EXPLORING THE INTEGRATION OF AI DECISION SUPPORT IN THE PHILADELPHIA FIRE DEPARTMENT: A QUALITATIVE ANALYSIS

Research Presented in Partial Fulfillment

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Executive Fire Officer Program

by

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Abstract

The Philadelphia Fire Department (PFD) operates in a dynamic and high-pressure environment, demanding swift and informed decision-making for optimal fire response and firefighter safety. This capstone research project investigates the potential integration of artificial intelligence (AI) decision support systems (DSSs) within the PFD, analyzing their perceived value, challenges, and potential impact on firefighter operations.

Employing a qualitative approach, the study will gather data through structured interviews with firefighters at various ranks and roles. The interview guide will examine firefighters' experiences with existing decision-making processes, their perceptions of AI and its potential integration, and their anticipated benefits and concerns regarding AI DSSs.

Thematic analysis will be used to identify key themes and insights, exploring perspectives on the current decision-making processes to understand the existing strategies, challenges, and limitations of the PFDs current approach to fire response. An assessment of firefighters' familiarity with AI can reveal their level of trust and potential concerns regarding the integration of AI DSSs into fire department operations. Examining the potential benefits and challenges of AI DSSs allows for the identification of areas where such systems can enhance decision-making, such as resource allocation, situational analysis, and risk assessment. This analysis should also address potential issues, including overreliance on technology and potential biases within the algorithms.

Based on the qualitative findings, the research will propose recommendations for effective and ethical integrations of AI DSSs into PFD operations, ensuring firefighter buy-in and maximizing the technology's potential to improve safety and response efficiency.

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Introduction

The Philadelphia Fire Department (PFD) is one of the largest and busiest fire departments in the United States, responding to approximately 300,000 emergencies each year (Philadelphia Fire Department, n.d.). The PFD operates in a complex and dynamic environment, which requires that responding personnel accurately make sense of dynamic and unfamiliar environments, assess potential opportunities and threats to develop response plans, and make critical decisions under significant time pressures, often with limited or incorrect information (Cohen-Hatton et al., 2015). In such complex environments, often only fragmented pieces of information are available, which then must be piecemealed together by decision makers. Before the technological age, data and information were passed along the fireground through various methods, with chief officers passing tactical orders through speaking trumpets, box alarms transmitted through a telegraph system, handwritten messages, or by voice. Today's public safety organizations transfer data through multiple types of mediums to include voice, video, text, and email.

In recent years, there has been a growing interest from the fire service and artificial intelligence (AI) developers in the use of artificial intelligence decision support systems (AI DSSs) to improve fire service operations. AI DSSs have been shown to assist in identifying and prioritizing hazards, assisting in deploying resources efficiently(Noonan-Wright et al., 2011), improving overall situational awareness, and expediting the decision-making process (Noble & Paveglio, 2020). There are quite a few challenges municipal fire departments face when attempting to incorporate AI DSSs into their operations, including the cost to develop and deploy DSSs, the complexity of the technology and operating system, the trust needed in the DSSs to be used effectively and the ethical concerns surrounding the use of AI systems (Wirtz et al., 2018).

AI DSSs must be accurate, reliable, and accessible when deployed in operational settings. Despite these challenges, the potential benefits of AI DSSs for fire department operations are significant, helping to improve firefighter safety and efficiency and reducing property damage and loss of life.

Background

Fire departments operate in complex and dynamic environments, and firefighters are responsible for a wide range of tasks, including responding to fires, medical emergencies, and other natural disasters. They must be able to make quick and accurate decisions under pressure, often with limited information.

Traditional fire department decision support systems are often rule-based and deterministic, meaning that they provide a set of rules or procedures that firefighters must follow. The National Incident Management System (NIMS) and the Incident Command System (ICS) are structures used to organize an emergency response; however, these systems only provide an organizational structure, they are not optimized to adapt to the dynamic nature of fire emergencies, and they can lead to suboptimal decision-making(Marinucci, 2015). The National Institute for Occupational Safety and Health (NIOSH) continues to cite “lack of command and control” as a leading factor in US fire service Line of Duty Death reports (*Fire Fighter Fatality Investigation and Prevention*, 2023). The use of AI DSSs in fire department operations has the potential to create a paradigm shift in the way that firefighters respond to emergencies, in both operational and executive roles, by providing firefighters with resources that can learn from experience and adapt to new and evolving situations. AI DSSs can be used to analyze large amounts of data, identify patterns and trends, and generate predictions, which can then be used to

support ICs by identifying and prioritizing hazards, deploying resources efficiently, and improving situational awareness.

The use of AI DSSs in fire department operations has the potential to improve organizational and community safety and resilience in several ways. For example, AI systems can be used to rapidly identify and prioritize hazards, which can assist ICs in overall scene management (Marinucci, 2015). AI systems can also be used to deploy resources more efficiently, which helps to ensure that firefighters are able to respond to emergencies more quickly and effectively. Additionally, AI systems can be used to improve situational awareness, which in turn can help firefighters to stay safe and make better decisions in dangerous environments.

While still in its early stages, AI has the potential to have a major impact on the future of fire and emergency services. In the past, AI has been used to develop a considerable amount of successful fire department applications, such as fire prediction and detection systems, resource deployment systems, and firefighter safety monitoring systems (Chang et al., 2022).

At present, fire departments throughout the United States are piloting and implementing AI DSSs. For example, the PFD is currently exploring the use of AI DSSs in its operations, partnering with 3am and their product Florian (Bompadre, personal communication, December 18, 2023). Florian is an AI enhanced personnel accountability system that the department is deploying throughout 2024. This deployment will be evaluated as a case study. The Los Angeles Fire Department is using AI to help dispatch firefighters (ABC News, 2021), and the New York City Fire Department is using AI to help identify and prioritize hazards (Vision Systems, 2022). Another example is the use of AI-powered drones to identify and track wildfires. In 2021, the California Department of Forestry and Fire Protection (CAL FIRE) began using AI-powered

drones to help them fight wildfires (Smith, 2023). The drones are equipped with cameras that can detect heat and smoke, and they can fly over large areas of land quickly and safely. This information can then be used by CAL FIRE to identify and track wildfires, and to deploy resources more effectively. In the future, AI is expected to play an even greater role in fire department operations. For example, AI is expected to be used to develop autonomous firefighting robots, AI-powered fire safety inspection systems, and AI-powered disaster preparedness and response systems (Rodgers, 2020).

The development and implementation of AI DSSs in fire department operations can be expensive. However, the long-term benefits of these systems, such as improved safety and efficiency, can outweigh the initial costs. Additionally, there are grants available to help fire departments fund the development and implementation of AI systems (Select Committee on Artificial Intelligence, 2023).

There are many cultural and ethical considerations that need to be addressed when developing and implementing AI DSSs in fire department operations. For example, end users, executives and administrators must be aware that AI systems are designed to support firefighters in their decision-making process, not replace them. From a cultural perspective, there is a need to ensure that firefighters trust and understand the recommendations of AI systems. Additionally, engineers must design AI systems in a way that respects the values and traditions of the fire service. From an ethical perspective, AI systems should be used in a responsible and ethical manner, and users must avoid using AI systems to automate decisions that should be made by humans.

The Center for Public Safety Excellence (CPSE) & the International City/County Management Association (ICMA) (2020) report identifies AI as one of the key technologies that

has the potential to transform fire and emergency services in the 21st century. Initiative 1 states that a priority is to "adapt to and leverage rapidly evolving technology to improve service delivery" (Comeau, 2020, p.25).This statement lends itself to the stated goals of the Executive Fire Officer (EFO) Program to prepare fire and emergency services leaders for the future and to develop new knowledge and innovative solutions to the challenges facing the fire and emergency services (United States Fire Administration, 2018). The research on AI DSSs in fire department operations that will be conducted is aligned with both goals.

Significance of the Study

This research will make a significant contribution to the field of fire department operations by providing valuable insights into the potential of AI to improve decision-making by identifying and assessing the challenges and opportunities for the use of AI DSSs in fire department operations. This will involve a review of the literature, interviews with fire department personnel and experts in AI, and case studies of fire departments that are currently using AI DSSs. The findings will help fire department leaders to identify the areas where AI can have the biggest impact and to develop strategies for adopting AI DSSs in their departments. This research will also investigate the human-AI interaction aspects of AI DSSs in fire department operations. This will involve studying how firefighters trust and understand the recommendations of AI systems and how AI systems can be designed to support firefighters in their decision-making process, not replace them. The findings will help PFD leaders determine if AI DSSs should be designed and implemented with the goals of maximizing benefits for firefighters while minimizing risks.

The findings of this research will be of interest to fire department leaders, policymakers, and researchers in the field of public safety. Fire department leaders will be able to use the

findings to make informed decisions about the adoption and implementation of AI DSSs in their departments. Policymakers will be able to use the findings to develop policies and regulations that support the responsible and ethical use of AI in fire department operations. Researchers in the field of public safety will be able to use the findings to inform their research on the use of AI to improve fire department operations.

While there is a growing body of research on the use of AI in fire department operations, there are deficiencies in some prior studies. First, many studies have focused on developing and testing AI algorithms in simulated environments (Coleman & Sullivan, 1996;Green et al., 1990;Grishin, n.d.). Simulated environments cannot fully replicate the complexity and dynamism of real-world fire department operations. Therefore, conducting research on the implementation and evaluation of AI DSSs in real-world fire departments is vital.

Second, many prior studies have focused on specific applications of AI in fire department operations, such as hazard identification or resource deployment (Chang et al., 2022). AI DSSs that are only designed for specific applications may not be able to support firefighters in all of their tasks. Therefore, there is a need for more research on the development of comprehensive AI DSSs.

Third, there is a need for more research on the human-AI interaction aspects of AI DSSs in fire department operations. Firefighters must be able to trust and understand the recommendations of AI systems, and AI systems must be designed to support firefighters in their decision-making process, not replace them (Xu et al., 2021).

Problem Statement

The problem is that the PFD may not be adequately integrating decision support systems to assist with critical decision making (DM) in complex environments. This is a problem because

the lack of AI DSSs usage could lead to an increased number of firefighter injuries and fatalities, longer response times, more damage caused by fires and other disasters, and a decrease in overall safety.

Human factors play a role in tactical decision making. Stress, sleep, environment, and other elements can adversely affect the incident commander's DM process. Literature shows that "acute stress influences cognition, and growing evidence shows that stress biases decision-making; stressors result in hasty and unsystematic decision-making that lacks consideration of the whole of available options" (Botero-Rosas et al., 2020, pp. 93–94). Incident commanders assisted by AI will be able to rapidly act upon more reliable information. Although these technologies exist, public safety organizations might not be taking advantage of technologies that can not only assist, but also greatly augment DSSs and DM processes.

Purpose Statement

The purpose of this qualitative research is to examine processes and applications in which AI DSSs can assist the PFD to increase operational productivity and to understand how firefighters, incident commanders and other stakeholders experience and perceive AI DSSs integration. The qualitative data will be collected from interviews with PFD leaders and AI subject matter experts, observations from current PFD operations, and open-ended interviews. This approach will allow for a comprehensive understanding of the use and potential of AI DSSs in PFD operations. The research is focused on understanding where the PFD currently stands in this process and if they are using all the tools available to help make better decisions. The findings will provide actionable recommendations for optimizing AI DSSs utilization within the PFD, maximizing its contributions to operational efficiency, and informing the adoption of AI DSSs in the fire service sector. The specific objectives of this research are to

- Identify and assess the challenges and opportunities for the use of AI DSSs in Philadelphia Fire Department operations.
- Investigate the human-AI interaction aspects of AI DSSs in Philadelphia Fire Department operations.
- Identify where the PFD stands when compared to other similarly sized municipal fire departments regarding the use of AI DSSs

Research Questions

The following research questions will be used to guide this study:

- What are the challenges and opportunities for the use of AI DSSs in fire department operations?
- How can a comprehensive AI DSS for fire department operations be developed and evaluated?
- How can AI DSSs be designed to support firefighters in their decision-making process?

Summary

The use of AI DSSs in fire department operations has the potential to improve organizational and community safety and resilience in many ways. This research aims to learn what the implementation of AI DSSs and DM tools would look like in today's Philadelphia Fire Department, and to gain a better understanding of what AI DSSs & DM mean to current PFD members, and whether these members see these modernization tools as a positive or negative for the organization.

CHAPTER 2: LITERATURE REVIEW

Introduction

Fire departments operate in a dynamic and highly pressurized environment, where decisions hold immense weight. Incident commanders are routinely faced with complex situations, often with limited information, and significant time constraints, all while tasked with ensuring the safety of civilians, property, and first responders. The distinguishing feature of the incident command environment is that "of the rapidly developing incident where information is incomplete, stress levels are high, and there is an acceptance that not making a decision is not an option" (Flin & Arbuthnot, 2017, p. 4).

This research delves into the underpinnings of decision making in this context, pulling from disciplines such as cognitive science, psychology, and emergency management. It examines how ICs navigate uncertainty, weigh risks, and ultimately choose courses of action under pressure.

The rise of AI also presents intriguing possibilities. The research will explore how AI DSSs (AI DSSs) are revolutionizing decision making across industries and investigate their potential in fire department operations. This research aims to answer the research questions by drawing from diverse fields like computer science, data analytics, and public policy.

By examining the intersection of human decision making and AI technology within the unique context of fire department operations, this research aspires to contribute valuable insights for enhancing firefighter safety, improving emergency response effectiveness, and ultimately, safeguarding communities.

Existing Literature

Fire Departments across the nation operate in a dynamic and demanding environment where decision making plays a pivotal role in safeguarding communities and minimizing the impact of fires and other emergencies. Effective decision making is the cornerstone of successful firefighting, as it determines the allocation of resources and personnel, the implementation of tactics, and the overall effectiveness of fire suppression efforts. Incident commanders face a myriad of challenges in making informed decisions under the immense pressure of rapidly evolving emergency situations.

The decisions made on the fireground and emergency scene by Incident commanders have profound consequences, impacting not only the safety of the civilians affected and the firefighters on scene, but also the protection of property and the containment of the emergency. A single misstep or error in the decision-making process can have disastrous outcomes, leading to loss of life, serious injury, and extensive property damage. Therefore, the ability to make sound decisions under pressure is a critical skill for all fire department personnel.

Before examining the decisions made on the fireground and emergency scene, how humans make decisions must be understood. Humans make thousands of decisions each day, both consciously and unconsciously. From what to eat, to which route to take to work, to whether you should attempt a quarterback sneak on 4th and short, are all decisions humans make. Decision making (DM) is the process of making choices by identifying a decision, gathering information, and assessing alternative resolutions (Lunenburg, 2010). In research, decision making is routinely examined as either group decision making, or individual decision making. In group decision making, multiple individuals work together to analyze a question or problem, consider alternative choices, and make a choice (Belovicz et al., 1968, p. 73), while individual thinking involves a seven step process in which one must identify a decision is needed, gather

relevant information, identify any applicable alternatives, weigh the evidence surrounding these choices, choose among the choices, take action, then reevaluate the situation and adjust accordingly (Alexander, 2012).

The group decision making process is usually marred by ‘groupthink’, a psychological phenomenon in which people strive to maintain cohesion and reach consensus within a group in order to maintain group harmony (Janis, 1985, pp. 43–44). While the group decision making process may be observed sporadically in fire and emergency settings, this research will focus on the individual DM process if the incident commander.

One way that humans make individual decisions is a concept known as bounded rationality, in which human decision-making deviates from perfect economic rationality due to limitations in mental capacity, available information, and time constraints (Jordão et al., 2020). Jordão et al. (2020) further state that instead of striving for the "best" choices, humans often settle for satisfactory ones. Perfect rationality would demand that we are unaffected by cognitive biases, have access to all possible information about potential alternatives, and possess ample time to meticulously weigh the pros and cons of each option. Given the near impossibility of meeting these requirements, decision makers often resort to shortcuts, called heuristics, making decisions that provide a satisfactory outcome, even if they are not the most optimal.

Heuristics are mental shortcuts that are used to make decisions quickly and effectively (Giblin & Stefaniak, 2020, p. 103). Hayibor & Wasieleski (2008) define four common heuristics as the availability, representativeness, anchoring and satisficing heuristics. The availability heuristic guides judgments based on how easily one can recall examples of an event. This quick approach can be helpful on scenes of fires and emergencies, but it can also lead to biases, as decision makers may over or underestimate the likelihood of events based on personal exposure.

Another heuristic is the representativeness heuristic, which involves judging the probability of an event based on its similarity to an existing mental image or stereotype. This heuristic, while often useful, can also lead to erroneous judgments, as one may overlook instances that deviate from their preconceived notions. The anchoring heuristic anchors human judgments to the first piece of information they encounter. This heuristic can be particularly dangerous in emergency settings where the initial observations may not match the actual issue and can substantially impact the outcome.

To complement these decision-making tools, the satisficing heuristic guides towards accepting the first satisfactory solution encountered, even if it may not be the most optimal choice (Barberà et al., 2021). This heuristic proves particularly valuable in time-constrained situations such as fires and other emergencies where rapid intervention is often necessary. While heuristics serve as valuable tools for expediting decision-making, their inherent limitations demand cautious application and critical evaluation.

The challenges faced by ICs in making informed decisions under pressure are multifaceted. They must contend with the ever-changing nature of the incident, the unpredictable layout and structural integrity of buildings, and the ever-present threat of personal injury or death. Additionally, they must make decisions while factoring in limited information, time constraints, and the overwhelming stress of an emergency. Despite these challenges, the ability to make effective decisions remains paramount in ensuring the safety of firefighters, protecting property, and minimizing the impact of fires and other emergencies.

One major influence is the cognitive architecture of the Incident Commander. Our attention span, memory capacity, and susceptibility to biases like overconfidence or framing effects all influence how we process information and arrive at choices (Merabi & Kolabi, 2012,

p. 181). Emotions, too, play a potent role. Fear, excitement, or even the mere presence of others can influence us towards certain options, sometimes overriding logic (Gagnon & Monties, 2022, p. 84). An example of this is a common discussion around any firehouse kitchen table, using the scenario of fire suppression versus victim rescue in staffing limited situations. Understanding these factors is crucial for making informed decisions. By acknowledging the biases and limitations of our minds, we can learn to mitigate and reduce their influence. Recognizing the impact of the environment allows us to actively seek out contexts that enable clearer thinking.

AI DSSs have revolutionized decision making processes across a wide range of industries, transforming how organizations gather, analyze, and utilize data to inform critical choices. AI DSSs are sophisticated software applications that leverage the power of AI to extract valuable insights from vast amounts of data, providing decision makers with actionable intelligence to support their strategic and operational decisions (Daniela, 2019, p. 77).

The growing adoption of AI DSSs is driven by several key factors: the exponential increase in data availability, the rapid advancements in AI algorithms and hardware, and the growing demand for data-driven decision making (Börner et al., 2020). As private sector organizations collect and store more data than ever before, they are seeking ways to harness this information to gain a competitive edge and improve their overall performance. AI DSSs provides a powerful tool for analyzing this data, extracting meaningful patterns and trends, and generating actionable insights that can inform critical decisions, which can be used across the public sector spectrum.

In the realm of fire department operations, AI DSSs have emerged as a transformative force, holding immense potential to revolutionize the way fire departments operate and enhance their effectiveness in responding to emergencies. AI DSSs can introduce a new level of

intelligence, efficiency, and situational awareness to fire department operations, enabling Incident Commanders to make more informed decisions, optimize resource allocation, and improve overall safety (Longo, 2022).

AI DSSs can analyze vast amounts of data from various sources, including sensor networks, building information models, and weather data, to provide real-time insights into the nature of fire incidents (Aqeel et al., 2023). This information can be used to predict fire behavior, assess potential risks, and optimize firefighting strategies. CAL FIRE use of AI to detect wildfires was recognized as a Best Invention of 2023 by *TIME* (Dixit, 2023). AlertCalifornia utilizes AI to monitor over 1,000 cameras throughout the state to detect wildfires, allowing CAL FIRE to respond faster. AI DSSs can also assist in resource allocation, ensuring that the right resources are deployed to the right locations in a timely manner. Leveraging expertise from Columbia University engineers, and Fire Department of New York (FDNY) subject matter experts, a new ambulance system optimization process has been implemented within the FDNY's computer-aided-dispatch (CAD) system. This system, informed by an earlier collaboration with the NYC Department of Transportation (DOT) to analyze traffic data, employs an optimization algorithm to prevent ambulance overcrowding at specific hospitals while maintaining capacity at neighboring facilities (Columbia Engineering, 2021).

The implementation of AI is not without its challenges. Elliott et al. (2021, p. 180) wrote that “it is crucial that we carefully consider the development and deployment of AI technologies to ensure that they are designed and used in ways that align with ethical and social values”. There is a growing need to carefully consider the ethical implications of AI. While it has the potential to improve efficiency, transparency, and decision making, it also raises a number of ethical concerns and social challenges that must be addressed. These include privacy concerns,

ethical decision making, the role of humans in the AI chain of action, and more (Robles & Mallinson, 2023). AI safety issues have been raised across multiple fields, including healthcare and transportation (Winter & Davidson, 2019;Winter & Carusi, 2022).

Several studies have researched military use of AI, specifically regarding AI weapons and AI DSSs, raising fundamental ethical questions and strategic concerns. Pope (2022) highlights the potential for military decision-making by AI systems, surpassing the capabilities of human commanders. However, this power comes at a cost, prompting questions and concerns about accountability and the potential for unintended consequences, especially when human lives are at stake. Countering such a technological paradigm shift will require innovative strategies beyond existing doctrines, calling for unconventional thinking and a reimagining of traditional warfare tactics. Ultimately, the development and deployment of AI weapons necessitates a critical examination of the ethical boundaries of such systems.

Synthesis of the Existing Literature

Effective decision-making is a cornerstone of successful fire service command. Incident commanders face a multitude of challenges in making informed decisions under the immense pressure of rapidly evolving emergency situations. Leadership plays a pivotal role in shaping the course of emergency response, ensuring the safety of firefighters, protecting property, and minimizing the impact of fires and other emergencies. Effective fire service leaders not only possess strong technical skills and tactical expertise but also demonstrate exceptional decision-making abilities under intense pressure.

The decision-making process in the fire service is characterized by its complexity, uncertainty, and time constraints. Incident Commanders must contend with rapidly evolving incident situations, limited information, and the ever-present threat of personal injury or death.

They must weigh factors such as fire behavior, building construction, resource availability, and potential risks to make informed choices that can have profound consequences. Despite these challenges, Incident Commanders must be able to make sound decisions under pressure in order to effectively manage fire incidents. Effective fire service leaders possess numerous qualities such as experience, intuition, and judgment that help them make informed decisions in these challenging situations.

AI has emerged as a transformative force in various industries, and its potential to revolutionize fire department operations is immense. AI DSSs can empower Incident Commanders with real-time data analysis, optimized resource allocation, and enhanced situational awareness, all of which contribute to more effective decision-making under pressure.

Summary

In conclusion, fire service Incident Commanders, the decision-making process, and AI are all interconnected themes that are essential for effective fire department operations. Effective fire service leaders possess qualities that help them make informed decisions under pressure, and AI has the potential to revolutionize the way that fire departments make decisions. As AI technology continues to develop, it is likely to play an increasingly important role in helping fire departments protect the public from fire.

Chapter 3: Methodology

Fire departments face increasingly complex challenges, requiring them to adapt and adopt new technologies to improve efficiency and effectiveness. AI DSSs have emerged as promising tools for enhancing firefighter safety, situational awareness, and emergency response capabilities. However, the feasibility of implementing and integrating AI DSSs into fire department operations remains a critical question.

The purpose of this research is to investigate the feasibility of employing AI DSSs in Philadelphia Fire Department operations and explore the challenges associated with its implementation. While the quantitative and mixed methods approaches have their own strengths and limitations, qualitative methods are particularly well-suited for this research.

Through a qualitative approach, the research will gather insights from key stakeholders, including firefighters and AI industry experts, to understand their perspectives, experiences, and concerns regarding AI DSSs adoption. The following research questions will be used to guide this research:

- What are the challenges and opportunities for the use of AI DSSs in fire department operations?
- How can a comprehensive AI decision support system for fire department operations be developed and evaluated?
- How can AI DSSs be designed to support firefighters in their decision-making process?

The intent of this research is to understand the current state of AI DSSs development and application in the fire service, investigate the potential benefits and limitations of AI DSSs for fire department operations, explore the challenges and barriers associated with implementing AI

DSSs in fire departments, and identify key considerations and recommendations for successful AI DSSs implementation.

Research Design

A qualitative research approach will be employed to investigate the feasibility and challenges of AI DSSs implementation within the Philadelphia Fire Department. This approach allows for in-depth exploration of the experiences, perceptions, and perspectives of various stakeholders involved in the implementation process. Kostere(2021) writes that the qualitative approach is useful when attempting to understand the human experience, and how people construct meaning interrelated to themselves, others social situations and world occurrences. The research focuses on a single fire department that is in the process of implementing an AI DSSs and explores the experiences, perceptions, and perspectives of various stakeholders involved in its use. This approach offers an in-depth understanding of the complexities and nuances surrounding AI DSSs implementation in a real-world setting.

The qualitative method was selected over the quantitative and mixed methods approach for a number of reasons. The quantitative method allows for large scale analysis of datasets that can be used to identify patterns and relationships between variables, such as correlations between AI DSSs use and response times. The quantitative findings can also be generalized to a wider fire department population if the sample size is appropriate. Quantitative methods also allow for statistical tests and hypothesis testing, providing strong evidence for causality. The quantitative approach is limited in that because it focuses on numbers and not experiences, the research may miss the nuanced experiences and perspectives of the firefighters and other stakeholders (Almeida et al., 2017, pp. 382–383). Quantitative data often lacks context and may not capture

the complexities of real-world fire department operations and may not provide insights into the complex decision-making processes incident commanders use with AI DSSs.

A mixed methods approach combining both quantitative and qualitative data would provide a more comprehensive understanding of the research question by combining quantitative data on outcomes with qualitative data on experiences and perspectives. It also allows for cross-checking and validation of findings from different data sources, increasing the overall reliability of the research, while also providing contextual understanding and a richer understanding of the context in which AI DSSs is used, including organizational culture, training, and individual differences(Creswell & Creswell, 2017).

The increased complexity of a mixed methods approach is a limitation, requiring expertise in both quantitative and qualitative methods, as well as careful planning and integration of data. Creswell & Creswell(2017) also note that combining data collection and analysis from multiple methods can be time-consuming and resource-intensive, and requires careful attention to potential bias in both data collection and analysis.

While quantitative and mixed methods offer valuable insights, a qualitative approach is particularly well-suited for studying the potential uses of AI DSSs in fire department operations for several reasons. The primary goal of this research is to understand how firefighters, incident commanders and other stakeholders experience and perceive AI DSSs integration. Qualitative methods, such as interviews and focus groups, are ideal for capturing these subjective experiences and perspectives. Qualitative methods allow researchers to explore the nuanced thought processes and reasoning behind critical decision-making processes, particularly when interacting with AI DSSs (Morse, 2003, p. 844). Qualitative methods are more flexible and

adaptable, allowing researchers to dive further into unexpected findings and discover new questions and insights that may not have been captured by quantitative research alone.

Population and Sample Size

The Philadelphia Fire Department (PFD) consists of 3,000 members assigned to either fire operations, EMS operations, or administrative staff. PFD fire suppression personnel hold the following civil service ranks: firefighter/EMT; lieutenant; captain; battalion chief; deputy chief; assistant chief (*Philadelphia Fire Department*, n.d.). To capture the multifaceted perspectives on this transformative technology, the research encompasses a diverse target population, including firefighters, incident commanders, and individuals with expertise in AI development, data analysis, and policymaking. Each of these groups have crucial perspectives on the potential uses of AI DSSs in fire department operations. Interviewing a diverse range of stakeholders provides a comprehensive grasp of the topic, encompassing practical realities, technical challenges, and policy implications.

Firefighters and incident commanders were chosen because they are directly involved in emergency response and decision making, offering insights into challenges, needs, and potential benefits of AI DSSs integration. Care is taken to select a population composed of new members, mid-career members and veteran members, from both operational and staff positions. This will allow for a more complete understanding of the operational picture. They can share valuable feedback on the usability, effectiveness, and potential improvements for implementing AI DSSs tools in actual fire department operations and can articulate their apprehensions and hopes as it relates to AI DSSs in fire operations.

AI Developers and data analysts can provide insights into the capabilities and limitations of AI DSSs technologies relevant to fire department operations and can also explain how data is

used to train and refine AI DSSs systems, addressing potential concerns about data privacy and bias. They can further offer suggestions for effective collaboration between developers and fire department personnel for designing and implementing user-friendly and efficient AI DSSs solutions.

Policymakers allow for insights into the broader context of policy and other considerations regarding AI DSSs. They can discuss the ethical considerations, regulations, and resource allocation requirements, as well as the policy development and infrastructure needed to support the success and sustainability of AI DSSs. This inclusive approach ensures the researcher hears from those directly impacted by AI DSSs on the front lines, as well as those shaping its development and implementation at a strategic level.

A purposive strategy approach will help the researcher select participants with a variety of experiences. Purposive sampling is a sampling technique in which a researcher relies on his or her own judgment when choosing members of the population to participate in the study (Morse, 2003, p. 39). This method allows the researcher to select participants with specific characteristics relevant to the research questions (Tongco, 2007, p. 147). The desired sample size is 10-15 participants for each group. Qualitative research aims for depth and richness of understanding, not necessarily representativeness of a larger population. This allows for smaller, purposive samples to provide diverse and informative perspectives relevant to the research question. A key principle guiding sample size in qualitative research is saturation. This means reaching a point where no new themes, insights, or perspectives emerge as more data is collected (Kostere & Kostere, 2021). With 10-15 participants interviewed for this research, similar themes tend to recur and additional interviews offer diminishing returns.

Abrams (2010, p.540) writes that purposive sampling refers to strategies “in which the researcher exercises his or her judgment about who will provide the best perspective on the phenomenon of interest, and then intentionally invites those specific perspectives into the study”. Purposive sampling involves strategically selecting the most insightful, relevant, and diverse data available. This allows researchers to gain deep understanding by carefully piecing together the puzzle, supported by compelling evidence. Researchers intentionally choose individuals, locations, documents, or artifacts that best contribute to the research. In this research, firefighters from various stations and ranks will be selected, ensuring representation of different operational contexts and career stages. Similarly, AI developers, data analysts, and policymakers with diverse backgrounds and perspectives on AI technology and its potential within the fire service will be approached.

By carefully considering the target population, sampling strategy, and recruitment methods, the research aims to gather a rich and nuanced dataset that reflects the multifaceted realities of AI DSSs implementation within the fire service. This diversity of opinions will be instrumental in informing the research findings and contributing to the responsible and effective development of AI technology for firefighter safety and emergency response effectiveness.

Instruments

This research relies solely on structured interviews as its primary data collection method. Structured interviews offer a robust and focused approach to gather rich insights into the complex landscape of AI DSSs.

Semi-structured interviews offer an intimate space for individual participants to share their personal experiences, insights, and concerns regarding AI DSSs. As a research collection method, interviews allow for in-depth exploration of the participants' experiences, thoughts, and

motivations, providing detailed data that is not easily captured through other research methods. Interviewers can adapt their questions and follow-up prompts to dive deeper into unexpected insights or clarify responses. Interviews also provide a unique perspective of personal experiences, which can be valuable in exploring subjective experiences.

Interview data is inherently subjective and prone to interviewer and participant bias (Creswell & Creswell, 2017, p. 264). This can be mitigated through careful sampling, training, and data analysis practices. The interviewer's own biases and expectations can influence participant responses, requiring careful self-awareness and reflexivity throughout the research process (Creswell & Creswell, 2017). Participants may not recall events or experiences accurately, leading to potential inaccuracies in the data. Conducting and analyzing interviews can also be time-consuming and resource-intensive, requiring careful planning.

Utilizing interview guides, this research will explore areas such as the perceived benefits and challenges, integration concerns, and expectations for future development. These in-depth conversations allow for nuanced understanding and uncover deeper dimensions of individual perspectives that may not be observed in group settings. See Appendix B for the structured interview guide.

Observations of AI DSSs implementation and use in real-world fire department operations will be conducted if feasible. Observing how firefighters interact with AI DSSs in real-time can reveal valuable insights and practical applications not captured through interviews or surveys. This could include witnessing how AI DSSs guide tactical decisions during emergencies, observing how AI DSSs features, such as task automation and optimization, can help streamline tasks and improve efficiency, and seeing how AI DSSs facilitates access to relevant data in high-pressure situations.

Through the complementary use of these instruments, the research hopes to gather a comprehensive understanding of the data encompassing individual narratives, collaborative dialogues, and diverse perspectives. This multifaceted approach ensures a complete understanding of the complex challenges and promising opportunities surrounding AI DSSs within the fire service, with the end goal of being used as a document that informs fire department executives of its possible effective integration for enhanced firefighter safety and emergency response effectiveness.

To assess the real-world efficacy and user acceptance of the AI decision support system, a rigorous field-testing program was implemented within the PFD. The interview guide was tested on three subject matter experts on urban firefighting operations during a workshop session for an upcoming decision support system being utilized within the department. The SMEs underwent comprehensive training on the system's functionalities and limitations, ensuring informed usage during test operations. Observations were made throughout the testing period, encompassing system recommendations, firefighter decisions, incident details, and post-incident surveys, which were then referenced to ensure a comprehensive interview guide. Semi structured interviews throughout the process provided valuable insights into the system's integration within the department's operational culture and potential areas for improvement. Through this field testing, the research discovered potential for the effectiveness and acceptability of the AI decision support system within the PFD.

Research Process

This research will be conducted in four phases designed to capture the complexities of data collection and analysis, followed by dissemination.

Before research can begin, groundwork is crucial. Initial steps involve securing approvals from the Philadelphia Fire Department and relevant ethics committees. Subsequently, interview guides are designed, along with an interview guide for consistency and open-ended questions to elicit strong data. The interview questions were field tested among subject matter experts for accuracy and relevancy. An observation protocol will document key aspects of AI DSSs implementation and use, focusing on specific response phrases, behaviors, and interactions. Finally, participant recruitment utilizes purposive sampling to ensure diverse perspectives.

With the foundation established, the research moves into data collection. Individual semi-structured interviews will provide a platform for firefighters and AI experts to share their personal experiences, perceptions, and opinions regarding AI DSSs implementation. These interviews will be scheduled for approximately one hour and will occur in person or over a web-based video conferencing product. Each participant will be provided with a consent form outlining the research, the protection of their identity, the confidentiality of their answers, and advised that they may withdraw from the interview at any point.

The raw data is transformed into insightful knowledge in the next phase. Audio recordings are transcribed, providing a textual representation of interviews. The transcription will be conducted utilizing Microsoft Teams transcription function, then verified by the researcher against the audio recording for accuracy. The transcribed data will be systematically coded using thematic analysis, identifying recurring themes, patterns, and categories across participants' experiences and perspectives. To facilitate this process, qualitative data coding software plays a vital role, allowing for effective data management and analysis. Identified themes will be refined and developed, exploring their relationships, nuances, and variations within the data. Incident-by-incident coding will be used, as opposed to line-by-line coding, to

capture the broader context and meaning within each participant's response. This approach is particularly suitable given the interview guide's design, which aims to elicit extended narratives rather than isolated sentence-level responses (Kostere & Kostere, 2021). Qualitative data coding software, in this case ATLAS.ti, was used to enhance the analysis by streamlining coding, organizing data, and offering deeper insights through visualization. The software allows the researcher to quickly identify key themes, comparing them across participants, and visually exploring relationships. The researcher's critical thinking remains essential for unlocking the true meaning within the data. To enhance the validity and reliability of the research, findings from different data sources and methods will be compared, providing a more robust and multifaceted understanding. Finally, to uphold research integrity, member checking involves revisiting findings with participants, ensuring data credibility and trustworthiness.

The culmination of the research ends with dissemination. A comprehensive research report summarizing findings, conclusions, and recommendations will be crafted. Finally, the research results will be shared directly with the Philadelphia Fire Department and stakeholders ensuring that the knowledge gained translates into tangible progress, paving the way for the responsible and effective integration of AI DSSs into fire department operations.

Ethical Considerations

Maintaining transparency is crucial to minimizing the risk of bias influencing this research. The researcher is a member of the PFD and is familiar with a majority of research participants. While the PFD is one of the largest departments in the country, it is still a small community with a lot of personal familiarity. This tight-knit nature presents the risk of "deductive disclosure," where readers or fellow researchers can identify interviewees based on geographic details, storytelling style, or other unique identifiers within the research findings. As

Kaiser (2009) emphasizes, this breach of confidentiality, even if unintentional, can occur when specific interview data published in the study allows for participant identification. The argument goes even further, suggesting that no research outcome, regardless of its potential benefit, should compromise participant anonymity. Therefore, researchers studying this community must prioritize confidentiality by critically evaluating their audience and implementing measures like name changes, location obfuscation, and other detail modifications. These actions ensure the protection of participant identities while still allowing for the valuable presentation of research results.

The personal and operational relationships that are established are at a minimal risk of influencing this research due to the nature of the topic. Maintaining confidentiality and respecting professional boundaries is paramount. The researcher should avoid projecting any experiences onto participants or allow the participants to influence data analysis.

This research prioritizes ethical considerations at every stage, recognizing the importance of protecting participants and upholding the integrity of the data. To minimize bias, a diverse group of participants will be recruited, encompassing various ranks, assignments, and experience levels within the Philadelphia Fire Department. This ensures a multifaceted perspective and avoids corrupting the results towards any specific viewpoints. To further mitigate bias, interview and focus group guides will be carefully crafted to be neutral and use open-ended questions. This allows participants to freely express their experiences and perspectives without being influenced by preconceived notions.

Transparency and informed consent are central to this research. Participants will receive detailed informed consent forms clearly outlining the research's purpose, procedures, potential risks and benefits, and their right to participate or withdraw at any time. Additionally, open and

transparent communication will be maintained throughout the research process, addressing any questions or concerns participants may have.

Confidentiality is paramount. All personally identifiable information (PII) will be secured with stringent measures. Data will be password-protected, stored securely, and accessible only to authorized researchers. The data will be retained securely for a period of four years, after which it will be destroyed. Participant anonymity will be further protected by assigning pseudonyms to all data and recordings. Any participant quotes shared in publications will not contain PII.

Finally, ensuring objective data analysis and interpretation is critical. To safeguard against misinterpretations or personal biases, neutral and unbiased analysis methods will be employed. Additionally, the researcher will leverage ongoing participant feedback for clarification and validation, as well as the thorough practice of member checking to ensure the accuracy and reliability of our findings. Through these measures, this research strives to be both ethical and informative. Protecting participants, guaranteeing data integrity, and promoting accurate interpretations are fundamental to producing trustworthy research that can meaningfully contribute to the responsible integration of AI DSSs in fire departments.

Summary

This capstone researches the complex realities of AI DSSs implementation within the Philadelphia Fire Department. Employing a multi-method research design, the research leverages a rich pool of data to capture diverse perspectives and contexts. Through in-depth interviews and real-world observations, the research will explore the experiences, perceptions, and challenges surrounding AI DSSs adoption from groups, including firefighters, fire department executives, AI industry subject matter experts and policymakers.

To ensure a comprehensive understanding, the research targets a broad population encompassing firefighters, Incident Commanders, AI developers, data analysts, and policymakers involved in AI DSSs implementation and use. Purposive sampling strategies will be employed to select participants with diverse backgrounds, ranks, and stations within the fire department.

Data collection utilizes a multifaceted approach. Semi-structured interviews look at individual perspectives, while focus groups observe shared experiences and foster collaborative discussions. Direct observations offer valuable insights into practical applications and challenges of AI DSSs implementation in real-world settings. To ensure data quality and validity, rigorous analysis will be employed. Thematic analysis will identify recurring themes and patterns, while qualitative data coding software can facilitate data management and coding. A coding framework developed based on research objectives and key themes will ensure an organized analysis, and triangulation across data sources will further strengthen the research's reliability. Ethical considerations will remain paramount throughout the process. Measures to minimize bias include diverse participant selection, neutral interview guides, and avoidance of preconceived notions. Transparency and integrity are upheld through detailed informed consent forms, while confidentiality is ensured by securing PII, password-protecting recordings, and restricting access to authorized researchers. Objective data analysis and interpretation are emphasized through ongoing participant feedback, member checking, and the use of neutral and unbiased methods.

By meticulously employing this multi-faceted methodology, the research hopes to unveil the nuanced realities of AI DSSs integration within the Philadelphia Fire Department. The insights gained will inform responsible and effective implementation practices, ultimately contributing to enhanced firefighter safety and emergency response effectiveness.

Chapter 4: Study Results

Introduction – Demographics of the Participants

A total of 12 Philadelphia Fire Department members participated in interviews exploring perceptions of artificial intelligence decision support systems. The sample possessed substantial cumulative expertise with over 165 years of combined fire service experience represented. Participants had an average of 13.75 years of experience and represented a range of ranks across the Operations Division, which is responsible for fire suppression and all-hazards response. A brief profile of participant demographics is provided in Figures 1, 2 and 3 below.

Figure 1

Primary Participant Role

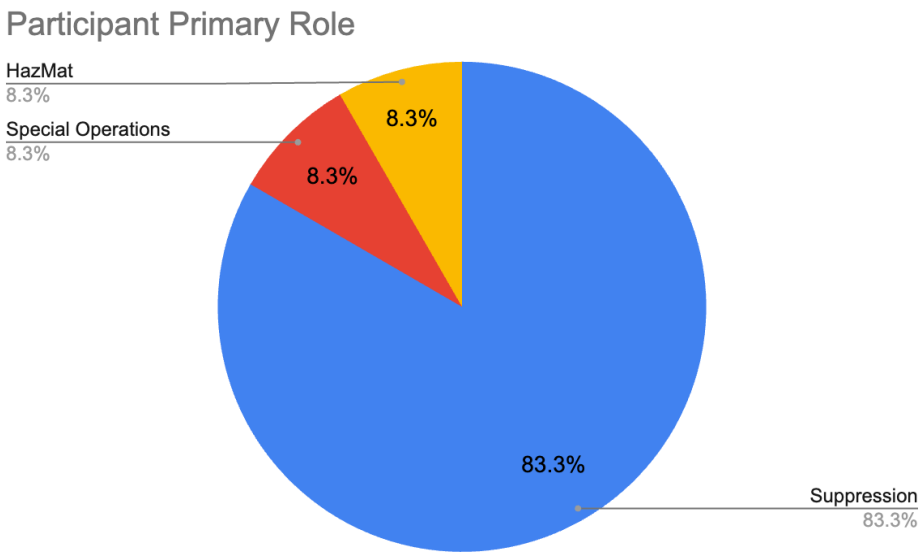


Figure 2

Participant Ranks

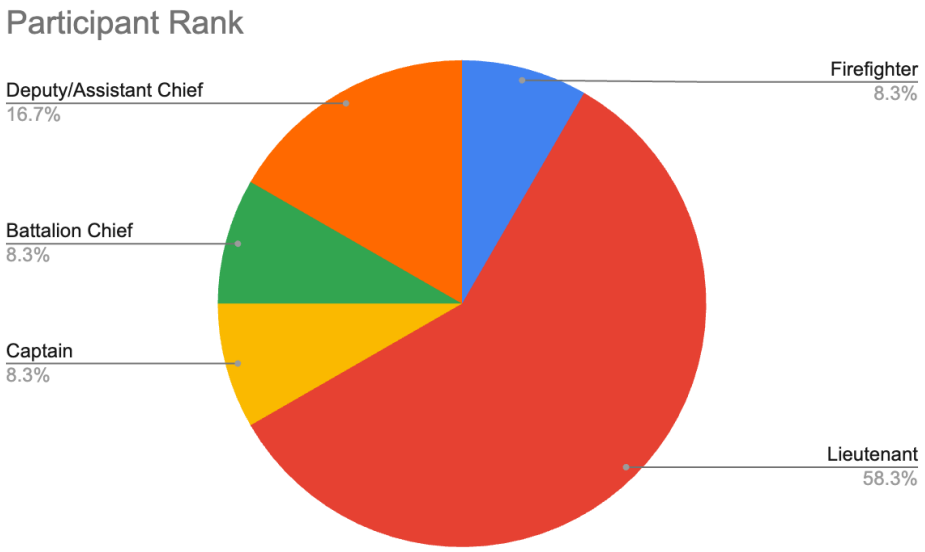
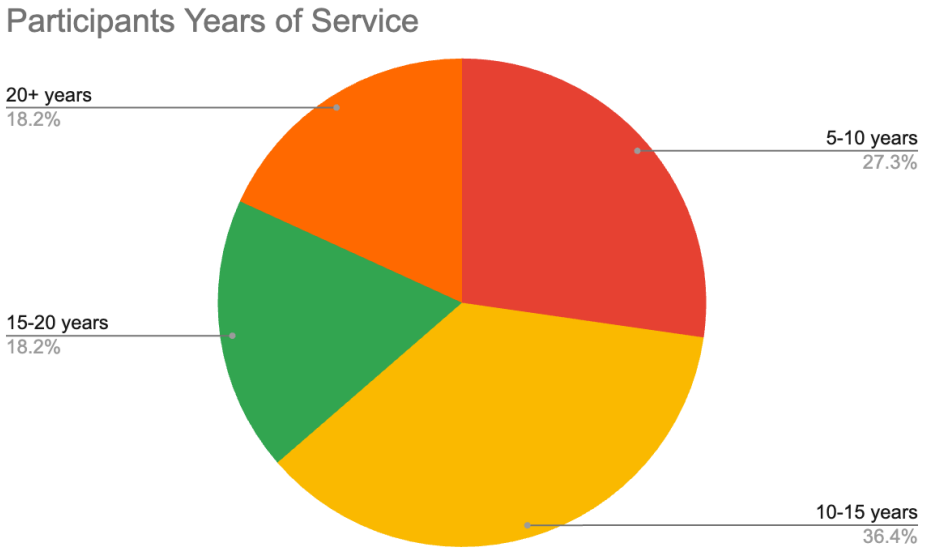


Figure 3

Participant Years of Service



Research Results

Responses yielded important qualitative insights around both opportunities and challenges related to effectively leveraging AI capabilities within fire operations. Answers to the research questions are supported by detailed results from these structured interviews. An interview guide was used to guide discussion and is provided as appendix B.

Regarding the challenges and opportunities for the use of AI Decision Support Systems in fire department operations, over 70% of participants identified cultural reluctance and technology avoidance as key barriers to adoption, with prevalent sentiments around significant change management needs. However, 82% of respondents emphasized AI's potential to enhance information and situational awareness, with building data, real-time alerts, and task automation noted as high-value capabilities.

When asked about developing and evaluating a comprehensive AI Decision Support System for fire department operations, all participants indicated the need for input from diverse department stakeholders during development to ensure relevance. More than 60% advised a phased piloting approach, focusing on non-critical applications first. Participants recommended gradual expansion contingent on perceived utility rather than immediate large-scale implementations.

Concerning the design of AI DSSs to support firefighters in their decision-making process, over 80% of participants noted the need to surface information without distracting or overwhelming users. They highlighted the importance of visual elements, clear communication of insights, and an emphasis on supporting rather than supplanting user analysis.

The findings indicate that members of the PFD recognize the potential of AI, but this is tempered with concerns about reliance and adoption of the technology. Slow integration that

allows combining experience and expertise is preferred over rapid replacement of knowledge and skills built through experience. Participants had concerns and suggestions that can provide a roadmap for the field use of AI's theoretical capabilities into practical fire service decision support.

Theme 1: Culture and Buy-In Are Key Challenges

The interview responses revealed culture change and adoption as central challenges in integrating AI in PFD operations. Participant K described the Philadelphia Fire Department as "very traditional and very non-technology dependent, a better way to describe it would be technology-resistant." Sentiments highlighting cultural reluctance toward embracing new technologies were common, with over 70% of respondents indicating this barrier. Integrating AI represented a massive transition from long reliance on legacy systems that members may oppose. Participant J emphasized deeper issues around universal adoption, stating "I think the biggest issue we have is that everybody needs to be on the same page. We can't have people doing what they wanna do." Concerns exist that some may utilize and value AI assistance while others disregard it, preventing cohesive implementation.

While no participants framed this culture barrier as insurmountable, all addressed the need to proactively address it. Suggested solutions centered on early and extensive inclusion of input from diverse department stakeholders in both development and implementation phases. As Participant K explained, "If every level isn't involved from the start it would be maximally difficult to achieve buy-in in such a technology resistant department. Inclusion helps to breed acceptance when acceptance would otherwise prove difficult." Further proposals involved starting AI expansion with administrative and non-critical functions to gently acclimate members

and avoid immediate high-stakes reliance. Despite recognizing predictable cultural reluctance toward rapid change, respondents identified realistic integration methods to obtain firefighter buy-in provided the systems tangibly add value.

Theme 2: Enhanced Information and Situational Awareness Are Major Opportunities

The potential for AI to enhance information access and improve situational awareness stood out as a major opportunity in the interview findings. Participant K encapsulated an optimistic perspective, stating "I think we're facing a brave new world when it comes to that level of technology in this department but it is exciting and has a tremendous amount of potential if it is properly embraced." This viewpoint on AI opening new possibilities was predominant across the sample.

In particular, over 80% of participants emphasized the value of additional data on factors like building stability, integrity, and construction; real-time visibility into member locations; hazard and occupancy details; and analytics to guide resource allocation. As a participant noted, "I think a variety of factors being considered could support the decision of whether or not committing personnel to an interior attack is appropriate." Participants saw promise in surface level automation of administrative tasks but even more potential in sophisticated decision support insights during emergency response. One participant explained that "Having to make decisions with limited information is the most serious challenge I face on the daily. Blind decision making, as in literally blind in zero-visibility environments and an unknown battlespace can be very limiting." Addressing this information gap was raised repeatedly as a high-value application of AI capabilities.

Additionally, several respondents focused on physiological monitoring and alerts through emerging biometrics and sensors. Participant A stated, "Our packs are coming up with new technology that AI might be integrated in our pack to tell me, hey, this is what's going on. You're not sensing this, and it might actually make us safer in the long scheme of things." Again, the theme of increasing situation awareness to empower risk assessments emerged in relation to AI opportunities. With possibilities spanning pre-emergency planning, real-time emergency response data, training insights, and safety accountability, participants displayed notable openness to AI as an information multiplier.

Theme 3: Start Slowly and Demonstrate Value

Sentiments around pacing AI adoption gradually to establish effectiveness emerged as another key qualitative finding. Multiple interviewees explicitly cautioned that “We can’t rush this or trust will be lost easily.” Reflecting concerns about resistance, participants emphasized methodical introductions focused on tangible value over speed. A participant recommended “Allowing for public constructive discourse and providing complete transparency with regard to the reasoning behind putting such a system into place would be most important.” Calls for open information sharing further highlight the perceived need to bring members along throughout the process.

Related recommendations centered on phasing expansions while building buy-in. Beginning AI initiatives administratively and assessing impacts before transitioning to emergency response settings was raised by over 60% of participants. As Participant K stated, “I would love to see as much pertinent information as possible be pushed to the first-in company

officer while enroute to an emergency and a broader scope provided to the IC.” This quote illustrates starting with a narrow use case of information sharing before expanding AI’s scope.

Theme 4: Maintain Human Decision Authority

Perspectives emphasizing that human judgment should remain central in emergency operations also emerged as an overriding theme. Participant L asserted that regarding who is responsible for making final decisions in a fire emergency with AI information available, the responsibility falls to “the incident commander. With or without AI, the actions implemented on the fire ground will fall on the IC. An educated and proven fire ground commander could use AI to their advantage while also using his experiences to dictate decisions."

This quote from Participant L reinforces the theme around human accountability and command authority in emergency operations. It aligns with the existing quotes on the primacy of the incident commander's judgment, emphasizing they cannot defer entirely to AI systems. The quote stresses the importance of an active, evaluative role for the IC rather than a passive, rubber-stamping function. It fits well with the theme of maintaining human oversight over final decisions.

Expanding on this theme, Participant L noted that “If we use this technology to our advantage in an administrative or fire prevention role it can notify the fire department quicker. It is currently being used in the wildland sector as an early notification for fires where manned fire towers once did.” This statement highlights appropriate assistive applications versus autonomous response. Participant J also explained that "I look at AI as a tool. It's just another tool with more data that helps me make a decision what the decision is still mine.” Again, the emphasis lies in augmentation, not automation in relation to emergency operations and accountability.

Participants also raised the need to safeguard against over-reliance on AI insights. As Participant K asserted, “The reliance on AI with the elimination of the boots-on-the-ground assessment could end up being severely detrimental. If an assessment is going to involve AI it needs to be holistic and the human intelligence needs to be considered also.” Maintaining situational awareness, critical analysis, and decisiveness irrespective of AI recommendations emerged as an important check on risks of complacency or loss of key skills.

Theme 5: Address Valid Fears Around Complacency

Apprehensions about increased reliance on AI and corresponding complacency were also evident in participant responses. One participant worried that “The reliance on AI with the elimination of the boots-on-the-ground assessment could end up being severely detrimental.” This concern over losing human perspective aligned with the majority stance on maintaining command authority. However, it further indicates fears that skills could erode if AI assumes key evaluative functions. Over 60% of participants surfaced similar concerns around risks of over-dependence on data-driven recommendations.

As Participant J cautioned, “You don't want somebody to just get the tunnel vision and just book for answers off of that, because that could be detrimental to all if somebody comes out and says, let's just use that all the time.” This statement points to the double-edged sword of information abundance – while AI can enhance situational awareness, it could also limit scene assessment. Participants emphasized that domain expertise must remain actively practiced and valued. Participant F noted that “If we work with the City of Philadelphia and its ethics and standards while equally working with the PFD and Local 22, I believe we would be on the right

path.” Involvement of multiple oversight groups reflects desires to preemptively address fears through accountability and transparency measures alongside AI adoption.

Theme 6: Plan Extensive Training and Gradual Immersion

Perspectives related to training requirements also featured prominently with AI adoption seen as requiring extensive skill development alongside carefully paced integration. Participant E recommended "The introduction of such a system would have to include a careful and deliberate roll-out with a focus on the ability to provide our service more efficiently and in a safer manner." This statement aligns with other guidance emphasizing gradual onboarding. Participant B asserted that "I think one of the biggest challenges in implementing technology is our diverse amount of employees in their experience with technology." 80% of participants highlighted that assumptions could not be made about universal technology literacy and aptitude within the department.

Interviewees mentioned that varied experience levels would require tailored support. Participant G explained that "so I think for us it's important to use everybody from all walks of life and all you know levels of seniority within a department because not necessary to get more hands on it, to mix it up. But just to get more information… ." Comments reflected accessibility requirements for both digitally advanced and reluctant user groups. There was strong emphasis on hands-on interactions maximizing understanding. As Participant H noted, “Maybe the guy that has to use it, mirroring some scenario or things that have happened, but I think that they should go through it.” The ability to practice routine usage scenarios was positioned as imperative for trust in new AI systems.

Suggestions also focused on scaling training programs in proportion to the degree of reliance on the technologies. Participant F asserted if the systems take on more risky applications like physiological monitoring, then "a couple day to a week class" could be warranted. For surface level assists however, introductory demonstrations might sufficiently orient members. Recommendations centered on complementary integration of AI alongside existing protocols through interactive skill building.

Theme 7: Ongoing Skills Development Still Needed

The final theme evident in participant responses involved maintaining proficiency irrespective of AI adoption. As a participant explained,

> Experience is dwindling as fires are not as prevalent as they were for prior generations, and what training is available can only partially fill the gap that is left by that lack of experience. The use of data-driven AI has the potential to assist in filling that gap a little bit further and could revolutionize the way our business is done.

This quote encapsulates the opportunity to supplement decreasing exposure through technology while requiring ongoing education. Even given advanced capabilities, foundational expertise must remain central.

Elaborating on this view, Participant C noted, "we might make something simple, more complicated. So it all depends like you know, it might be too much info. You might have too much of a good thing" in discussing overload risks. This ties back to the imperative for members themselves to prioritize inputs through learned critical thinking. Participant C also warned of deskilling, stating "maybe the officers might know how to punch the buttons, but maybe they might not know the exact formulas of how they got there because they would be relying on the

technology to do the work for them." While not dismissive of AI supports, the respondent cautions over dependency. Participant B summed up the theme by asserting "we can't have robots going into these buildings and things of that nature. So you know, I think in conjunction with AI, and with the smart firefighters… I think we can kind of utilize both." The takeaway lies in complementing technology with know-how rather than substituting one for the other.

Summary

The interview findings reveal insights into firefighter perceptions of integrating AI DSSs. While AI opportunities exist, barriers around adoption and reliance must be addressed. Participants note that information enhancement capabilities in AI could strengthen emergency response and planning when used collaboratively. Concerns surfaced about overdependence leading to deskilled unaided assessment. Extensive training and phased adoption focused on tangible value were advised to ensure AI complements expertise. Cultural hesitance toward rapid change was evident. Recommendations centered on participatory development, demonstrating functionality for basic applications first before expanding to emergency contexts. Maintaining human accountability alongside AI assists was considered critical. The themes highlight a willingness to explore AI's potential if deployed gradually in information enhancement rather than experience replacement capacities. Further research around balancing technology with experience is warranted.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

Summary of Results

The structured interviews with 12 Philadelphia Fire Department members revealed several overarching themes regarding the potential integration of AI DSSs in fire operations. While participants acknowledged the opportunities AI presents, they also highlighted significant challenges that must be addressed for successful adoption.

One of the most prominent themes was the cultural resistance to change and technology within the department. Participants emphasized the need for extensive change management efforts and the inclusion of diverse stakeholders in the development and implementation processes to foster acceptance. Despite these challenges, the majority of participants recognized AI's potential to enhance situational awareness and provide valuable insights. They identified areas, such as building data, real-time alerts, and task automation as high-value applications. However, they also stressed the importance of designing AI systems that support decision-making without overwhelming or distracting users. Participants strongly advocated for a gradual, phased approach to AI integration, starting with non-critical applications and expanding based on demonstrated value. They emphasized the need for comprehensive training programs tailored to varying levels of technological proficiency within the department.

Another significant theme was the importance of maintaining human decision-making authority and accountability. Participants viewed AI as a tool to augment, rather than replace, human judgment and expertise. They cautioned against over-reliance on AI and highlighted the need to preserve critical thinking skills and situational awareness. Participants also expressed valid concerns about the potential for complacency and deskilling if AI assumes too many

evaluative functions. They stressed the importance of ongoing skills development and the need to complement AI with human expertise rather than substituting one for the other.

Overall, the themes identified in the structured interviews suggest a willingness among PFD members to explore the potential of AI, provided that its integration is carefully managed and its limitations acknowledged. The findings underscore the importance of a collaborative, transparent, and gradual approach to AI adoption that prioritizes human agency, accountability, and continuous learning.

Conclusions Based on Results

The study highlights the complex interplay between the recognized potential of AI to enhance firefighting operations and the significant concerns around cultural acceptance, overreliance, and skill maintenance. These findings underscore the importance of a nuanced, stakeholder-centric approach to AI implementation that goes beyond technical considerations to address the human dimensions of change.

The research reveals that successful AI integration in the fire service will require more than just deploying advanced tools; it will necessitate a fundamental shift in organizational culture and individual mindsets. The PFD, like many fire departments, has a proud tradition of relying on human expertise and judgment honed through experience. Introducing AI assistants represents a significant departure from this paradigm, and the study illuminates the need for careful change management to navigate this transition.

By shedding light on firefighters' hopes and fears surrounding AI, the findings provide a roadmap for designing AI systems that align with the unique needs and values of the fire service. The research suggests that AI tools should be developed and framed as decision support aids that complement rather than replace human skills. Emphasizing the continued primacy of firefighter

judgment while leveraging AI's data processing and pattern recognition capabilities can help strike the right balance.

The study also highlights the crucial importance of participatory design and collaborative implementation. Involving frontline firefighters, incident commanders, and other key stakeholders in the AI development process from the outset can help ensure that the resulting tools are relevant, trustworthy, and accepted. This collaborative approach can also help identify and address important ethical considerations around data governance, transparency, and accountability. Additionally, the findings underscore the need for extensive, ongoing training to prepare firefighters for effective AI collaboration. The research suggests that hands-on, scenario-based training tailored to varied technology comfort levels will be essential for building trust and proficiency. Equally important will be regular skill reinforcement to guard against deskilling and overreliance risks.

For the PFD, this study provides actionable insights to guide its AI implementation. By pursuing a phased, stakeholder-driven approach to AI integration, the department can harness the technology's potential to enhance situational awareness, resource allocation, and risk assessment while preserving the vital human judgment and expertise at the core of its mission. The findings can inform the development of AI governance frameworks, training programs, and performance evaluation metrics.

More broadly, the research contributes to the growing body of knowledge on responsible AI adoption in high-stakes public sector contexts. As other fire departments and emergency response agencies grapple with similar challenges, the lessons learned from the PFD's experience can serve as a valuable reference. The study highlights the importance of proactively engaging

with the human dimensions of AI integration and provides a template for doing so in a way that upholds organizational values and public trust.

As AI technologies continue to evolve, ongoing research will be crucial for understanding and optimizing their impact on fire department personnel. This study makes a significant contribution to the understanding of the complex realities of AI adoption in the fire service and presents a model for harnessing AI's capacity to improve public safety while respecting the invaluable human knowledge that forms the core of the fire service.

Limitations

While this qualitative study provides valuable insights into the perceptions of AI DSSs within the PFD, the limitations of the technology must be acknowledged. These limitations should be considered when interpreting the findings and assessing their broader applicability. One significant limitation of the study is its focus on a single fire department. The PFD, while a large and diverse organization, operates within a specific urban context and has its own unique culture, history, and challenges. As such, the findings may not be directly generalizable to other fire departments, particularly those serving smaller, rural, or suburban communities. The perceptions and concerns of PFD members regarding AI may differ from those of firefighters in other departments with different demographics, resources, and operational contexts.

Another limitation is the relatively small sample size of 12 participants. While this sample provided rich, in-depth qualitative data, it may not fully capture the range of perspectives within the PFD. The study could have benefited from a larger, more diverse sample that included a broader cross-section of ranks, roles, and demographics. For example, the sample was predominantly male, which, while reflective of the general gender composition of the fire service, may not adequately represent the views of female firefighters.

The study also relied on self-reported data gathered through interviews. While this approach allows for deep exploration of individual perceptions and experiences, it is subject to potential biases and limitations. Participants may have been influenced by social desirability bias, expressing views they believed were expected or acceptable rather than their true opinions. Additionally, the interviews captured perspectives at a single point in time and may not reflect how views could evolve as participants gain more exposure to and experience with AI technologies. The study also focused specifically on AI DSSs and did not explore perceptions of other types of AI applications in the fire service, such as predictive maintenance for equipment or automated dispatch systems. The findings may not be generalizable to these other AI use cases, which may present distinct challenges and opportunities.

Finally, the study was conducted in the context of the PFD's current level of AI adoption, which is still in its early stages. As the department progresses in its AI journey and more firefighters gain hands-on experience with these tools, their perceptions and attitudes may shift. The findings should be interpreted as a snapshot of views at a particular stage of AI implementation rather than a definitive assessment of firefighter perspectives.

Despite these limitations, the study makes a valuable contribution to the understanding of the human factors that shape AI adoption in the fire service. The findings provide a foundation for future research that can expand on this work by including a larger, more diverse sample of firefighters from multiple departments and exploring perceptions of a broader range of AI applications. Further studies that track how firefighter views evolve as AI technologies are integrated into daily operations could also provide valuable insights.

While the limitations of this study should be acknowledged, they do not diminish its significance in advancing the knowledge of the complex realities of AI adoption in the fire

service. The findings offer a rich, nuanced understanding of firefighter perspectives that can inform responsible AI implementation strategies and highlight areas for further exploration. As the fire service continues to navigate the challenges and opportunities presented by AI, ongoing research that builds on this work will be crucial for ensuring that these technologies are developed and deployed in a manner that enhances public safety while respecting the expertise and values of the brave men and women who serve their communities.

Implications and Recommendations to the Field

The findings from this study offer several important implications and recommendations for the fire service as it navigates the integration of AI technologies. First, the study highlights the need for fire departments to adopt a proactive, strategic approach to AI implementation. Rather than rushing to deploy AI tools without careful consideration of their impact on firefighters and organizational culture, departments should engage in a deliberate planning process. This process should involve assessing the specific needs and challenges the department hopes to address with AI, identifying the most appropriate AI applications, and developing a phased implementation roadmap that prioritizes building trust and demonstrating value.

A key recommendation is to involve frontline firefighters and other key stakeholders in the AI planning and development process from the outset. The study underscores the importance of participatory design in ensuring that AI tools align with the practical needs and concerns of those who will be using them. By engaging firefighters as active partners in shaping AI implementation, departments can foster a sense of ownership and buy-in that will be critical for successful adoption.

Another important implication is the need for fire departments to invest in comprehensive training and skill development programs to prepare firefighters for effective collaboration with

AI. The study suggests that training should go beyond technical instruction on how to use AI tools and also address the cognitive and cultural dimensions of working with these technologies. This could include scenario-based training that helps firefighters understand how to interpret and apply AI-generated insights in real-world contexts, as well as discussions of the ethical and philosophical implications of relying on AI in high-stakes decision-making.

The findings also highlight the importance of framing AI as a tool to augment and support human expertise rather than replace it. Fire departments should emphasize that AI is not intended to substitute for firefighters' judgment and experience but rather to provide an additional layer of information and analysis to inform decision-making. By marketing AI as a collaborator rather than a competitor, departments can help mitigate concerns about deskilling and overreliance while still leveraging the technology's potential to enhance situational awareness and risk assessment.

Another key recommendation is for fire departments to establish clear governance, frameworks, and policies around AI use. The study suggests that firefighters have significant concerns about issues such as data privacy, algorithmic bias, and accountability for AI-assisted decisions. To address these concerns, departments should develop transparent guidelines for data collection, storage, and use, as well as mechanisms for monitoring and auditing AI systems to ensure they are operating as intended. Regularly communicating with firefighters and the public about these governance measures and involving them in ongoing discussions about AI ethics and oversight can help build trust and confidence.

Finally, the study underscores the importance of collaboration and knowledge-sharing across the fire service as departments navigate the challenges and opportunities of AI adoption. Fire departments should actively seek out opportunities to learn from the experiences of other

organizations that have successfully integrated AI and to share their own lessons learned. Engaging in open dialogue and collaboration can help the fire service to develop best practices and standards for responsible AI use that prioritize the safety and well-being of both firefighters and the communities they serve.

Recommendations for Future Research

The scope of this research was limited to a small sample size within a single fire department. To further advance the understanding of the implications of AI in the fire service, several avenues for future research should be explored.

First, expanding the study to include a larger and more diverse sample of firefighters from multiple departments across different geographical regions would provide a more comprehensive understanding of the perceptions and challenges associated with AI adoption. This would allow for the identification of common themes and variations across different fire service cultures and operational contexts.

Second, future research could dive deeper into the specific applications of AI that hold the most promise for enhancing firefighter safety and operational effectiveness. This could involve conducting targeted studies on the impact of AI-powered tools in areas such as building data analysis, real-time monitoring, and resource allocation. By focusing on specific use cases, researchers could develop more tailored recommendations for AI implementation and training programs.

Third, long term studies that track the implementation and impact of AI systems over time would provide valuable insights into the long-term effects of AI adoption on firefighter decision-making, skills development, and organizational culture. Such studies could help identify

best practices for managing the integration of AI and mitigating potential risks associated with over-reliance or deskilling.

Fourth, interdisciplinary research collaborations between fire service professionals, AI experts, and human factors specialists could yield innovative approaches to designing AI systems that effectively support human decision-making while minimizing cognitive load and distraction. Such collaborations could also explore the ethical implications of AI in high-stakes emergency response contexts and develop guidelines for responsible AI development and deployment.

Finally, future research could investigate the potential for AI to support training and skills development in the fire service. This could include the development and evaluation of AI-powered simulation tools, adaptive learning platforms, and personalized feedback systems that help firefighters maintain and enhance their expertise in an era of increasing technological complexity.

By pursuing these avenues for future research, scholars can contribute to a more nuanced understanding of the opportunities and challenges associated with AI integration in the fire service. The knowledge gained from such studies will be invaluable in guiding the responsible and effective adoption of AI technologies that ultimately support the mission of protecting lives and saving property.

Conclusions

In conclusion, this study provides valuable insights that can guide fire departments in their efforts to harness the potential of AI while addressing the very real concerns and challenges associated with these technologies. By adopting a proactive, collaborative, and human-centered approach to AI implementation, and by investing in ongoing training, governance, and knowledge-sharing, the fire service can position itself to leverage AI in a way that enhances its

mission to protect lives and property. As AI continues to evolve and become more integrated into firefighting operations, ongoing research and dialogue will be essential for ensuring that these powerful tools are developed and deployed in a manner that aligns with the values and expertise of the fire service.

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Appendix A: Field Testing of Questions

The following individuals were solicited to assist in field testing the questions for the structured interviews and all have given permission to have their names published in this document:

DC Anthony Bompadre
St Joseph's University
Master of Science - Public Safety Administration
Philadelphia Fire Department

BC John Calamia
Anna Maria College
Master of Public Administration - Fire & Emergency Services
Upper Darby Township Fire Department

CAPT Timothy DiNardo
Neumann University
Bachelor of Science - Public Safety Administration
Philadelphia Fire Department

The researcher appreciates the time and effort of the field testers in assisting with the development of the interview questions.

Appendix B: Interview Questions

Structured Interview Guide: Exploring AI Decision Support Systems in the Philadelphia Fire Department

Introduction:

Thank you for taking the time to participate in this interview. This research aims to understand how firefighters perceive the potential integration of artificial intelligence (AI) decision support systems (DSSs) in the Philadelphia Fire Department(PFD). Your insights and feedback are invaluable in shaping this discussion.

Background:

- Briefly tell me about your role and experience within the PFD.
- Have you heard of AI or AI-powered tools being used in firefighting? If so, what are your first impressions?

Perceptions of AI:

- What comes to mind when you hear the term "artificial intelligence"?
- Do you have any concerns or anxieties about the integration of AI in the PFD?
- What potential benefits do you see for utilizing AI DSSs in your daily work?
- Imagine AI analyzing real-time data during a fire emergency. What specific information or insights do you think would be most helpful?

Potential Applications of AI DSSs:

- Can you think of any scenarios where AI DSSs could improve fire response or firefighter safety?
- In your opinion, which aspects of your current decision-making process could be

enhanced by AI?

- Are there any potential limitations or drawbacks to using AI DSSs that you foresee?
- How important do you think it is for firefighters to be involved in the development and implementation of AI DSSs for the PFD?
- Do you think AI DSSs could help improve response times, situational awareness, or resource allocation?
- How do you think AI DSSs could impact your workload and stress levels?
- What challenges do you foresee in integrating AI DSSs into the PFD workflow?
- How could we ensure ethical and responsible development and use of AI-powered DSSs in the fire service?

Trust and Responsibility:

- How important is trust in the accuracy and reliability of AI recommendations for you?
- Who should be responsible for making final decisions in a fire emergency with AI information available?
- How do you think AI integration could impact the teamwork and communication dynamics within the PFD?

Current Decision-Making Processes:

- Describe your typical process for making decisions during emergency response situations.
- What factors do you consider when making decisions about resource allocation, entry points, and firefighting strategies?
- What challenges or limitations do you face in your current decision-making process?
- Are there any existing technologies or tools you use to support decision-making? (e.g.,

maps, databases, communication systems)

Recommendations and Future Vision:

- If you were involved in developing an AI DSSs for the PFD, what features or functionalities would you prioritize?
- What do you think the future holds for AI in the fire service?

Recommendations for Successful Integration:

- If AI-powered DSSs were to be implemented in the PFD, what would be important for ensuring a successful integration process?
- What level of training and support do you think firefighters would need to effectively use AI-powered DSSs?
- How do you think the PFD should address concerns and anxieties about AI-powered DSSs among firefighters?

Conclusion:

- Do you have any final thoughts or concerns about the potential integration of AI DSSs in the PFD?
- Is there anything else you would like to share about your experience and perspectives on this topic?

Appendix C: Site Access Letter

Devon Richio
215-279-3185
devon.richio@gmail.com

1/16/2024

Deputy Fire Commissioner J. Thompson
Philadelphia Fire Department
240 Spring Garden Street
Philadelphia, PA 19123

Dear Deputy Commissioner Thompson,

I am writing to request permission to conduct a research study exploring the potential integration of artificial intelligence decision support systems (AI DSSs) within the Philadelphia Fire Department as part of the Executive Fire Officer Program at the National Fire Academy. This study aims to understand the opportunities and challenges associated with implementing AI-powered tools to enhance firefighter safety and improve response efficiency.

As you know, the PFD operates in a dynamic and high-pressure environment, demanding swift and informed decision-making for optimal fire response. AI DSSs has the potential to analyze vast amounts of data in real-time, providing firefighters with valuable insights on factors such as building layout, victim location, fire behavior, and optimal resource allocation. This information could potentially lead to quicker response times, improved situational awareness, and ultimately, a reduction in civilian and firefighter injuries and property damage.

My research employs a qualitative approach, utilizing structured interviews and focus groups with firefighters at various ranks and roles. This approach allows me to gain a nuanced understanding of firefighters' perspectives on AI, their current decision-making processes, and their anticipated benefits and concerns regarding AI integration.

To ensure minimal disruption to PFD operations, I propose the following:

- Flexible scheduling: Interviews and focus groups will be conducted at the convenience of firefighters, outside of their regular operational hours.
- Shortened sessions: Each interview and focus group will be limited to a maximum of 1 hour to minimize time commitment from participants.
- Location: Interviews and focus groups can be held at a PFD facility or any location convenient for the participating firefighters.

- Emergency response: Participating firefighters and officers will remain available to respond to any emergencies that may arise during the study period.

I am confident that this research will provide valuable insights for the PFD as it considers the potential integration of AI DSSs. The findings will contribute to the ongoing dialogue on the role of AI in emergency response, informing future policy decisions and shaping the future of fire safety in Philadelphia.

I have attached a detailed research proposal for your review, which further outlines the study's methodology, timeline, and anticipated outcomes. I am available to answer any questions you may have and would be happy to discuss the project further at your convenience.

Thank you for your time and consideration.

Sincerely,

Devon A. Richio