, "remote monitoring of fire alarms, sprinklers, and other devices and if you could put sensors that automatically transmit the signal of the temperature is high, low, then maybe AI would be interpreting that and saying whether it was good or bad." Participant C agreed stating "if AI could figure out whether this is cooking smoke versus an actual fire that would be of great value right? Could it tell us if this is cooking smoke, dust, or from the vacuum or shower steam, or identify an issue with the electrical system, a ground fault, or even a mechanical short." Participant D2 added "Those would be huge, cause, you know a number of calls every year are just burn the popcorn. Oh, yeah, we do so many false alarms."

Theme 3: Obstacles

All participants (11 of 11) noted some level of obstacles with using/implementing AI/ML technology in the fire service. Evaluating the obstacles to the integration of AI/ML led to several different themes. The issues that appeared most consistently were regulation/oversight, the need for backups/failsafes, oversimplification (dumbing down), and finally IT/security issues. Although the issue of "lack of knowledge" was not asked directly, the explanation for this theme is described in detail below. Figure 2 shows the frequency of occurrence of these issues as they were identified in the data.

Figure 2

Obstacles to AI/ML Integration in the Fire Service



The data listed above represents the number of times an issue was identified during the 11 interviews, accordingly; an item may have been identified more than once per interview resulting in a total of more than 11.

Regulation and Oversight Data

Regulation and oversight was found in 54.5% of the interviews (6 out of 11) and was mentioned the most of any obstacle with 14 separate comments. The issue of regulation and oversight was made up of two sections. Oversight of the system and its operation, and the issue of how it is created and utilized. The idea of "garbage in/garbage out" or good data in, good data out was a significant concern to the participants. Participant D1 stated "The biggest concern for me would be well vetted inputs. I am most concerned with vetting the information used to create the technologies." This sentiment was echoed similarly by Participant G who stated "So if we have an understanding of where they are getting that data from, how are they using it, properly or improperly?" Participant G also commented "So if we upload wrong data or out-of-date data or something that is just blatantly wrong. The computer is only going to spit out what it knows right? Not knowing if it is right or wrong, but what it's been taught is what it will spit out."

The second piece of the oversight obstacle was surrounding the regulation of the usage of this type of technology. Participant C, "Control right? Ultimately, like how wide, how big, how specific, learning how best to use it. We haven't even thought about crossing that." This desire to set boundaries on the usage was stated by Participant F who stated "It's a tool, I think, and as long as we have that oversight and control of the tool, it can be a good thing."

Oversimplification (Dumbing Down) Data

The issue of fear of oversimplification of job tasks, or "dumbing down" of the skills needed by line employees was mentioned in four separate interviews a total of eight times. Participant B states,

> Taking common sense out of what it is to be a firefighter paramedic is the concern. If we start having, you know, this artificial intelligence kind of saying, this patient needs XY, and Z to our individuals, who went to school. I think it can be utilized as a tool if that's the direction that you know healthcare goes. But I don't think it needs to be the end all be all.

Participant G echoed this concept discussing concerns about AI/ML by stating,

> Maybe just being too reliant on the answer, it spits out and not thinking for ourselves. You know, a lot of split decisions have to be made in the fire service a lot. We can take time, weeks, or months to plan out which I think is a great

> application for an AI to help cross-check what we've already done or where we're going. But I feel like some of the newer generation may rely too much on it. So when it comes time for that split decision, they maybe can't. They don't have that experience of oh, I have to process and think for myself. I'm used to just telling this computer. And it tells me the answer, whether it's right or wrong, it gives me some guidance. So if I you know, if I just stop making decisions cause I don't have this tool. Where am I going to be? What am I going to do? I think that could be a concern or detriment to our thought process in our industry.

Participant C also stated "I think the ability to use a voice-activated report writing format would be great. But I don't need, I don't think I would want to know that that's how you wrote the whole narrative. I want to know what you thought about your call. not how the computer thinks about the call." This individual added later "I don't want to see a dumb down of certification levels."

Backups and Failsafe's Data

Concerns about AI and ML's need for backups and failsafes were identified 7 total times in 4 of the 11 interviews. Participants B, E, G, and I brought this issue forward. Participant I discussed the severity of a flaw or issue stating, "I would not want that to be the end, all be all. I think that technology is a great tool. but it is not the Almighty and many times we can see that there is a glitch in the system, and I would not want to bargain a glitch in the system with someone's life."

Participant G discussed the issue of backups in two separate areas of the interview. First stating "I mean, I can see the benefit, right? Until you get burned on that one time, and it's like, Wow!

You sent this one instead of this one. And now the house burned down, or somebody died," the concern about not having a backup presented itself again as they stated,

> Let's slowly introduce it. We're gonna do one plan a month, or one plan a week, or something, but not everything. So we need to ensure that our infrastructure, our technology software, and hardware can have that. You know, we flip a switch. We get rid of all of our paper. And then the system crashes. And now we have no paper backup. We have no AI system. How do we do things?

Participant B attempted to put this issue in terms of the fire service vernacular stating,

> You know, we are failure-adverse. If the device were to fail and not do it, stop right, we say in the fire service. We don't fail. We don't say we can't. We always get it done, you know, artificial intelligence or machines could fail. Batteries could die. Things could short out, you know, so obviously that not acceptable.

IT/Security Data

Another obstacle that was brought forward by multiple participants was the issue of internet technology (IT) security and protecting the private data that would exist within this type of system. Although this issue was only brought up in three of the 11 interviews, it still generated six separate comments from different areas of the data collection instrument. Participant H discussed the issue as a problem from the outset of integration of AI/ML stating, "probably, more importantly, at least on our IT side of things that they contract out for would be cyber security. Maybe having some of that involved with the onboarding process of the AI, and maybe a slow approach to it." This participant followed that statement later in the interview by saying "when it comes to using AI or machine learning that can teach itself, we want to make sure that everything is protected, all the information. You know that nothing gets leaked out because that just creates a public distrust." Another participant acknowledged that while security is necessary there is a fine line between secure and ineffective, and it is difficult to tell where that line is. Participant I recounted the following story,

> I have my EMS chief. He had to send me an email for me to forward it to our IT specialist to remove (they call it the white flag) anything that's labeled Viagra. So I see that some of these layers of security measures are absolutely needed, you know because anyone can kind of infiltrate the system. However, before we started talking, I received 2 spam emails and instead, you know, I didn't reply to the individual I texted the individual, did you send me an email? They're like, Nope, it's spam.

Participant C likened the concerns to the military, stating,

> The other part of it is that we don't necessarily have the bandwidth within the fire service. For the IT side to really be the instigators of AI. We don't have those kinds of folks for that IT in [community name redacted], it's done through the town. I'd be curious. I'm wondering if the military is going to be super careful with it, because they have similar security issues to ours.

Theme 3: Ethics and AI/ML

The final theme that emerged was the issue of the ethics of utilizing AI/ML in the fire service. The data collection instrument asked a specific question regarding this topic in question four. The issue of ethics also arose in responses to other areas of the data collection instrument. All 11 interviews discussed the subject of the ethical implications of AI/ML in the fire service due to a question directly asking for responses. The stated responses to the question of ethical concerns with the integration of AI/ML in the fire service were split down the middle with Participants C, E, F, and H indicating an ethical concern. Participant C stated,

> If you gave the AI "Joe Smith" would AI on Joe Smith look up and find things that were not part of the conversation? So the fact that he did jail time when he was 19, for example, is not relevant to his medical care today. But if we had access to your date of birth, or something like that in the box. Yeah, easy for it to come back around.

This issue of what access AI should have to an individual's background was presented again by Participant F who stated,

> I'm sure somewhere in that program would be, how much does this Fentanyl cost, and it (AI) does a cost analysis? So I've already given a person a hundred mics, should I break another vial, and is it worth that cost to break another vial, to give them another 25 or 50 mics? You know where, morally speaking, someone's in pain, and we want to treat that pain, and there are whatever number you want to give it. They are 3, and we want to get them to one. But somewhere in that AI, there's programming that there's got to be values and limits. And you know, like I said, it's not taking into effect the moral or the feeling part of it. You know the part that makes us human. It's just logical.

Participant G confirmed an ethical concern from a different perspective stating,

> I think so, because I think they don't quite have it dialed in. And if you're going to use AI to write a story, and the story accuses you of being, you know, a criminal or a child molester or something else. And you're going, hey? That's not true, you know. If a person did that to you they'd be liable for that information. So how do

> you ethically program that system so that it checks itself or other people check it? So I think there are those ethical concerns and people should know that it's coming from an AI source instead of a person.

Participants B, D1, D2, G, and I stated they did not believe there was an ethical concern. Participant B succinctly stated “Ethically? No, I don’t, again if it was tested, vetted, and proven, and had NFA, certifications, that kind of stuff. I don’t necessarily see an ethical concern with it.” Participant D2 also had a brief response stating, “I don’t necessarily know that I have any more ethical concerns about AI than what is already out there.” Participant G commented, “I would think a machine or computer cannot be, shouldn't be biased, right?” However, this participant immediately contradicted that statement by saying,

> Unless we have input something that says, Hey, for every sprinkler job or fire alarm job. We want you to spit out this company or use this brand product or something. So I think it definitely can. If the input. Or if the user has input data that says for every fire alarm drawing, make sure you use Tommy's brand so that way when they keep spitting them out the person purchases that. So I think there definitely could be you know, if they say, Hey, here's the top 10 and use the best one fit for the job. I would imagine there are ways for it to be non-biased and use the best product that you have taught it.

Participant I brought the ethical issue right back on the individual, and off the AI, stating “I don't think so. I don't. I mean your moral compass is your moral compass, and I think that, regardless of any AI that could provide the ease for someone to do something that's not ethical, that they were going to do it regardless.”

Participants J and A were unsure when answering the question. Participant J stated I'm unsure at this point, I think it's still very new." Participant A leaned a little both ways stating,

> I think probably not on the ethical side of things. Although, because it has such a broad scope of what you could do with it, from what I can tell. You know what's the end game with it? A little bit of how much is too much right? so it's you know what? What's the end goal that you're trying to get out of it? And what are you really trying to use it for? I think for certain aspects there are limitations. And I think maybe in municipal government there may be some ethical limitations, but in the private sector, it's a little bit easier because they have fewer rules to follow.

Summary

Chapter 4 presented the data as it was identified in the generic qualitative inquiry process. Themes related to the potential usage of AI/ML in the fire service, obstacles to the integration of this technology, and the ethics of AI/ML were presented as found in the interviews. Chapter 5 will interpret this data and provide meaning to it in the context of this generic qualitative inquiry study's three research questions.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

Introduction

Chapter 5 will analyze the themes presented in Chapter 4 and discuss the relevance and impact of the themes on the issue of AI/ML usage in the fire service. The chapter will provide a summary of the results and themes, followed by conclusions drawn from those results. Next, a discussion of the limitations of this qualitative generic inquiry study will be provided. The chapter will conclude with a discussion of the implications of the results and recommendations for the field and future studies.

Summary of the Results

The themes identified in Chapter 4 addressed each of the research questions posed for research:

1. In what way may the implementation of AI/ML technology offer a safer future for the fire service?
2. What obstacles currently exist, and what future obstacles may arise that prevent the integration of AI/ML technology within the fire service?
3. What actions can fire service executives take to enable their department, and the fire service as a whole to begin integrating AI/ML technology?

The overarching theme that presented itself most frequently in this generic qualitative inquiry study addressed both research questions two and three. Participants indicated that there was a lack of understanding of AI/ML technology by leaders in the fire service which provides both an obstacle and an action opportunity. Participants represented chief-level officers from departments of varying sizes, make-ups, and geographic locations across the United States. Despite this wide array of participants, not a single respondent indicated a comprehensive understanding or comfort with AI/ML technology. The importance of this as the first theme cannot be overstated. The lack of understanding limits the effective evaluation of risks, benefits, obstacles to, and challenges associated with, integrating the technology in its current form; in addition to stifling the type of creative vision necessary to drive the development of this technology into the future of the fire service.

The potential uses identified by the participants reinforced the limiting effect of the lack of knowledge of AI/ML technology, while at the same time directly answering research question one. The participants' suggested uses are examples of ways that these technologies may contribute to a safer and more effective future of the fire service. Many of the suggested uses revolved around the current form of machine learning with very little consideration of a fully artificial intelligence product. Respondents suggested EMS products that could evaluate patient care reports (PCR's) for IV success rates when compared to local or national standards. These products noted focused on refusal rate comparisons for shift-to-shift or organizational trends; however there was no consideration of a more sophisticated product that could learn from symptoms or skills performed, integrate information with existing monitors, sensors, or medical devices, or improve its output based on its expanded database created by use.

Training is likely the most effective way that these themes address question one. Although many other uses of these technologies offer a potential increase in efficiency to service, training provides a clear increase in safety. Participants discussed the use of virtual reality headsets, or simulations, but did not offer ideas of fully AI-run programming. Technology that would mimic local conditions or respond to actions taken by the trainees are the types of AI systems that could exist if the need was identified by fire service leaders. False alarms and monitoring systems was an area where a single participant ventured into the concept of a truly autonomous system. The interaction of smoke detectors, heating cooling and ventilation (HVAC), and sprinklers was suggested as a means to create a system that could respond to specific cues and take action to mitigate a fire scenario. This concept was only presented by one single participant, however, and was not the norm for these responses.

Identifying obstacles to the implementation of the concepts was an area where the data collection exceeded expectations. The list of obstacles presented by the participants directly answered research question two with the participants providing both current and future obstacles. Participants consistently identified concerns that would reasonably interfere with the integration of the technology. The concept of cost was intentionally removed from this study as municipal spending is a more complex issue that was outside of the scope of the research. The concerns listed by the participants appeared to represent realistic concerns regarding the day-to-day use of any AI/ML programming. Regulation and oversight, IT and security issues, backups and fail-safes, and oversimplification all represent concerns that exist with current technology implementation in many different fields of work. It is reasonable to assume the same issues will be generated by a more robust use of technology in a high-risk field like firefighting. The concern about the effect on workforce size (loss of jobs) is more theoretical; however, can also be demonstrated through other industries that have lost workforce size due to technological advances. The auto industry is an excellent example of this type of response to expanded reliance on technology. The discussions that occurred during the interview also touched on research question three as the participants made many suggestions of ways that these obstacles could be addressed on both a local and national level.

Questions two and three were addressed in the final theme that was identified. The potential ethical issues that surround the introduction of these technologies into the fire service. Identified partially under the theme of obstacles to implementation it was also a separate topic discussed as a potential consideration of whether or not AI/ML is a good idea for fire service implementation. Although not all participants believed there was an ethical component to the usage of these technologies, the ones who did all indicated a path to successful navigation of any ethical problem that these technologies presented. The consideration of these ethical concerns represented obstacles that may arise and prevent the integration of these technologies; however, the steps to ensure accurate data suggested by the participants is an actionable step that the fire service and technology industry can take to help this integration.

Conclusions Based on the Results

The most pressing issue that faces the fire service in the implementation of AI/ML technology to the response side of the industry is the need for an increased understanding and exposure to the current state of the technology, as well as a more thorough understanding of the direction the current advancement trends are going. If the fire service is going to effectively utilize artificial intelligence and machine learning, then leadership must learn what the technologies offer in their current form, as well as understand how the technologies can be developed to address the issues of tomorrow. Seminars, conferences, and trade shows that bring new products and concepts to fire service leaders are likely the most effective pathways to increase knowledge and familiarization with the products. The challenge will lie in differentiating between fad products and concepts and true technological advancements that will benefit the industry as a whole.

The list of obstacles presented in the study is representative of the obstacles that all new technologies face as they enter an industry that has concerns about municipal oversight, medical care, and public safety. The themes identified in Chapter 4 do present real challenges that will require very specific solutions. Security breaches with internet technology is a current topic that many industries are trying to address (Madnick, 2024). Data loss and data-based attacks have affected scheduling software and credit card companies in ways that have brought the need for effective backups and fail-safes to the front of conversations across industry borders. Additionally, changes in technological advancements have shifted workforces in many industries. This evolution of workforce makeup is challenging but a part of the growth of any industry. Finally, regulation and oversight are a discussion facing everything from cryptocurrency to health insurance, in some cases related to the very technologies this study explored (Radanliev, 2024; Reddy, Allan, Coghlan, & Cooper, 2020). Although these complex issues may not have easy solutions, the solutions to the questions remain and are currently being enacted at varying levels. The obstacles that are likely to challenge the fire service as it integrates the technology will require modifications to existing policies and protocols. It will likely require that the fire service embrace oversight in a new format or from a different body than exists today. Regardless of the specifics of the challenges, they do not represent an insurmountable blockade to a fire service that benefits from this technology.

Identifying the next steps for fire service leaders is the more difficult research question to address. The research indicated that departments across the country should ensure their IT security and backups are established and safeguarded. Departments should also have high-quality technology policies, and SOGs for both professional and personal social media usage. These baseline steps will make the integration of an AI or ML-based product easier to complete.

Departments that want to be on the leading edge of utilizing this type of technology, or who identify a problem that has a solution based on this type of program must be knowledgeable about the abilities and limitations of current products while also seeking to push the envelope of what can be done. Departments that capitalize on these recommendations, and adhere to existing best practices for IT and data security will also have taken the first step in addressing potential ethical concerns with these technologies, Although it is impossible to foresee all ethical components of this integration, secure and accurate data that is based on clearly written guidelines and policies will demonstrate intent and be adaptable to problems that are identified after these technologies are put into use. During the research process, commercially available, fully automated, AI systems were not identified for use. Additionally, the participants indicated knowledge of some programs with components of AI technology, but no participant was able to identify a fully AI technology that they utilize.

In order to embrace a future where the fire service utilizes this technology, leaders must support the current trend in data-driven decision-making and reliance on both internal and external (to the organization) data sources. Departments can compare their call volume, response times, turnout times, etc. to nationally accepted norms and capture data like time to water on the fire, or door to 12-lead time on EMS calls. Participants identified EMS most frequently as a suggested use for this technology. Heavy data collection and reporting in EMS is an excellent example of an industry utilizing data-driven decision-making to advance industry-wide improvements in efficiency. Collecting the data accurately is a task that can be completed with existing technology such as computer-aided dispatching (CAD), but the effort must be made by departments to accurately collect and report such data (Pek, et al., 2021). Evaluation of this form of data will help to overcome the concerns about the validity of the data being used to create the software programs that future systems will utilize.

Limitations

Although the research presented an examination of the concept of AI/ML technology in the fire service, as well as opinions of a sample of the leadership on this topic, when using a generic qualitative approach, there is no guarantee that the data is representative of the fire service as a whole (Creswell, 2018). The study attempted to gather data from a wide range of departments both geographically and by department size and makeup, however; the sample size was too small to make accurate generalizable predictions of the opinions of fire service leadership across the country. As a result, in order to generalize findings on the topic, further research is needed.

Another limitation of the study was the sensitivity of the assessment instrument concerning the research questions. The instrument was validated and field-tested by three industry professionals however after data collection was completed and coding began it became clear that the instrument provided quality feedback on two of the three research questions but provided less robust data concerning the third question. Interpretation and analysis of the data collected led to reasonable conclusions regarding how AI/ML technology could offer a safer future for the fire service, as well as identifying obstacles to the implementation of this technology. The question of what actions fire service executives can take to begin implementation can be inferred through the obstacles identified by the participants; however, a true plan of next steps was not effectively identified by the data collection instrument.

Although inferences and generalizations have been drawn from the thematic elements identified in the data collection, this data, like all data from a generic qualitative inquiry study is difficult to objectively measure and verify (Creswell, 2018). Time constraints on the project prevented additional validation in the form of bringing the thematic coding back to the participants to ensure accuracy. In the future, a second round of participant evaluation should be conducted. A review of the themes derived from their answers would allow the participants to verify the interpretation of data collection, and not just the wording of their answers.

Implications and Recommendations to the Field

Recommendations for the next steps fall into two categories. The first category focuses on the actions that can be taken based on existing technologies. The fire service must embrace the concept of data collection, evaluation, and data-driven decision-making. The days of “we always did it this way” must be a thing of the past as science-based strategies and tactics become the norm. This cannot be left to the decision of the first arriving officers but rather must be embraced by department cultures. Training, SOGs, and pre-plans must embrace the concepts of data-backed decision-making for both fireground and organizational strategies and tactics. Participants consistently referred to the need to verify data utilized for these technologies. Terms like “tested, vetted, and established” were used repeatedly when describing the concerns of these technologies.

Data collection is the next area that the fire service must capitalize on now. Many of the concerns noted by participants focused on the future of AI/ML programs revolving around the concept of where the data would come from for the software decision-making programming. The onus rests on the fire service today to collect quality data, record it, and enter it into local and national databases. Advances in radio communications and computer-aided dispatch (CAD) software allow crews to record accurate time stamps on data points like time on scene, initial patient contact, forced entry, door to 12-lead, water on fire, and a host of other data points that many departments are not capturing. This information establishes the foundation for the fully automated systems discussed in this research paper. It is the responsibility of the fire service leaders of today to ensure accurate and comprehensive data collection to build the databases for future use.

Finally, all departments should be investing in robust and comprehensive data security systems that allow searchable access to the information collected. CAD systems and EMS PCR's with drop-down lists offer extensively searchable databases of the information that organizations are entering. As listed above, quality information must be collected and entered, but a searchable database is necessary for the information to be utilized. The data also must be protected from external access and backed-up in a manner that allows for minimal downtime in the event of a loss of access or corruption of the system. Recognizing that IT investments for security and functionality could be a required piece of organizational budgeting would be a change for many departments. A recommendation resulting from the findings indicates that larger departments consider investing in IT professionals who work for the department and manage updates, security, and concerns based on organizational objectives. Smaller departments and communities will need to reach the goals community-wide by either using a professional for all departments or possibly by teaming up with surrounding communities to fund a position that works for everyone.

The second category of recommendations revolves around the development of future technologies and the status of machine learning and artificial intelligence systems that currently exist. The proliferation of seminars and conferences to address trends and developments in this area is widely observable. The Fire Department Instructors Conference (FDIC), held annually in Indianapolis, IN is an example of how this topic is gaining traction at these types of events. Groups like the International Association of Fire Chiefs (IAFC), International Association of Fire Fighters (IAFF), Center for Public Safety Excellence (CPSE) and the International City/County Management Association (ICMA) have all made recommendations regarding the importance of data and technology in the future of the fire service, but local leaders must help push these agencies to prioritize this subject in future planning and incident mitigation.

Recommendations for Future Research

This generic qualitative inquiry research paper provided a broad overview of the issue. The current status of technology, along with the fire service's history of reacting slowly to change, has resulted in a gap in the literature and study on this topic. Future research should focus on AI/ML programming to meet specific needs within the fire service. The lack of knowledge identified in this paper, paired with the open-ended questions of the study instrument resulted in opinions about theory as opposed to impressions of possibilities. The process of linking the internet of things (IOT) with the software being developed in the field of AI could result in commercially available products to solve common fire service problems in the future. In the past, the best products have come from the minds of those who have faced these problems and sought out solutions (the Halligan firefighting tool is one example). The partnership of computer software and firefighting may seem far-fetched and will require input from those outside of the fire service to be successful, but the idea of linking pieces of this unique occupation together to allow them to help create safer buildings that can be extinguished with more effective tactics should be the focus. The CPSE and ICMA white paper laying out critical issues to the future of the fire service lists two initiatives under the critical issue of technology. Both of these initiatives support the above effort, listing the anticipation and development of new technologies, AI, and robotics in the future of service delivery (Bruegman, & Martel, 2020).

Another area that has a large impact on the issue and will need to be studied further is the area of funding for the technologies. Municipal budgets across the country are strained to try to meet the status quo of current standards. Only a limited number of municipalities effectively plan for future expansion and potential growth. As with any new technology the initial iterations are likely to come with a hefty price tag. The wide area of integration and data collection allows an opportunity for increases in efficiency in many sectors of government. The fire service may not have to fund this enterprise alone if the benefits to water departments, traffic, IT, and other municipal departments is made clear early. This type of larger-scale integration is likely required for the effective implementation of these tools and research will be necessary to help communities commit to the type of changes and upgrades that will be necessary. A 2022 study of European municipalities (Mikalef, Schaefer, Ylinen, Fjortoft, Torvatn, Gupta, & Niehaves, 2022), utilizing a survey-based method of data collection identified similar recommendations for AI integration into municipalities. Mikalef, et al. (2022) found the need for clear funding streams to be a primary determinant of a municipalities ability to incorporate AI capabilities.

Conclusion

The emergence of artificial intelligence and machine learning-based technologies appears to present a wide range of opportunities for the fire service. The traditionally slow pace of the fire service to embrace new concepts and technology is slowly giving way to best practices in the form of strategies and tactics based on data, and evidence. The anecdotal decision-making based on a single individual's perception of an event with many different factors appears to be ready to give way to research and data. Artificial intelligence may have a role in improving prevention, notification, and response to fires and other emergencies. The small sample studied in this generic qualitative research study indicates an openness to embracing this new technology, along with a wide range of potential areas for use. Although the understanding of the technologies is not yet where it needs to be for the fire service to fully capitalize on its use, the data collected here shows a willingness to utilize this new technology and a belief that it can provide a safer future for the fire service as a whole. Bruegman and Martel (2020) described data-driven decision-making, and the embracing of technological advances as two requirements for the fire service to maintain its relevance in the coming decades. This paper reflected a willingness to meet those requirements but also expand the knowledge base to support the willingness in the fire field to understand and use technology to continue to evolve.

References

Bakas, I., & Kontoleon, K. J. (July 2023). Meta-narrative review of artificial intelligence applications in fire engineering with special focus on heat transfer through building elements. Fire (2571-6255) 6, no. 7. https://doi.org/10.3390/fire6070261.

Blomberg, S. N., Christensen, H. C., Lippert, F., Ersbøll, A. K., Torp-Petersen, C., Sayre, M. R., Kudenchuk, P. J., & Folke, F. (2021). Effect of machine learning on dispatcher recognition of out-of-hospital cardiac arrest during calls to emergency medical services: A randomized clinical trial. *JAMA Network Open*, 4(1), e2032320. doi:10.1001/jamanetworkopen.2020.32320

Bruegman, R. R, & Martel, P. M. (2020). 21st century fire and emergency services [White paper]. https://www.cpse.org/wp-content/uploads/2020/07/21st-Century-Fire-and-Emergency-Services-White-Paper-Final-07.15.20.pdf

Creswell, J. W., & Creswell, J. D., & (2018). Research design qualitative, quantitative, and mixed methods approaches (Fifth ed.). Sage Edge.

DeVane, S. (2017, July 18). Rural volunteer fire dept. reluctant to implement technology. FireRescue1. https://www.firerescue1.com/fire-products/technology/articles/rural-volunteer-fire-dept-reluctant-to-implement-technology-sfFSY1LyCxkudUIZ/

Finazzo, S. (2017, May 1). Assessing the impact of technology on fire departments. Fire Engineering. https://www.fireengineering.com/leadership/assessing-the-impact-of-technology-on-fire-departments/

Khan A. A., Tianhang, Z., Huang, Xi., & Usmani, A. (2023). Machine learning driven smart fire safety design of false ceiling and emergency response. *Process Safety and Environmental*

Protection 177, 1294-1306. https://www.sciencedirect.com/science/article/pii/S0957582023006730

Haq, M. A., Ahmed, A., Khan, I., Gyani, J., Mohamed, A., Attia, E., Mangan, P., & Pandi, D. (2022). Analysis of environmental factors using AI and ML methods. *Scientific Reports (Nature Publisher Group), 12*(1) https://doi.org/10.1038/s41598-022-16665-7

Kaginalkar, A., Kumar, S., Gargava, P., & Niyogi, D. (2021). Review of urban computing in air quality management as smart city service: An integrated IoT, AI, and cloud technology perspective. *Urban Climate*, 39. https://doi.org/10.1016/j.uclim.2021.100972

Kostere, S., & Kostere, K. (2022). The generic qualitative approach to a dissertation in the social sciences: A step by step guide. https://doi.org/10.4324/9781003195689

Littman, M. L., Ajunwa, I., Berger, G., Boutilier, C., Currie, M., Doshi-Velez, F., Hadfield, G. K., Horowitz, M., Isbell, C. L., Kumakura, H., Levy, K., Lyons, T., Mitchell, M., Shah, J. A., Sloman, S. A., Vallor, S., & Walsh, T. (2022). *Gathering strength, gathering storms: The one hundred year study on artificial intelligence (AI100) 2021 study panel report*. https://arxiv.org/ftp/arxiv/papers/2210/2210.15767.pdf

Lum, C., Koper, C.S., Stoltz, M., Goodier, M., Johnson, W., Prince, H., & Wu, X. (2020). Constrained gatekeepers of the criminal justice footprint: A systematic social observation study of 9-1-1 call takers and dispatchers, *Justice Quarterly*, 37(7), 1176-1198, https://doi.org/10.1080/07418825.2020.1834604

Madnick, S. (February 19, 2024). Why data breaches spiked in 2023. *Harvard Business Review*. https:// https://hbr.org/2024/02/why-data-breaches-spiked-in-2023

Mauri, L, & Damiani, E. (2022). Modeling threats to AI-ML systems using STRIDE. *Sensors*, 22(17), 6662. https://doi.org/10.3390/s22176662

Mikalef, P., Lemmer, K., Schaefer, C., Ylinen, M., Fjortoft, S. O., Torvatn, H. Y., Gupta, M., & Niehaves, B. (October 2022). Enabling AI capabilities in government agencies: A study of determinants for European municipalities. *Government Information Quarterly*. 39(4), 101596. https://doi.org/10.1016/jiq.2021.101596

Naser, M. Z. (November 2021). Mechanistically informed machine learning and artificial intelligence in fire engineering and sciences. *Fire Technology* 57(6), 2741–2784. https://doi.org/10.1007/s10694-020-01069-8

National Institute for Occupational Safety and Health. (2015, November 18). *Firefighter fatality investigation report F99-47*. Centers for Disease Control and Prevention. https://www.cdc.gov/niosh/fire/reports/face9947.html

National Institute for Occupational Safety and Health. (2015b, November 18). *Firefighter fatality investigation report F2007-18*. Centers for Disease Control and Prevention. https://www.cdc.gov/niosh/fire/reports/face200718.html

Pek, P. P., Lim, J. Y. Y., Leong, B. S.-H., Mao, D. R.-H., Chia, M. Y.-C., Cheah, S. O., Gan, H. N., Ng, Y. Y., Tham, L. P., Arulanandam, S., Shahidah, N., Lin, X., Ho, A. F. W., & Ong, M. E. H. (2021). Improved out-of-hospital cardiac arrest survival with a comprehensive dispatcher-assisted CPR program in a developing emergency care system. *Prehospital Emergency Care*, *25*(6), 802–811. https://doi.org/10.1080/10903127.2020.1846824

Percy, W. H., Kostere, K., & Kostere, S. (February 1, 2015). Generic qualitative research in psychology. *Qualitative Report*, 20(2), 76–85.

Peng, H., Siddiqui, M., Rhind S., Zhang, J., Teodoro da Luz, L., & Beckett, A. (February 16, 2023). Artificial intelligence and machine learning for hemorrhagic trauma care. *Military Medical Research* 10(1). https://doi.org/10.1186/s40779-023-00444-0

Radanliev, P. (January 31, 2024). The rise and fall of cryptocurrencies: defining the economic and social values of blockchain technologies, assessing the opportunities, and defining the financial and cybersecurity risks of the metaverse. *Financial Innovation,* 10 (1), 1–34. https://doi.org/10.1186/s40854-023-00537-8

Reddy, S., Allan, S., Coghlan, S., & Cooper, P. (March 2020). A governance model for the application of AI in health care. *Journal of the American Medical Informatics Association*, 27 (3), 491–497. https://doi.org/10.1093/jamia/ocz192

Scholz, M. L., Collatz-Christensen, H., Blomberg, S. N. F., Boebel, S., Verhoeven, J., & Krafft, T. (2022). Artificial intelligence in emergency medical services dispatching: Assessing the potential impact of an automatic speech recognition software on stroke detection taking the capital region of Denmark as case in point. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*, 30(1), 36. https://sjtrem.biomedcentral.com/articles/10.1186/s13049-022-01020-6

Sinkovics, R. R., Stottinger, B., Schlegelmilch, B. B., & Sundaresan, R. (2002). Reluctance to use technology-related products: Development of a technophobia scale. Thunderbird International Business Review, 44(4), 477-494. https://doi.org/10.1002/tie.10033

Tam, W. C., Fu E. Y., Li, J., Huang, X., Chen, J., & Huang, M. X. (October 1, 2022). A spatial temporal graph neural network model for predicting flashover in arbitrary building floorplans. *Engineering Applications of Artificial Intelligence* 115, 105258. https://doi-org//10.1016/j.engappai.2022.105258

Todd, D. (June 1, 2021). NIST trained AI could save firefighters. Secureworld, https://www.secureworld.io/industry-news/nist-ai-could-save-firefighters#:~:text=NIST%20develops%20tool%20to%20save%20firefighters%20The%20U.S.,a%20warning%20of%20when%20a%20flashover%20will%20occur

Warrick, D. D. (2023). Revisiting resistance to change and how to manage it: What has been learned and what organizations need to do. Business Horizons, 66(4), 433-441. https://doi.org/10.1016/j.bushor.2022.09.001

Wu, X., Park, Y., Li, A., Huang, X., Xiao, F., & Usmani, A. (March 2021). Smart detection of fire source in tunnel based on the numerical database and artificial intelligence. *Fire Technology* 57(2), 657–682. https://doi.org/10.1007/s10694-020-00985-z

Zhou, M., Zhou, B., Zhang, Z., Zhou, Z., Liu, J., Li, B., Wang, D., & Wu, T. (May 2023). Fire egress system optimization of high-rise teaching building based on simulation and machine learning. *Fire Technology*. 6(5), 190. https://doi.org/10.3390/fire6050190

Appendix A

Interview Consent Form

Identification of Investigators & Purpose of Study

You are being asked to participate in a research study conducted by Steven Chandler from the National Fire Academy (NFA) and Columbia Southern University. The purpose of this study is to develop a better understanding of a critical issue in the fire and emergency services. This study will contribute to the researcher's completion of their final project for the Executive Fire Officer program.

Research Procedures

Should you decide to participate in this research study, you will be asked to sign this consent form once all of your questions about the study have been answered to your satisfaction. The study consists of an interview that will be administered to individual participants. You will be asked to provide answers to a series of questions related to your experience within a particular community. **An [audio/video] recording of the interview will be taken for transcription purposes. The [audio/video] file will be deleted at the conclusion of the study and will not be shared with anyone other than the researcher.** You may turn off your camera if you do not wish to be filmed.

Time Required

Participation in this study will require approximately 45 minutes of your time.

Risks

The investigator does not perceive more than minimal risks from your involvement in this study (that is, no risks beyond the risks associated with everyday life).

The NFA, Columbia Southern University, and its contractors take no responsibility for the actions or outcomes of the research study.

Benefits

There are no direct benefits to the participant; however, information from this study may benefit your community, and other communities, in the future.

Incentives

There are no incentives (financial or otherwise) associated with participation in this study.

Confidentiality

The results of this research will be presented to NFA and Columbia Southern University program faculty and students. The results of this project will be coded in such a way that the respondent's identity will not be attached to the final form of this study. The researcher retains the right to use and publish non-identifiable data. While individual responses are confidential, aggregate data will be presented representing averages or generalizations about the responses as a whole. All data will be stored in a secure location accessible only to the researcher. Upon completion of the study, all information that matches up individual respondents with their answers (including audio and/or video recordings) will be destroyed. Final aggregate results will be made available to participants upon request.

Participation & Withdrawal

Your participation is entirely voluntary. You are free to choose not to participate. Should you choose to participate, you can withdraw at any time without consequences of any kind.

Questions about the Study

If you have questions or concerns during the time of your participation in this study, or after its completion, or you would like to receive a copy of the final aggregate results of this study, please contact:

Steven Chandler
Student
National Fire Academy
Chandlers@amherstma.gov

Dr. Justin Heim
Course Manager
Columbia Southern University
Justin.Heim@columbiasouthern.edu

Giving of Consent

I have read this consent form, and I understand what is being requested of me as a participant in this study. I freely consent to participate. I have received satisfactory answers to my questions. The investigator provided me with a copy of this form. I certify that I am at least 18 years of age.

☐ I give consent to be filmed and audio recorded during my interview. ________ (interviewee initials)
☐ I give consent to be audio recorded during my interview. ________ (interviewee initials)

Interviewer Signature		**Date**:	

Interviewee Signature		**Date:**	
Interviewee Signature		**Date:**	

Appendix B

Data Collection Instrument

1. Please introduce yourself. Describe your position, department, and experience.
    - Facilitators
        - How many years in position
        - Responsibilities of current role
        - Size of population your department serves.
        - Call volume per year.
        - EMS as well or Fire/Rescue alone
        - Call, Volunteer, or Combination
2. Please describe your level of understanding/familiarity with artificial intelligence and machine learning
3. What is your opinion about the potential for Artificial Intelligence/Machine Learning in the fire service?
    - Facilitators
        - Does your department/community do any data analysis for planning or operational decision-making?
        - Does your department (or the larger municipal government you work for) utilize AI/ML technology for any part of your operations?
        - Does your community or organization have a policy on AI/ML technology?
4. What, if any, are the challenges or issues with bringing AI/ML technology into the fire service?
    - Do you believe there are ethical concerns (if so, please explain)?

- Do these concerns extend throughout municipal government, or do we have specific concerns in emergency services (if they exist, please explain why you feel this way)?

5. Are you aware of any AI/ML-based tools currently marketed to the fire service, if so can you discuss/describe them?
    - If yes, which ones did you consider? Please describe what the product does and how you believe it would aid your department.
    - If yes, did your department consider using this product, why or why not?
6. What concerns, if any, do you see with the integration of AI/ML into the fire service?
7. If an AI/ML product existed that addressed a need in your organization, would you consider utilizing it, please explain why or why not?
    - Examples: Technology that could alert you to the type of materials on site and make resource allocation recommendations, or drone technology that could position itself to evaluate survivable areas of a burning structure.
    - What concerns would you have with this type of technology?
    - Other than cost, what factors would affect your decision to utilize such technology?
8. What role does education and training have in the integration of technology (specifically AI/ML) in the fire service?
9. How much does public perception influence your capital spending and budgeting?
    - Do you measure public perception (surveys, online feedback, etc.) or do you infer public opinion through public comments/word of mouth?
    - If you felt the public had concerns about this technology, do you think those concerns can be addressed? Should they need to be addressed?

10. Currently there are examples of technology using artificial intelligence that monitors for smoke from wildfires, there is AI software that helps divert 911 calls of a non-emergent nature, and extensive usage of AI/ML in building design and egress access. What do you think is an area of the fire service, if any, that could benefit from AI/ML technology?
11. Do you have any additional comments or information about this topic that you would like to share?