High-rise Firefighting: Firefighter Preparedness to Life-Safety Vulnerabilities

by

Chris Coulthard

A Thesis Submitted to the Faculty of Social and Applied Sciences in Partial Fulfillment of the Requirements for the Degree of

MASTER OF ARTS in DISASTER AND EMERGENCY MANAGEMENT

Royal Roads University

Victoria, British Columbia, Canada

Supervisor: Dr. Jean Slick

March, 2021.

COMMITTEE APPROVAL

The members of Chris Coulthard’s Thesis Committee certify that they have read the thesis titled High-rise Firefighting: Firefighter Preparedness to Life-Safety Vulnerabilities and recommend that it be accepted as fulfilling the thesis requirements for the Degree of Master of Arts in Disaster and Emergency Management:

Dr. Jean Slick [signature on file]

Dr. Christopher Warren [signature on file]

Final approval and acceptance of this thesis is contingent upon submission of the final copy of the thesis to Royal Roads University. The thesis supervisor confirms to have read this thesis and recommends that it be accepted as fulfilling the thesis requirements:

Dr. Jean Slick [signature on file]

Abstract

The city of Toronto is experiencing rapid growth in vertical settlement patterns with the construction of very tall high-rise residential buildings that are classified as super high-rise's by the Ontario Building Code. Due to their height and complexity, SHR buildings present challenges for firefighters during firefighting operations. This research study was conducted to explore the preparedness of firefighters to these vulnerabilities which can impact life-safety and what limits or support preparedness. Using a mixed methods sequential design, a survey questionnaire was distributed to Toronto Fire Service firefighters, and this was followed by interviews; the survey and interviews explored firefighter risk perception, technical and environmental knowledge, training, and preparedness capacities. The findings suggested there were differences in commands and districts with respect to these measurable properties, and firefighters were also split in their perception of risk. In conclusion, the influencing factors that support or limit preparedness are leadership, technical and environmental knowledge, training, and budgetary and organizational priorities. Optimism bias and technical and environmental knowledge were found to influence firefighters' risk perception and their ability to accurately assess risk.

Keywords: Super high-rise, preparedness, risk perception, vulnerabilities, training, technical and environmental knowledge, capacity.

List of Abbreviations

AAR – After Action Report

CFAI – The Commission on Fire Accreditation

CNBC – Canadian National Building Code

FDC – Fire Department Connection

FDNY – Fire Department of the City of New York

HR – High-rise

KPA – Kilopascal Pressure Unit

LPM – Liters Per Minute

NFC – National Fire Code

NFPA – National Fire Protection Association

NIST – National Institute of Standards and Technology

OBC – Ontario Building Code

PRD – Pressure Reducing Device

PRV – Pressure Reducing Valve

PSI – Pounds Per Square Inch

SA – Situational Awareness

SHR – Super High-rise

SME – Subject Matter Expert

SOG – Standard Operating Guideline

TFS – Toronto Fire Service

VRT – Vertical Response Time

Acknowledgements

I would like to thank the dedicated firefighters of the Toronto Fire Service for their significant contributions. Without your support, encouragement, and participation, this research project would not have been possible.

I would also like to thank the Toronto Professional Firefighters Association who graciously provided a platform through their website for the delivery of my survey to the membership, I thank you for your support and help in promoting this project.

The Toronto Fire Service fielded my questions with transparency and provided me with access to information whenever I requested it. I thank all those individuals from different divisions who went out of their way, providing me timely data and explaining subject matter I was unfamiliar with.

To Dr. Jean Slick, (Saint Jean) no words can express my gratitude for your endless patience, providing directional guidance and editing suggestions. Your encouragement is infectious, and you kept me focused and moving forward. Thank you for taking me on, and this project after unforeseen circumstances.

To Dr. Christopher Warren, thank you for your support and guidance with the design and implementation of the quantitative process. Without your support and direction, I would still be trying to figure out how to process data in Excel.

Lastly to my family who have been so patient with my lack of presence and self absorption, I could not have done this without your unconditional love and support. Thank you for continuing to believe in me.

Table of Contents

Chapter 1 - Introduction

The on-going global trend of rapid urbanization has led to increased real estate values in our cities and a lack of affordable housing for many. The bulk of the Canadian population is already urbanized with a rapid acceleration of continued urbanization expected in the future. These pressures have led to vertical settlement patterns with a boom in construction of ever taller high-rise (HR) residential structures. The City of Toronto is experiencing rapid vertical growth with 184 HR buildings under construction and an additional 393 proposed new builds as of 2018 (Annetts, 2018). Statistics Canada has suggested that 44% of Toronto residents live in apartment suites with this number expected to grow as population density increases (Statistics Canada 2016, as cited by Millan, 2017). As of 2019, Toronto had an inventory of approximately 788 residential HR buildings over 20 storeys (TFS, 2019). Within this inventory there is a subset of 342 buildings that are classified by the Ontario Building Code (OBC) as super high-rises (SHR), which are buildings that are 84 meters or greater in height (Friedman, 2014; TFS, Analytics, 2019). This rapid growth in building inventory coupled with the increasing trend towards the construction of SHR, present significant challenges for the Toronto Fire Service (TFS) who are responsible for an “all hazards” response model delivery of life-safety services.

When a fire occurs in HR buildings, firefighters can be faced with many challenges due to complex building design and building systems. In SHR buildings, firefighters depend upon building systems to successfully conduct firefighting operations. These building systems are subject to infrastructure failure interdependencies, if one area of a system fails it may create a domino effect impacting many other systems (Leavitt & Keifer, 2006). While firefighting operations are generally successful, the TFS operations division who respond to HR fires have experienced infrastructure failures that have complicated firefighting operations creating life-safety concerns for firefighters. To mitigate firefighter life-safety concerns and achieve successfully fireground outcomes, it is critically important for firefighters to have the necessary preparedness capabilities to respond. Firefighter preparedness consists of technical and environmental/contextual knowledge, specialized/focused training, and firefighter experience. Additionally, preparedness is a function of the resource capacity of TFS as an organization to deploy the necessary complement of personnel and equipment to a HR fire event.

When responding to HR fires, one aspect of preparedness is the ability for firefighters to accurately assess risk. A firefighters technical and environmental knowledge of HR vulnerabilities will shape their perception of risk and influence the corresponding self-protective actions and behaviours they implement. Increased environmental knowledge of vulnerabilities faced when fighting SHR fires contributes to firefighter's situational awareness and their ability to assess risk with greater accuracy. The degree of risk a firefighter perceives has a correlational influence on a firefighter's self-protective actions and behaviours (Rodriguez-Garzon et al., 2012). A firefighter's perception of risk will influence tactical decision-making processes and ultimately, mitigate outcomes. A danger exists that optimism bias may influence firefighter risk perception. For firefighters operating in a HR building, optimism bias could lead to the underestimation of the potential risks and an overestimation of their personal ability, preparedness, and the success of operational outcomes.

Background

The height of SHR buildings present unique challenges for firefighters who rely on building systems and design to effectively fight fires. Firefighters require technical and environmental knowledge of HR vulnerabilities to be adequately prepared for firefighting operations. Knowledge is acquired through experience and training and forms the basis for accurate risk assessments on the fire ground. Firefighter's face numerous challenges in SHR buildings, one challenge is the vertical response time (VRT) which is the additional secondary response time it takes fire crews to get from the initial building address to the secondary location in the building. VRT accounts for an additional 6 mins above the initial response time on average (TFS, 2019). A delayed response time means larger, hotter, and more dangerous fire conditions in buildings as a free burning fire doubles in size every 30 seconds (McGraw, 2007). Firefighters rely on the buildings lift capacity to move personnel and equipment to the fire floor to mount an effective fire fighting force. If a failure in lift capacity is experienced, it may take crews an exceedingly long time to ascend to upper floors in a building creating extremely dangerous conditions. While VRT and the reliance on a building's lift capacity can be problematic, water supply for fire suppression in HR and SHR buildings often present challenges for fire crews.

Firefighters operating in SHR buildings use building standpipe systems to supply water for fire suppression. The standpipe system requires a series of pumps to overcome the elevation and friction loss present in these very tall buildings. If an infrastructure failure occurs and a pump fails, firefighters connect to the building standpipe system through the fire department connections (FDC) to boost the water pressure or become the sole source water supply. In buildings over 30 storeys, the operating pressures required to overcome the weight of the head pressure in the standpipe system, as well as the elevation and friction loss exceeds the fire departments pump and equipment capacity. Even without an infrastructure failure, adequate flow rates and nozzle pressure can be difficult to achieve. The National Fire Protection Association (NFPA) 14 states that building standpipes must deliver a minimum flow of 1892 liters per minute (LPM) at the two upper most or hydraulically remote outlets at 450 kilopascal (kpa) residual pressure pre-1993 and 700 kpa of pressure in post 1993 buildings (NFPA 14, as cited by Freidman, 2014). Buildings in Ontario are not required to follow the NFPA 14 standard, rather they follow the OBC mandate which only requires buildings to meet a minimum requirement of 450 kpa and 1800 LPM of water flow (TFS Training Note, December 2019). While these do not represent all the challenges firefighters must be prepared for when conducting firefighting operations in SHR buildings, they do highlight some of the implications for firefighting preparedness with a City that is experiencing rapid vertical growth.

Problem

The decentralization of public safety in Canada has produces an effective model for disaster response due to the granting of local autonomy to municipalities and provinces (Hataley & Leuprecht, 2014). This autonomy gives local emergency services and emergency planners the ability to respond based on their tailormade plans and intimate knowledge of the locale; this is sound logic given that “all emergencies are local” (Henstra, 2013, p. 3). This autonomy however does not apply to building and fire code. The Canadian National Building Code (CNBC) and The National Fire Code (NFC) are model building and fire codes developed by the National Research Council of Canada, from which the provinces and territories can base their codes. Many of the fire and life safety standards in the CNBC and NFC have been adopted or are influenced by NFPA standards. The provinces and territories can then decide to adopt all or some of this code, or create their own code, and they even have the right to have no code if they choose (McGillivray, 2018). These codes remain in provincial jurisdiction with no mechanism available for cities to make amendments. Local municipalities have no right to impose measures that exceed what has been mandated provincially (McGillivray, 2018. Not all cities in Canada have the same exposure to HR life-safety complexities nor the same rate of growth and increase in urban density. The lack of control by municipalities to design and implement building code, despite their unique niche complexities, leaves cities like Toronto with 100% of the responsibility to provide emergency response without the ability to tailor code to address building vulnerabilities. This creates additional preparedness challenges for TFS who must overcome these vulnerabilities and deliver emergency services.

Research Purpose and Questions

The purpose of this study was to measure firefighter preparedness to vulnerabilities in SHR and HR buildings, which can have life-safety implications for firefighters on the fireground during HR fire operations. Additionally, this research sough to understand which factors will lend support or hinder firefighter preparedness. The following research questions provided the direction of this study: (a) What is the level of preparedness of fire service personnel to inherent vulnerabilities in high-rise residential buildings that could threaten firefighter's life-safety during a fire event? (b) Which factors limit or support preparedness for fire service personnel? The results of this research aim to generate a greater understanding of firefighter preparedness which will inform actionable recommendations to improve firefighter life-safety through enhanced preparedness.

Methodological Overview

This study followed a mixed method explanatory sequential design which is in keeping with the philosophical perspective of pragmatism. To establish a measurement of preparedness, a quantitative approach was followed, using an online survey instrument that was made available to TFS operations personnel. An interview protocol was then developed, which was informed by the results from the survey responses; the interviews, as a qualitative method, provided a greater understanding of which factors influence preparedness.

Chapter 2 - Literature Review

This literature review begins by describing the vulnerabilities that exist in SHR residential buildings and the numerous life-safety concerns that can arise for both residents and fire-fighters when a fire occurs. The review then examines the preparedness capacity of the fire service, focusing on both technical/resource and personnel capacity of the fire service to respond to HR events effectively. The technical/resource capacity to respond includes adequate firefighting equipment, the redundancy of apparatus, sufficient staffing levels, and adequate fire station coverage which impacts response times. Personnel capacity considers firefighters' level of education, knowledge, experience, and training. This literature review explores the interconnected relationship between existing vulnerabilities and capacities. Additionally, this review identifies the complexities of SHR building designs and the interdependency of these systems that are subject to possible failure interdependencies. If one area of a system fails it may create a domino effect impacting many other systems (Leavitt & Keifer, 2006).

Vulnerabilities in High-rise Residential Buildings

HR buildings create numerous challenges for firefighters tasked with life-safety operations (Friedman, 2014). As buildings increase in height, so do the challenges they present. Response times for HR buildings are typically longer due to the secondary ascent time which increases in duration with elevation. Fire crews must arrive at the building address and then ascend to the secondary event location adding costly minutes to the overall response time (Sharp, 2018). The NFPA 1710 response time standard does not take into consideration the secondary vertical response time for HR buildings. Certain Toronto neighbourhoods that have experienced rapid vertical growth patterns present challenges to the TFS in meeting NFPA 1710 response time standards (Sharp, 2018). Fires in HR buildings require firefighters performing fire attack to utilize building standpipe systems to supply the adequate volume and water pressure to establish effective firefighting streams, the standpipe system is pressurized by stationary fire pumps in the building. If these pumps fail, the fire service supplies the standpipe system from the fire department connections. However, in very tall buildings it is not possible to overcome the elevation and friction loss nor the head pressure in the standpipe to establish effective fire streams above 30 stories (Friedman, 2014). For very tall buildings an increasing concern is that the fire department connections to the standpipe and the standpipe system itself cannot handle the high pump pressures that are needed for effective nozzle pressure and water volume. Due to the high operating pressures in very tall buildings, pressure reducing valves and devices are installed to regulate the pressures fire crews receive. PRV's are designed so fire crews on lower floors do not receive dangerous pressures. However, they are often not field adjustable and may malfunction or be installed incorrectly, leading to wild variations in nozzle pressure. Despite the challenges that these structures bring, the OBC sets the standards for HR building safety, however it is up to the municipalities to enforce this code. Municipalities do not have the power to require buildings to exceed areas of the OBC, despite the large inventory of SHR structures with unique vulnerabilities that could place residents and municipal fire services at risk. Building design and the smoke control measure chosen for that building informs what type of evacuation measure residents should follow, however evacuation procedures are not always well understood by residents, TFS recommends that all residents leave the building via stairwells as soon as the alarm activation occurs if it is safe to do so, if smoke is encountered it is recommended to try another stairwell or lastly to shelter in place remaining in the apartment unit. TFS takes a flexible approach to evacuation so residents can choose the best course of action that they deem appropriate.

Response Times

HR buildings present unique structural challenges for fire services. Unlike traditional low-rise structures, these buildings significantly increase overall emergency service response times (sharp, 2018). Large urban Canadian fire departments face response time challenges due to reduced roadways from bicycle lanes, street parking, fixed public transit routes (street cars), traffic calming devices in addition to rush hour pedestrian and automobile traffic (Sharp, 2018). For fire services who must meet National Fire Protection Association (NFPA) response time standards, these issues increasingly make meeting that standard difficult. HR buildings present an additional challenge in contrast to low-rise structures due to the VRT. VRT is the time it takes fire personnel who have arrived at the initial address to ascend to the fire floor within the building. The additional VRT typically doubles the overall response times of fire services (Sharp, 2018). This additional response time increases risk to residents and firefighters because HR buildings have much greater population density (occupancy load) and a greater concentration of material (fire load). A delayed response means larger, hotter, and more dangerous fire conditions in buildings as a free burning fire doubles in size every 30 seconds (McGraw, 2007).

The National Fire Protection Association (NFPA) 1710 response time standard allots a total response time of 6 minutes and 23 seconds for fire services to arrive to all initial event addresses. The time standard is broken down into segments; 1:04 for dispatch and call processing,1:20 for turnout time (e.g., donning of PPE, driver map orientation) and 4:00 for response travel time. The Toronto Fire Service achieves the NFPA 1710 response time standard of 4 minutes travel response time to all initial event addresses 76% of the time, however, neither this analytic nor the NFPA standard take into consideration the additional VRT for HR structures (Toronto Fire Services, 2018, p. 36). Sharp (2018) explored the feasibility of TFS meeting the

NFPA 1710 standard with the addition of a VRT added in to the 6:24 total. The allotted 4-minute response travel time was halved providing 2 minutes response travel time and 2 minutes for VRT. The downtown core of Toronto with the greatest HR density had adequate fire station coverage to meet the 2-minute travel time to the event address. However, moving out from the high density downtown core to lower density areas of the city a lack of coverage emerged (Sharp, 2018). The geographic area of Humber Bay, ward 6, Etobicoke-Lakeshore in the west end of Toronto was one area that was identified as lacking sufficient TFS coverage for the 4-minute travel response time to be achieved. This area has witnessed a 55% increase in population between 1996 to 2016 and contains 24 HR buildings with more buildings proposed (Sharp, 2018). A second area of concern was the Toronto community of Crescent town, Danforth, ward 31 Beaches East York; this community is made up of a series of SHR buildings with the greatest population density east of downtown Toronto (Sharp, 2018). TFS was able to meet the 4-minute travel time to the address event, however, when it was reduced to 2 minutes travel time to allow for VRT, the target benchmark could not be met. TFS service coverage diminishes when HRs are introduced into traditionally lower density areas of the city. For those with substantial numbers of HR buildings and population density, the inability for municipalities to amend building and fire codes to reflect the unique requirements a municipality might have for public safety creates vulnerabilities.

Building and Fire Codes

As previously noted, the CNBC and NFC are model building and fire codes developed by the National Research Council of Canada, from which the provinces and territories can base their codes. Currently six provinces and three territories have adopted the CNBC code, while the provinces of British Columbia, Alberta, Quebec, and Ontario, which have cities with a significant inventory of HR buildings, have their own codes. The OBC integrates some aspects of NFPA standards such as NFPA 14 (installation of standpipe and hose systems). However, the OBC does not follow NFPA, NFC or NFPA standards carte blanche. The provinces delegate enforcement of building codes to the municipalities. However, the local municipalities do not have the right to impose measures that exceed what has been mandated provincially (McGillivray, 2018). Not all cities in Canada have the same exposure to HR life-safety complexities nor the same rate of growth and increasing urban density. The lack of control by municipalities to design and implement effective building code, despite their unique niche complexities, leave cities with their hands tied at the policy level yet saddled with 100% of the risk and emergency response if a catastrophic fire event were to occur. The ability for municipalities to influence and develop building code to create safer HR buildings is an important component of reducing vulnerability that remains elusive for cities like Toronto. SHR buildings are dependent on complex systems to maintain fire safety which must meet engineering standards that are not necessarily prescribed by the OBC.

Fire Suppression Dependencies in High-rise Buildings

HR buildings rely on complex fire protection systems to detect fire and to activate suppression systems. These suppression systems require a series of pumps to overcome the elevation and friction loss present in these very tall buildings. These life safety systems are tightly coupled systems that are interdependent upon each other (Perrow, 1999, p. 94 as cited by Leavitt & Keifer, 2006), if one pump fails in this system, there is no longer adequate fire protection for residents. Pumps can fail for numerous reasons, such as a power outage, a failure in a back-up power system, poor maintenance, malicious intent, or from a natural hazard such as pluvial flooding (Friedman, 2014). Fire departments rely on these pump systems to provide adequate water pressure for effective fire suppression streams. If the pressure is inadequate or the system has failed, fire departments connect to the building standpipe system through fire department connections (FDC) and either boost the water pressure or become the sole source water supply.

NFPA 14 (Standard for the Installation of Standpipe and Hose Systems) stipulates that the maximum working pressure of a standpipe system is 350 pounds per square inch (psi.) While this is generally adequate for buildings under 30 storeys, it does not reflect the necessary working pressures required to achieve the minimum 100 psi of nozzle pressure for fire suppression in buildings greater than 30 storeys (Friedman, 2014, p. 6). For example, when considering elevation and appliance friction loss, a building with 58 storeys would require pressures exceeding 480psi to meet NFPA 14 and provide effective fire suppression streams for firefighters. NFPA 14 also states that building standpipes must deliver a minimum flow of 1892 liters per minute (LPM) at the two upper most or hydraulically remote outlets at 450 kilopascal (kpa) residual pressure pre-1993 and 700 kpa of pressure in post 1993 buildings (NFPA 14, as cited by Freidman, 2014). Buildings in Ontario are not required to follow the NFPA 14 standard and the OBC mandate only requires buildings to meet a minimum requirement of 450 kpa and 1800 LPM of water flow (TFS Training Note, December 2019). For this reason, firefighters arriving at a building that has properly functioning stationary fire pumps are unsure what water pressure they will receive from a standpipe system. Adequate pressure and water flow are essential for rapid fire suppression by firefighters. Another factor influencing water pressure is the hose and nozzle used. The current TFS HR hose kit (PAL PAK) consists of two 15m lengths of 38mm hose and a combination nozzle. The friction loss calculation for this HR kit is 135 kpa per each 15 m hose length with a 500 kpa pressure requirement at the nozzle for a total of 770 kpa If a crew must advance three or four lengths of hose from the floor below the fire floor, the operating pressure must increase to account for the additional friction and elevation loss thus requiring 940kpa to 1075 kpa of water pressure (TFS, Training Note, December 2019). Therefore, even in buildings that have exceeded the OBC minimum requirement and meet the NFPA 14 post-1993 standards of 700 kpa, the water pressure may still be insufficient to achieve proper operating pressure and rates of water flow for effective hose streams, the situation deteriorates rapidly for those buildings only meeting the OBC minimum standard of 450 kpa. TFS is currently testing HR kits that utilizes 65mm hose with lower friction loss values in combination with a low pressure straight bore nozzle to overcome low standpipe pressures and achieve more desired flow rates (TFS, Equipment Note, April 4, 2018). While achieving adequate operating pressures is a challenge for firefighting operations within a building, additional difficulty arises if stationary pumps fail. The fire department is required to pump through the building standpipe system and become the sole source of water supply for fire suppression in a building.

Standpipe system design and installation are often inadequate for a fire department to deliver sole source water supply in buildings over 30 storeys (Friedman, 2014). NFPA 14 stipulates that the maximum working pressure at any point in the standpipe system must not exceed 350 psi (2413 kpa) (NFPA 14 as cited by Friedman, 2014). In SHR buildings a stationary fire pump failure could require a fire department to exceed the 350-psi limit in order to supply water at upper floors. The OBC does not specifically dictate maximum pressures that a fire department can place on a standpipe, however it does state that standpipe systems will be constructed and tested in accordance with NFPA 14 provisions. An assumption can be made that the maximum working pressure of 350 psi would apply to fire department sole source pumping.

The failure of FDC's when pumping into a building standpipe are well documented, as the TFS has experienced connection failures many times at pressures far below the NFPA 14, 350 psi maximum. As Savelle, (2007) reported, the standpipe/sprinkler system architect of the first NBC Center acknowledged that most standpipe components that connect piping together are only rated to 300 psi, the failure of couplings at the FDC have additionally been documented by the Fire Department of New York (FDNY) at pressures of 250 psi (P. 9). Most fire department equipment, including fire engines, appliances and hose couplings are not rated to handle the high pressures that are required in SHRs. Fire service apparatus in Toronto have a maximum net pump capacity of 200 psi and hose lines have a test rating of 300 psi (Friedman, 2014, p. 8). Current TFS Standard Operating Guidelines (SOG's) state that the maximum pump discharge pressure applied to a standpipe should not exceed 1400 kpa or 200 psi (TFS, Training Note 101.1.5, December 2019).

When connecting to the FDC to supply sole source water supply, or to supplement or boost pressure to a standpipe in a building, the pump operator historically would count the number of stories from the ground floor to the fire floor and add 5 psi (35 kpa) per floor to compensate for elevation loss (Stuckey, 2015). As Stuckey (2015) reported, this calculation is accurate for a dry riser in a standpipe in most residential buildings, however, this calculation is based on the assumption that each storey is 10ft in height, in many modern condo's variation in height per storey can be found. In most commercial office buildings, the height between storeys is often 13.5ft which changes the per storey calculation for pump operators (p. 96). When counting from the ground floor to the fire floor not only is there height variations per storey in different buildings but some mixed-use residential/commercial buildings have large open atriums that can be many storeys in height before the residential floors begin. This means that although the fire floor might be recognized as the 24th floor, in actual over all building height it may be the 30th floor once the atrium height is taken into consideration, thus changing pump pressure calculations (Stuckey, 2015).

In most residential buildings the standpipe riser is wet, full of water with a one-way check valve stopping the water from leaving the system or leaking out the FDC connections. The weight of this column of water is called head pressure, exerting force on the one-way valve to keep it closed (Stuckey, 2015). In order to be able to pump water into the standpipe, a greater force must be applied to open the one-way valve and overcome the head pressure from the column of water, in a 30 storey building that column of water could be exerting 180 psi of force against the one-way check valve. This would mean that a pump operator must pump at a pressure greater than 180 psi (1241 kpa) just to open the check valve, then must account for the hose friction loss and appliance loss on the fire floor. For TFS crews using this scenario, fighting a fire on the 15th floor, the pump operator would need to calculate 1241 kpa + 770 kpa (friction lose values for hose and nozzle) requiring 2,011 kpa. The pump pressure required in this scenario exceeds the 1400 kpa maximum pump operation pressure of TFS apparatus and is at the pressure threshold of where failures in standpipe couplings have occurred (Savelle, 2007).

In very tall buildings, the standpipe system is often broken into zones, for example a low zone may supply floors 1 through 24, and a second zone will supply floors 24 through to 48. A main pump will supply the low zone and relay water to a second pump which serves the second zone at the 24th floor to the 48th. The zoned system keeps overall standpipe pressures below the 350 psi maximum allowable pressure (Stuckey, 2015). These pumps must generate enough pressure to deliver 100 psi to fire department connections on each floor. This means that a low zone pump must generate at least 250 psi to meet NFPA 14 standards and deliver 100 psi at the

24th floor. The weight of the column of water in the riser creates .434 psi per foot of elevation, therefore at the top of the column there is no gravity pressure, but the pressure builds towards the bottom of the standpipe (Stuckey, 2015). Due to increased pressures on lower floors, pressure controlling mechanisms are used to regulate pressure at each floor. These mechanisms, pressure reducing devices (PRD's) and pressure reducing valves (PRV's) must be in place or dangerously high pressures would be encountered by firefighters on lower floors. For each floor the device must be set to deliver not more or less than 100 psi (700 kpa), often these devices are improperly set creating a problem for fire crews who may experience extremely high pressure or insufficient pressure. Some of these devices are field adjustable by fire crew's while others are not. This means that no matter what pressure is delivered through the standpipe, the device will regulate the pressure to what it is set to (McGrail, 2007; Stuckey, 2015). The fire at the One Meridian Plaza in Philadelphia, a 38-storey HR building illustrates the danger. As McGrail (2007) explained, improperly set PRV's reduced the water pressure on the 22nd floor to 60 psi, fire crews could not establish effective fire streams for successful suppression. The fire burned for 19 hrs, consuming 8 floors of the building, and taking the lives of 3 firefighters (p.57)

Life-safety Concerns in Super High-rise Building

Life-safety in SHR buildings relies on the successful synergistic interactions between numerous life-safety systems. These systems include building design, building code, technological life-safety systems, evacuation life-safety messaging and fire department capabilities and capacity.

Residents of HR buildings are often unaware as to which method of evacuation should be used during an emergency. A survey of both commercial and residential occupants in Chicago, New York and San Francisco conducted by Zmud (2008) found that commercial HR tenants participated in far more fire drills then residential tenants. Residential tenants perceived a fire emergency as their greatest safety concern, had a general knowledge of evacuation procedures such as not using lifts for egress and knew the location of emergency exits, but still thought evacuating to the roof of a structure was a viable evacuation option (Zmud, 2008, p. 335). Resident's confusion regarding evacuation procedures is understandable given the variation in evacuation methods and the lack of a prescribed method to follow. In most Canadian cities, evacuation procedures are not prescribed, and are left to the building resident to evaluate in order to determine if they will evacuate via stairwells, or if they will follow a strategy know as defend in place. Defending in place is a process where residents remain in their apartment unit, relying on compartmentation to protect them from fire spread. The rationale being that to evacuate to a stairwell could result in residents being overcome by smoke inhalation (CBC, 2017). The defend in place strategy was broadcast to the residents of Grenfell Towers by fire services with the same belief that residents would be safe because of compartmentation, the results were devastating with the loss of 77 lives (The Economist, 2017).

Evacuation procedures and methods vary greatly by region and building design. Hong Kong fire safety code only recognises stairwells as a safe and viable method of evacuation (Chow et al., 2013). This code is problematic as it limits the successful egress of those with mobility issues in very tall residential structures. From a review of the limited literature available on very tall residential buildings, Chow et al., (2013) concluded that "occupants in supertall buildings may find it difficult to evacuate in the same manner as in shorter buildings…a new safety standard for supertall buildings is required" (p. 31). Refuge floors are an increasing common design implementation component for life safety in very tall buildings is the use of refuge floors. For example, Hong Kong fire safety code stipulates that residential buildings over

25 stories require refuge floors. Refuge floors are engineered safe floors that are designated throughout a building that allow occupants to shelter on a safe floor instead of exiting the building in the event of a fire (Chow et al., 2013). The refuge floor provides fire breaks in buildings. This design consideration changes the necessity for residents to follow traditional evacuation models which require total egress from the building. It provides a means of shelter for residents internally and a means of ingress for emergency services personnel. This design component is especially important given the height of many supertall residential structures and the demographic trend in North America of an aging population that has less mobility. Chow and Chow (2009) utilized computational fluid dynamic scenarios, simulating typical fire intensity (2 megawatts) in a supertall building to ascertain the viability of refuge floors. Their results suggested that refuge floors provide a viable safe means for residents during a fire emergency and could provide relative safety from fires with moderate intensity (p. 235).

Within the OBC, there is no requirement that SHR buildings need to include entire floors designated as sanctuary/refuge floors. The OBC document SB-4 Measure for Fire Safety in High Buildings, stipulates a similar design known as measure L, which is when “two pressurized areas of refuge are provided on every fifth floor or alternatively staggered on intermediate floors, except in buildings of class C occupancy that are greater than 75M in height, the areas of refuge will be provided on every storey” (MMAH Supplementary Standard SB-4, 2012, p. 26). Alternatives to measure L exist and these are usually favoured by builders and designers. One option is Measure M, which stipulates that “in residential buildings the greater part of the requirement for control of smoke movement are waived where each suite has access to a balcony” (MMAH Supplementary Standard SB-4, 2012, p. 51). Therefore, if each unit has a balcony, the balcony is considered a sufficient smoke control design for resident refuge.

Measure M is the most common building design measure adopted in HR residential buildings in Canada (B. Nguyen, personal communications, September 25, 2018). This is understandable as developers may be reluctant to give up marketable, liveable space for areas of refuge. Measure A, another option, relates to fully sprinklered buildings where all floor areas are sprinklered. A sprinkler system is considered by the OBC as a smoke control measure, therefore buildings that implement Measure A do not necessarily need to implement another measure such as M or L (MMAH supplementary Standard SB-4, 2012, p. 12). A sprinkler system in a building is reliant on fire pumps, often the standpipe system and sprinkler system are combined, as are the FDC connections that feed both systems (sprinklers and standpipe). If stationary fire pumps fail, the smoke control measure (sprinklers) will fail, the same difficulties that are present in standpipe systems in very tall buildings may be replicated again with the sprinkler system (Savelle, 2007). It is estimated that in buildings with sprinkler systems, 1 in 14 systems fail during a fire (NIST, 2013, p. 13).

Depending on which measure a building has adopted, the OBC prescribes a different, preferred method of evacuation that does not necessarily coincide with TFS Standard Operating Guidelines (SOG's). If a building designer applies measure A, the OBC states that upon the detection of fire by an automatic device or manual pull station the alarm will sound on all floors. The residents on the fire floor are to evacuate via the stairwell to street level or an intermediate area, all other residents may remain until instructed to evacuate by instructions from the central alarm and control facility (MMAH, Supplementary Standard, SB-4, 2012, p. 14). Where measure M is adopted (balconies as refuge) residents on the fire floor are to evacuate if possible, all other residents may remain in their suites to wait for instructions (MMAH, Supplementary Standard, SB-4, 2012, p. 51). In buildings implementing measure L (areas of refuge), upon detection of fire an alarm will activate on all floors, the occupants are to move to areas of refuge throughout the building and await voice communication (MMAH, supplementary Standard, SB-4, 2012, p. 49). These preferred methods of evacuation assigned to the different smoke control measures are more suggestive in nature than legislative. For residents in Toronto, TFS recommends that all residents leave the building via stairwells as soon as the alarm activation occurs if it is safe to do so, if smoke is encountered it is recommended to try another stairwell or lastly to shelter in place remaining in the apartment unit ("Fire in Your High-rise" 2017). For firefighters responding to a HR fire event and the residents of the building, the OBC smoke control measure implemented by the building designer and the corresponding evacuation protocol for that measure would likely remain unknown. TFS evacuation messaging provides flexibility for residents who may be dealing with difficult and changing fire conditions, however, the choice and evaluation of which method to follow may not be clear and intuitive. Building design and smoke control measures are examples of the technical and specific environmental knowledge that affect preparedness capacities.

Preparedness Capacities

Preparedness can be defined as "Actions taken prior to an emergency or disaster to ensure an effective response" (Ontario Ministry of Community Safety and Correctional Services, 2011). The response capacity of fire departments to effectively mitigate a HR fire event is another component of life-safety systems in HR buildings. Knowledge, training, and technical capacity are the foundation of preparedness and impact the success of firefighting operations in HR buildings.

Knowledge

A firefighter's technical and environmental knowledge of HR vulnerabilities shape their perception of risk and influence the corresponding self-protective actions and behaviours they implement. Increased environmental knowledge of vulnerabilities, expands firefighter's situation awareness and their ability to assess risk with greater accuracy. The degree of risk that a firefighter perceives has a correlational influence on a firefighter's self-protective actions and behaviours (Rodriquez-Garzon et al., 2012). A firefighter's perception of risk will influence tactical decision-making processes and ultimately, mitigation outcomes.

Risk perception theory provides a framework to identify and assess an individual's perception of their exposure to risk (Blackwood, 2017). Risk perception can be defined as "a subjective assessment of the likelihood of experiencing an accident or disease caused by exposure to a source of risk" (Sjoberg, as cited by Rodriguez-Garzon et al., P. 754). As Rodriguez-Garzon et al., (2012) suggested, risk perception and the concept of risk ("something negative that may happen in the future"), (Hermansson, 2012, as cited by Rodriguez -Garzon et al., 2015, p. 754) are inter-connected and lead to certain behaviour risk taking patterns. The level of a workers perceived risk has a direct correlation to self-protective behaviours (p. 755). In a firefighting context, the level of perceived risk and subsequent self-protective behaviour can be viewed through a fireground maxim "risk a lot to save a lot" (unknown). In other words, a firefighter will assume increased risk in direct correlation with the severity and value of what is to be saved, the highest value being the lives of others. As Rodriguez-Garzon et al., (2012) reported, a greater level of education and experience leads to a higher risk perception in firefighters, specifically those who are university educated (p. 768). Higher risk perception has also been associated with acute stress reaction, training, and practical experience (Prati et al., 2011). The variations in firefighter's level of education, training, and practical experience will alter a firefighter's risk perception and self-protective behaviours as well as their ability to accurately access risk. The ability to accurately access risk may be further influenced by optimism bias. Optimism bias can be defined as "a systematic error in perception of an individual's own standing relative to group averages, in which negative events are seen as less likely to occur to the individual than average compared with the group, and positive events as more likely to occur than compared with the group (Weinstein, 1980, as cited by Dalziel & Soames Job, 2006, P. 490). In other words, we underestimate our chances of becoming ill, getting divorced, or being in a car accident while overestimating our successes such as stock market gains, the ability to get a project completed on time and within the budget, or our personal job marketability (Sharot, 2011). Optimism bias thus plays a role in firefighter's situational awareness, potentially influencing the ability for accurate and unbiased scene size-up. For firefighters operating in a HR building, optimism bias could lead to the underestimation of the potential risks and an overestimation of their personal ability, preparedness, and the success of operational outcomes.

When responding to a fire call, firefighters need to have situational awareness, which is defined as "[the] perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status into the near future" (Endsley, 2004 as cited by Gasaway, 2013). As Gasaway (2013) explained, situational awareness in immediate danger to life and health (IDLH) environments relies on the intuitive and creative processes of the right brain. The intuitive, gut-based decisions are the culmination of stored images of tacit knowledge and experiences (Gasaway, 2007). The ability to develop intuitive decision making requires firefighters to be subject matter experts (SME's). Their expert knowledge and experience allow for intuitive split-second problem solving and decision making which doesn't require conscious thought (Gasaway, 2007). Firefighters rely on formal and informal education and training, equipment notes, and SOG's to develop the body of knowledge that is needed to become an SME. As Gasaway (2007) suggested, it takes many years for an individual to attain the education and experience to become an SME and have the bulk of experience to detect problems (Gasaway, 2007).

A firefighter's technical knowledge and education become even more important as the depth of firefighter experience lessens. With the introduction of detection and fire suppression systems in HR buildings, in combination with accelerated fire code inspection and enforcement, the fire service has seen a steady decline in the frequency of fire calls which translates into less operational experience. This decline in frequency of fire calls is compounded by an aging work force. Senior firefighters with the most operational real-world experience are retiring leaving an experience knowledge gap that must be bridged by increased technical knowledge and education (Siu-hang Lo, 2010). The Hong Kong Fire Service Department (HKFSD) mirrors what TFS is experiencing with the loss of experienced senior people and the need to fill that knowledge void. As Siu-hang Lo (2010) explained "Fire-fighting safety and efficiency counts as much on expertise as practical experience. However, the decreasing trend of building fire calls over the decade and average retirement rate of more than 100 experienced fire fighters a year creates a knowledge management problem" (p. 20).

TFS has moved to close the knowledge and experience gap by raising the educational bar of entry for this profession. Recruit firefighters must have National Fire Protection Association (NFPA) 1001 level 1,2 and NFPA 472 standard qualifications for professional firefighters as pre-service requirements. Additionally, they must pass NFPA 1031, Standard for professional qualifications for fire inspector and plan examiner and NFPA 1035 Standard on Fire and Life Safety Educator, Public Information Officer, Program Manager Professional Qualifications (TFS, “Becoming a Firefighter”, 2019). While increasing educational qualifications and establishing a thorough repository of technical information through training notes, SOG’s and equipment notes is necessary to develop SME firefighters, the successful application of that knowledge in the field requires kinesthetic repetition through training (Gasaway, 2019).

Training

The importance of training in fire service preparedness is widely recognized. Training is essential to maintain and develop core competencies that are essential to the profession. SHR buildings present numerous life-safety vulnerabilities which require specific training and frequency of training to adapt to and overcome during a fire. As McGrail (2007) noted “Firefighter safety and survival is directly related to the type and amount of training you receive” (p. 12). Fires in HR buildings require enormous resources in both equipment and personnel. Personnel must be trained to execute specific core competencies in a well-rehearsed synchronistic fashion, while being flexible enough to adapt and improvise tactics and approaches as conditions dictate. To achieve this level of competency and adaptability, training methodologies become as important as the subject matter being disseminated.

Neuroscience and the physiological changes firefighter’s bodies and brains experience is an important component in the understanding of training requirements. When a firefighter is exposed to a high-risk environment with rapidly changing conditions, physiological changes that include the release of bio-chemicals in the body can rapidly impact the ability to make the necessary high-risk decisions and complete important tasks (Gasaway, 2019, as cited by Kinakin, 2019 20:40). This physiological process is often referred to as the Fight-or-Flight syndrome, with increased blood pressure and heart rate, releasing chemicals from the adrenal cortex such as epinephrine and cortisol (Gasaway, 2019, as cited by Kinakin, 2019, 22:05). These chemicals narrow focus so just the most crucial elements of immediate survival become the primary goal, this focus can impede complex processes that need to be accomplished. The narrowing of focus has been referred to in military combat as "amnesia in the field", where the left-brain function is impaired, and the right brain primarily takes over (Gasaway, 2019). Training conducted for the purpose of SHR firefighting should consider this physiological stress response when developing effective training programs. It is important to marry the repetitive kinesthetic hands-on learning with the cognitive knowledge of what, when and why simultaneously (Gasaway, 2019, as cited by Kinakin, 2019, 52:08). The repetitive drilling of task evolutions is a utilized approach in military organizations, with the goal of developing a soldiers' skills so they can be replicated easily under stress and changing conditions without the need for conscious thought.

Adaptive performance, or the ability to improvise in the field (Joung et al., 2003 as cited by Childs, 2005) is an important ability in high-risk, rapidly changing environments. Crews may deviate from SOG's to overcome unexpected obstacles that do not conform to the present, prescribed guidelines. When this occurs, regardless of outcomes, a training opportunity exists in the form of a post incident review. Critical reflection is the process of enquiry into a profession's conduct, ethics and decision making; this process is common practice in the fields of nursing, education, and policing (Child, 2005). As Child (2005) explained,

> "instructional methods based on rote learning, chalk, and talk, and show and tell training are insufficient as a means of developing firefighters capable of responding and adapting to the complex demands implicit within increasingly professionalized firefighting labor. Future firefighters will need to be adaptive, reflective and accountable; able to

demonstrate discursive and inquisitive capabilities; and engage in reflected actions both on and off the incident ground" (p. 558).

Novel approaches to training and tactics may also be impacted by the notion of tradition. As Dixon (2015) pointed out, firefighters use to feed horses that were used to pull the fire apparatus, this tradition has stopped because of technology. The fire service must instill a culture of adaptability and best practices (para. 14). Fire service culture and tradition has been repeatedly cited anecdotally as a barrier to progressive transitions. It is exemplified in a fire culture maxim which states "150 years of tradition unimpeded by progress" (na). This is a potentially dangerous cultural phenomena that impacts preparedness, firefighters may believe that they have a greater level of training and preparedness then they do. As Gasaway (2019) asserted, "We don't know what we don't know", (Gasaway, 2019, as cited by Kinakin, 38:30). The misappropriated self-perception of preparedness by firefighters opens the door to the possibility of optimism bias.

Fighting a fire in a super-high-rise building takes knowledge and training, but it also requires enormous resources in both technical capacity (physical assets and equipment) and personnel capacity (human resources). The foundation of fire service preparedness begins with having enough well trained and knowledgeable firefighters to respond to the event.

Technical and Personnel Capacity

The term capacity can be defined as "The set of diverse knowledge, skills and resources people can claim, access and resort to in dealing with hazards and disasters" (Gaillard et al., 2019, p. 863). It is paramount that the firefighters can access diverse knowledge skills and resources to respond to the rapidly changing conditions presented during a HR fire with the technical and personnel capacity to expand or contract to support the strategies that command has chosen to implement.

The NFPA fire protection handbook assigns risk classification for occupancies, a HR building is considered a high-hazard occupancy (Fire Protection Handbook (2008), as cited by Fire Metropolitan Chiefs (2010). The operational preparedness of a fire service responding to a high-hazard occupancy depends on the resources available and reliability of those resources. In a busy fire department, the availability of resources decreases with increased call volume. Apparatus and trained staff may already be committed to another event and unable to respond. Adequate redundancy in the system is needed to build preparedness (Fire Metropolitan Chiefs (2010). For high-hazard occupancies the NFPA fire protection handbook recommends a staffing deployment of 24 firefighters and 2 Chief officers, a safety officer, and a rapid intervention team for a total of 31 personnel (Fire Protection Handbook, 2008, as cited by Fire Metropolitan Chiefs 2010). The accompaniment of apparatus recommended for a high hazard occupancy for an initial response is a minimum of 4 pumpers, 2 ladder trucks, 2 chief officer vehicles and specialized apparatus as needed (Fire Protection Handbook, 2008, as cited by Fire Metropolitan Chiefs 2010). For a small municipality this could prove incredibly challenging to provide this level of staffing within the allotted response time on an initial response. If the building is a SHR, matching the appropriate resources to the risk may not be possible.

The critical importance of adequate staffing when responding to a HR fire was highlighted in the National Institute of Standards and Technology (NIST) technical report 1797. NIST conducted fireground field experiments in a 13-story HR, measuring 38 fire ground tasks that were considered essential for successful mitigation of operations. Fire attack (advancing a hose line) is considered one of those essential tasks where speed of deployment and the rapid application of agent to suppress the fire are critical to limit fire advancement and stop the spread of toxic gases that impact firefighter and resident safety. The advancement of a secondary hose line is also essential for redundancy in case the first fire attack team becomes compromised or if fire intensity requires additional suppression (NIST, 2013). Teams were assembled into 3, 4, 5 and 6 person crews, and timed from the start of deployment to the successful completion of their assigned task. The NIST study revealed that significant task time reductions occurred when a crew of 3 was up staffed to a crew of 4 during initial fire attack. As crews increased in size, overall task completion times decreased. However, the largest improvement in task completion time was when a crew of 3 became a crew of four (NIST, 2013, p. 133). TFS staffs all pumper trucks with a crew size of four, however when responding to a HR, the first in crew quickly diminishes in size. The driver/pump operator remains outside the building to establish a water supply to the standpipe, this reduces crew size to 3 firefighters initiating fire attack. One firefighter must assume the role of elevator control from the crew, reducing the initial attack team to just 2 personnel, a firefighter, and the company officer. The crew of 2 now must connect to the standpipe system and advance a hose line, the company officer is now juggling hats between tactical command and performing at the task level until command is transferred to another officer. In most areas of Toronto, the initial attack crew will be backed up by a crew of 3 from the second in apparatus, however in some areas of the city this deployment may not occur as rapidly as desired depending on the distance between neighbouring fire station locations or if apparatus is already committed at a simultaneous event.

Summary

Successful firefighting operations in HR buildings require a fire service with great depth in technical and environmental knowledge. Firefighters require a high degree of preparedness and awareness to overcome the many inherent vulnerabilities they may encounter in this hostile and unforgiving environment. This literature review highlighted many of the unique vulnerabilities firefighters may encounter when conducting operations in HR and SHR buildings. The literature informed the survey questions measuring technical and environmental knowledge of vulnerabilities. Additionally, the literature review explored the unpredictable and volatile nature of firefighting, where decisions are often based on limited information with shifting conditions and limited resources requiring adaptive performance, or the ability to improvise in the field. The work of Gasaway (2019) highlighted the physiological changes firefighters experience which impact situational awareness. When a firefighter is exposed to a high-risk environment with rapidly changing conditions, physiological changes that include the release of bio-chemicals in the body can rapidly impact the ability to make the necessary high-risk decisions and complete important tasks. By acknowledging these physiological changes, firefighter training programs can be designed to develop firefighter's ability for adaptive performance. The literature review provided the contextual knowledge needed to create survey questions that measured the methodologies used and frequency of training being conducted. The knowledge of risk and vulnerability when responding to a HR fire event is an important component of a firefighter's situational awareness (SA). A firefighter's risk perception will influence tactical decision-making processes and ultimately, mitigation outcomes. A danger exists that firefighters risk perception may be altered by optimism bias thus influencing a firefighter's ability for accurate and unbiased scene size-up, underestimating the potential risks and overestimating their personal ability and level of preparedness. The theoretical frameworks of optimism bias and risk perception theory presented in this literature review contributed to the overall design of this study. Both theoretical concepts were inserted in the survey questions to measure the presence or absence of optimism bias and to measure firefighters risk perception. The findings of Rodriguez-Garzon et al., (2012), that suggested higher risk perception was associated with greater levels of education was also measured in this study. While the availability of academic research on HR firefighting remains limited, this literature review provides an overview of the interconnected complexities that positively and negatively impact HR firefighter preparedness.

Chapter 3 - Methodology and Methods

This chapter provides an overview of the rationale for choosing a sequential mixed methods approach for this study. A brief review of the philosophical perspective used in this mixed methods study is presented. Additionally, this chapter highlights the approaches used for sampling, recruitment, data collection, and data analysis of both quantitative and qualitative phases of inquiry.

Rationale for the Study Design

This study utilized a mixed method explanatory sequential design aligned with the philosophical perspective of pragmatism due to the nature of the two research questions and the population being studied. The first question, which was explored in the initial qualitative phase of the study was: What is the level of preparedness of fire service personnel to inherent vulnerabilities in HR residential buildings that could threaten firefighter's life-safety during a fire event? To establish a measurement of preparedness, a quantitative approach using an online survey instrument established base line measurements that could then be filtered by demographic characteristics. The survey made it feasible to collect data from a sample of 2700 TFS operations personnel in a timely manner, which is in keeping with the study's pragmatic focus. To answer the second question: Which factors limit or support preparedness for fire service personnel? An interview protocol was developed, which was informed by the results from the survey responses. The qualitative approach provided a lens to help understand with greater detail, which factors influence preparedness, and provided the opportunity to have interview participants share their interpretation of some of the survey responses. Additionally, this methodology was chosen with the aim to improve the validity and reliability of the study through incorporating two different but complimentary research method phases.

Mixed Methods Philosophical Approach

Mixed methods, as the term implies is a research design that combines the use of both qualitative and quantitative data. The goal of combining both types of data is to capitalize on the individual strengths of each research type and overcome their limitations with the aim of better answering the research question (Creswell & Creswell, 2018). There are debates about the viability of combining research methodologies that have fundamentally different paradigms (Creswell, 2006). The notion of pragmatism as a worldview for mixed methods research has gained traction by many researchers. The pragmatic method accepts that there are both singular and multiple realities of inquiry that are directed towards solving real world problems (Creswell & Plano Clark 2007, as cited by Feilzer, 2009). Despite calls to adopt pragmatism as a paradigm, mixed methods research design has no fixed paradigm, rather the epistemological and ontological assumptions remain fluid with a dynamic philosophical foundation that can fit into one or many combinations of worldviews (Creswell & Tashakkori, 2007).

It is with a pragmatic worldview that this study has been conducted, as the goal of this study was to develop actionable recommendations that will reduce life-safety risk and vulnerability for firefighters during fire events in HR residential structures. This subject matter makes inquiry into a real-world problem that can be defined as a wicked problem (van Duijne, & Bishop, 2018), involving both social and technical complexities and thus fits well with pragmatism as a paradigm.

There are many different types of mixed method designs. This study employed a mixed-methods explanatory sequential design. This design had two phases of data collection, which began with a quantitative first phase (Creswell, 2018). The results from the analysis of the first phase was used to inform the design of the questions to be asked during the secondary qualitative phase. The second phase explored the results gathered in the first design phase to generate a more thorough understanding of the phenomena being studied (Creswell, 2018). From a pragmatic perspective, interviews were the most appropriate way to gather greater understanding of the factors influencing awareness and preparedness.

There were three reasons for choosing a mixed methods explanatory sequential design. One is credibility, as the approach capitalized on the strengths of both quantitative and qualitative data while reducing the limitations present if just one method had been chosen (Creswell & Creswell, 2018). The second is development, as this design used the results of one method of inquiry to inform the development of the second phase of qualitative inquiry (Schoonenboom & Johnson, 2017). The third rationale is complementarity, as the qualitative design seeks to elaborate on the initial quantitative findings and explore which factors limit or support awareness and preparedness, enhancing the understanding of the results from the first phase (Schoonenboom & Johnson, 2017).

Data Collection and Analysis

Quantitative Design

The research began with the survey, which was designed to measure the level of awareness and preparedness of TFS personnel to inherent vulnerabilities in HR structures during a fire. The variables were related to three measurable properties: knowledge, preparedness, and training. The survey examined knowledge by asking respondents four questions measuring technical field knowledge and a fifth question probed respondent's awareness of risk. Five questions regarding the technical response capacity of TFS included the staffing levels of fire trucks and the personal risk perception of firefighters as it relates to technical capacity and preparedness. Questions probing the types and frequency of training being conducted by TFS explored both formal (i.e., the exercises and courses being conducted by the TFS training division) and informal training (e.g., Captain and crew lead training initiatives). Appendix B shows survey questions categorized by property. The design of the survey was informed by the research questions and theoretical framework. The survey consisted of 22 questions (see Appendix A), with 16 questions using a 5-point weighted, uni-polar Likert scale, following an answer format of (1) Strongly agree, (2) Agree (3) Neutral, (4) Disagree, (5) Strongly disagree. The remaining six questions established demographic information consisting of age, gender, years of service, the highest level of education attained, command and fire district they work in, and if they have SHR buildings located in their fire district.

The sampling method chosen for this research design was non-random (non-probability) sampling, specifically multi-stage purposive sampling (Schoonenberg & Johnson, 2017). This type of sampling targets selected individuals, groups or areas that will yield information density and maximize the understanding of the research questions (Schoonenberg & Johnson, 2017). The target sample element chosen for this study was operations division personnel from the Toronto Fire Service. TFS is the fifth largest fire service in North America with 2,710 operations staff. The quantitative data collection began with the assistance of the Toronto Professional Firefighters Association, local 3888 (TPFFA). The survey had a theoretical maximum sample element of 2,710 operations personnel (“Demographics Fire Watch”, 2018, vol.13, p. 21), at the time of close the survey received a total of n=280 responses or 10.3% of TFS operations staff.

An introduction to the study and invitation to participate was posted on the TPFFA website with a link to the survey, which used the Survey Monkey platform. The Survey opened on November 1, 2019, and remained open until December 16, 2019, for a total duration of 36 days. A reminder to the membership was posted under the current news section of the TPFFA website one week before the survey closed with an additional invitation to participate. Survey monkey analytics revealed that the survey took respondents an average of 7 mins and 56 seconds to complete.

For the data analysis phase, the responses to the questions were assigned a weight ranging from 1 (strongly agree) to 5 (strongly disagree). The survey data was exported to Excel, and the responses to the questions were assembled into the three properties, knowledge, preparedness, and training. For some questions, the weight of 5 was the most correct or desirable answer, for others, the weight of 1 was the most desirable choice. A reversal of weightings was performed for those questions that had an ideal answer of a lower numerical weighting (1) strongly agree. A mean and median score was then totalled for each measurable property representing all 280 responses. Further analysis of the data was done to compare responses from each of the four fire commands: North (n=88), South (n=66), East (n=65), and West (n=63) and mean property scores for each distinct command were established to see if there was variation between commands. A further exploration of respondent's answers was performed using filters in Survey Monkey to analyse data based on demographic characteristics. The filters applied sorted data by education, years of service and fire district. The filtering of data provided the isolation needed to reveal variances that exist in firefighters risk perception depending on education and experience (years of service) as well as their awareness and preparedness of SHR residential buildings in their fire districts.

Qualitative Phase

A combination of non-probability and snowball sampling was used for interview participant recruitment (Dane, 2018). High-value participants were contacted via email, inviting them to participate in the study (see appendix C). Those who agreed to participate were asked to recommend other possible participants. The interview participants were senior officers in TFS who had served in multiple commands, thus all four commands were represented. Four interviews were conducted remotely using Skype and Zoom platforms between July 22, 2020 and August 5, 2020. The interviews were recorded using skype and Zoom platforms, the files were then transferred to Otter.Ai for transcription.

The interview questions were open-ended questions, designed to harvest detailed insight from the participants (Creswell & Creswell, 2018). The interview questions followed a six-part format: Part I - Preparedness; Part II - Operational Readiness; Part III - Risk and Risk Perception; Part IV - Required Knowledge; Part V - Technical Capacity; Part VI - Survey Responses from Q5, Q9, Q6 and Q15 (see Appendix B). Questions Q5, Q9, and Q6 from the survey had a median of 3, revealing an equal split of opinion among respondents and a large portion of respondents choosing the neutral position on the Likert scale. Participants interpretation of the responses to these specific questions was sought.

The qualitative data analysis followed a general inductive approach (Creswell & Creswell, 2018). An inductive approach was chosen as the most suitable approach for data analysis because the qualitative phase of this study does not attempt to prove a theory or hypothesis but rather explore which factors limit or support preparedness for fire service personnel, as informed by the measurements established from the quantitative results. A thematic analysis was conducted revealing six over-arching themes and many interconnected, re-occurring sub-themes. The themes were arrived upon after several coding cycles, the data was assigned a sentence or a single word code that summarized the salient content. The re-occurring codes throughout the data formed thematic patterns which were then assembled into the six over-arching themes of training; leadership; knowledge; preparedness; Firefighter risk perception and SHR vulnerabilities.

Validity and Reliability

The term reliability can be defined as the consistency or reliability of a measurement. The term validity refers to how reliable or consistent the measurement supports the theories or concepts being measured (Dane, 2018). This study provides rigour and trustworthiness by following the established guidelines and sound design principles of a mixed methods sequential design through all levels of this study. The mixed methods sequential design measured the concept (preparedness) using two different research methods providing triangulation. The themes that were generated during the qualitative analysis were derived from the perspectives of multiple participants, creating a convergence of data (Creswell & Creswell, 2018). Additionally, participants were provided with selected extracts of the quantitative results that revealed a median of 3, with a large sample element that selected the neutral position on the Likert scale. The participants were asked for their interpretation as to the possible meaning of these results.

By incorporating their participation, the validation process of member checking was used (Creswell & Creswell, 2018). As Creswell and Creswell (2018) noted, by involving TFS personnel in the review of the study's findings and soliciting their perspectives, this process adds trustworthiness to the study (p. 200).

The use of discrepant information was employed when evidence emerged which ran contrary to the themes presented. Deficiencies in Leadership is an example of a theme that emerged from the qualitative phase, where contrary evidence was presented in the discussion which supported a more balanced perspective of Leadership. With the presentation of negative information which ran contrary to the thematic claims, the intent was to provide a more balanced and realistic perspective. Presenting information that is contrary to an account, mirrors the real world where many differences of opinion are expressed. The presentation of differences in the accounts increases credibility for the study (Creswell & Creswell, 2018).

This study was subjected to an independent review by an external examiner who was not familiar with the study, the researcher, or the research supervisors. As Cresswell and Cresswell (2018) emphasized, the review of a study by an external auditor throughout the research project or at the conclusion of the project is another validating strategy.

Limitations

Cultural bias

With any research conducted there exists the possibility that interpretations made by the researcher are subject to cultural bias, even if it is unintentional (Creswell &Creswell, 2018). It is acknowledged that the researcher is a TFS operations division Firefighter and an active member of the Toronto Professional Fire Fighters Association, local 3888.

Data Reliability

The source of the quantitative data was an anonymous Likert survey that was available on-line through the TPFFA. The survey relies on self-reported data that can not be independently verified, the responses must be taken at face value. This is a limitation as it is not possible to know if the 280 responses or 10% of operations firefighters who responded, accurately reflect the views of the entire operations division. For example, if those who responded exhibit a heightened level of engagement or professional development in comparison to those who did not respond, the data may not accurately reflect the entire sample element and could influence results in unpredictable ways.

The qualitative sample size for this study is relatively small N=4. This study employed a combination of non-probability and snowball sampling for interview participant recruitment. This study sought senior officers within TFS that had operational experience with HR and SHR firefighting response. The availability of subject matter experts in this area of firefighting is extremely limited, and further constrained by the selection being limited to just a single organization (TFS). The availability of participants was further impacted by the covid-19 pandemic which altered participants schedules and limited their availability to conduct interviews remotely.

Ethical Considerations

While all studies have ethical considerations, this study has several key ethical considerations that were addressed. The research involved participation from senior officers of the TFS and operational personal within the fire service. The TFS is a type one organization that follows a hierarchical military chain of command structure. It is acknowledged that the researcher is an employee of this organization and as such, is subject to possible power imbalances (Creswell & Creswell, 2018) based on hierarchical rank within the organization. There are no power imbalances or biases with operational staff who participated in this research project (by completing an anonymous survey), however it is acknowledged that the researcher may be a direct supervisor of some of the operational staff who participated in the quantitative phase. It is further acknowledged that the TFS personnel that participated in the qualitative interview process, while not being direct supervisors of the researcher, are senior officers within the organization. This raises the possibility that a power or influential imbalance between the participants and the researcher could exist. Due to the relatively small number of senior officers in TFS, the researcher was diligent in protecting the anonymity of the participants throughout the course of this study.

Reflexivity

I have been an operations division firefighter for twenty-two years with TFS. While I have worked in other commands and districts for short periods of time, the bulk of my experience from the rank of recruit to Acting Captain has been in East command and primarily in district 2. At the time of my hire, an amalgamation process was underway to consolidate six former municipalities into one city, the city of Toronto. This process involved the amalgamation of six former fire departments, each department had different standard operating guidelines, equipment, communications centers, and most importantly unique cultures. While amalgamation happened 23 years ago, some regional cultural attitudes prevail. I attempted to be free of bias in the design, implementation, analysis, and interpretation of this research. However, it is acknowledged that the work culture and leadership influences experienced throughout my career do contribute to bias even if it is sub-conscious. For this reason, the quantitative process was designed to gather firefighter's interpretations from all commands and districts. This approach was repeated for the qualitative process with the recruitment of participants from all four commands to ensure multiple perspectives and interpretations were captured.

Chapter 4 - Quantitative Results

This chapter introduces the quantitative results, presenting a demographic summary of the sample element, which includes years of service, gender, age, Command location, and levels of education. A mean measurement for the properties of Knowledge, Preparedness and Training are presented, followed by filtered mean measurement isolating the property results by Command, fire Districts with the greatest inventory of SHR buildings, years of service and levels of education. A mean measurement of firefighter's risk perception is presented filtered by levels of education. Additionally, a summary of the results from survey questions which had a median of three are presented, as they represent a split in opinion among respondents. The questions cover the topics of firefighter risk perception, training frequency, adaptive performance, knowledge of vulnerability and capacity and environmental knowledge.

Demographics

This table presents the demographic break down of the quantitative sample element (N=280) by years of service, gender, age, and Command location.

Years of Service	%	Sample Size	Gender	%	Sample Size	Age	%	Sample Size	Command	%
1 to 5	12%	N=32	Male	92%	N=255	20 to 30	4%	N=11	North	24%
5 to 10	19%	N=52	Female	6%	N=17	30 to 40	24%	N=68	East	23%
10 to 20	23%	N=64	Non pronoun	1%	N=2	40 to 50	29%	N=81	South	32%
20 to 30	32%	N=90	Other	1%	N=2	50 to 60	38%	N=105	West	22%
30+	15%	N=41				65+	5%	N=15		

Educational demographics were collected from the sample element. The breakdown is as follows, High school represented 11% or N=30, Trade school/Community college represented 52% or N=144, this was the largest educational catchment. University educated firefighters represented 38% or N=106, with 2% or N=5 having completed a master's degree and N=1 or .3% having completed a PHD.

Properties Measured

The results are presented according to the three measurable properties of Knowledge, Preparedness and Training. An accumulated mean total provided a collective numerical summary of all four fire commands representing the entire TFS operations division. The accumulated mean score for the properties were as follows: Knowledge 72%, Preparedness 71%, and Training 52%, (N=280).

Properties Measured by Command

Further analysis was conducted to isolate respondents by command to see if there was variation in property measurements between commands.

Command	Sample Size	Knowledge	Preparedness	Training
North	N=66	71%	69%	52%
South	N=88	75%	74%	54%
East	N=65	73%	69%	49%
West	N=64	74%	67%	55%

South Command had the highest measurements for the property of knowledge with a mean of 75% as well as the highest recorded measurement for the property of preparedness at 74%. West command had the highest measurement for the property of training with a mean of 55% while East command had the lowest measurement for the property of training with a mean of 49%.

Properties Measured by SHR Inventory

Analysis was conducted filtering data by the fire districts that have the largest inventory of SHR buildings across the four commands.

Command	District	Sample Size	# Super High-rise	Knowledge	Preparedness	Training
South	3	N=42	105	72%	76%	52%
South	1	N=20	80	74%	74%	59%
North	1	N=38	50	68%	68%	52%
East	4	N=12	23	70%	65%	56%
West	3	N=9	22	74%	75%	47%

South command district 1 and West command district 3 both measured a mean of 74% for the property of Knowledge. South command district 3 had the highest measurements for the property of preparedness. South command district 3 also has the greatest inventory of SHR buildings. Despite district 3 having the highest mean score for these two properties, South command district 1 had the highest mean measurements for the property of training. West command district 3 had the lowest recorded mean measurement for the property of training, yet the highest mean measurement when analyzed at the macro command level inclusive of the four districts that comprise West command.

Properties Measured by Years of Service

The demographic section provided data containing the number of years of service each respondent had completed with TFS. An excel file was generated and exported, filtering individual responses based on the number of years of service they had completed. The parameters chosen for the filter was firefighters that had completed 1-5 years of service, 5-10,10-20, 20-30 and those with 35+ years of service. This provided a properties measurement based on the experience level of firefighters.

Years of Service	Sample Size	Knowledge	Preparedness	Training
1 to 5	N=32	67%	70%	51%
5 to 10	N=52	76%	72%	54%
10 to 20	N=64	69%	72%	54%
20 to 30	N=90	70%	72%	50%
30+	N=40	69%	68%	66%

The 5 to 10 years of service catchment had the highest mean measurements for the property of knowledge with 76%, this was the highest mean measurement received for this property across all filtered results. The mean measurements for the property of preparedness was 72% for three of the five catchments, those in the 5-10, 10-20 and 20-30 years of service. These three catchments represent 74% of survey participants N=206 and show results that are consistent with the overall mean measurement of 71% for the property of preparedness for all survey respondents. The highest mean measurement for the property of training was 66% reported by the 30+ years of service catchment. This was the highest mean measurement received for the property of training across all filtered results.

Properties Measured by Level of Education

A filtering of individual responses was then conducted based on the education levels indicated in the demographic data, results were analysed based on 5 educational levels, High School, Community College/Trade School, University degree, Masters degree and PHD.

Level of Education	Sample Size	Knowledge	Preparedness	Training
High School	N=30	67%	69%	53%
College/Trade School	N=144	74%	71%	53%
University	N=106	70%	72%	52%
Masters degree	N=5	73%	70%	51%
PHD	N=1	70%	100%	65%

Respondents that attended Community College/Trade School had the highest mean measurements for the property of Knowledge. Across four of the five educational levels, the mean measurements for the property of Preparedness were remarkably similar, ranging between a mean of 69-72%. The exception was for the PHD category where the mean measurement was 100%. This mean was established based on the data received from a single survey respondent. The mean measurement for the property of Training across four of the five educational levels was similar with a range of 51 to 53% except for the PHD category where the mean measurement for the property of Training was 65%.

Firefighter's Perception of Risk

Survey question 5 explored the personal risk perception of firefighters while performing operations in buildings above 30 storeys. A filter was applied to analyse responses based on the highest level of education achieved, comparing those who are high school educated vs Community college/Trade school and those who have a University degree, Master's degree and PHD. On the Likert scale a respondent who answered strongly disagree was numerically assigned 5 and those who strongly agreed with the statement was numerically assigned a 1. Thus, a higher mean represents an elevated level of risk perception. Firefighters who had a high school education had a mean of 58%, community college 53%, University 60%, MA 56% and PHD 100%. The result from question 5 also showed a median of 3, which showed that respondents were split in their opinion. Further, 25% gave a neutral response.

Strongly Agree 1	**Agree 2**	**Neutral 3**	**Disagree 4**	**Strongly Disagree 5**
4.6% N=13	36.6% N=102	25.1% N=70	24.4% N=68	9.3% N=26
Median =3	**Mean** =2.97	**SD** =1.08	**Avg** 2.97% N= 279	

Training Frequency and Adaptive Performance Preparedness

Question 6 explored respondents' frequency of training and their preparedness for adaptive performance to overcome water supply vulnerabilities. The results show a median of 3 which means respondents were split in their reflective experience.

Q6. Does this statement reflect your experience? My fire crew is well prepared and trained in how to implement an improvised interior/exterior standpipe system if a standpipe system in a building fails.

Strongly Agree 1	Agree 2	Neutral 3	Disagree 4	Strongly Disagree 5
7.6% N=21	27.4% N=76	13.4% N=32	36.1% N=100	15.5% N=43
Median =3	**Mean** =3.27	**SD =**1.04	**Avg** 3.25% N= 277	

Knowledge of Vulnerabilities and Capacity

Question 9 explored respondents' knowledge of water supply vulnerabilities in high-rise buildings and the capacity of equipment used for HR fire suppression. The results show a median of 3, which means respondents were split in their agreement with this statement. Further 28% gave a neutral response.

Q9. Do you agree with this statement? Very tall buildings can present challenges to fire crews who require adequate nozzle pressure for fire suppression. TFS high-rise kits (Pal Pak) provide adequate equipment (low pressure nozzles etc) to overcome low water pressures in buildings.

Strongly Agree 1	Agree 2	Neutral 3	Disagree 4	Strongly Disagree 5
2.5% N=7	24.7% N=69	28% N=78	33% N=91	12.2% N=34
Median =3	**Mean** =3.27	**SD =**1.04	**Avg** 3.27% N= 279	

Environmental Knowledge

Question 14 explored the environmental knowledge of the presence of SHR buildings located in fire districts using the NFPA definition for a Very Tall High-rise Building. The results show a median of 3, which means respondents were split in their opinion of whether these buildings are in their districts.

Q.14 NFPA 20 defines a Very Tall High-rise building as a building that is so tall that it is impossible for the fire department apparatus to pump into the fire department connection at the street and overcome the elevation loss and friction loss in order to achieve 100 psi at the most remote 2.5" (65mm) hose outlet. Do you feel that this definition applies to buildings in your first run fire district?

Strongly Agree 1	Agree 2	Neutral 3	Disagree 4	Strongly Disagree 5
16.9% N=47	25% N=70	18.6% N=52	26.5% N=74	12.9% N=36
Median =3	**Mean** =2.94	**SD** =1.30	**Avg** 2.94% N= 279	

Environmental knowledge to the presence of SHR buildings in fire districts was asked again in question 22 using the OBC definition for SHR buildings. This was a directional question requiring a yes or no answer, results were filtered by districts with the greatest inventory of SHR buildings.

22. The Ontario Building Code (OBC) deems a building that is greater than 84^ m in height a SHR. Do you have any buildings in your first run fire district that meet this definition?

Command	District	Sample Size	No	Yes
North	1	N=37	32%	68%
South	1	N=20	15%	85%
South	3	N=42	21%	79%
East	4	N=12	75%	25%
West	3	N=9	22%	78%

It is of note that of the 5 districts presented, East Command District 4, had 75% of respondents who answered no. This contrasts with the other four districts where the majority answered yes that these buildings are in their districts.

Summary

These results provided a demographic overview of the sample element as well as a mean numerical summary of the three measurable properties of Knowledge, Preparedness, and Training. These measurable properties are also presented with results filtered by levels of education, years of service, command and by Districts with the greatest inventory of SHR buildings. The results from survey questions with a median of three were presented, which covered the topics of firefighter risk perception, training frequency, adaptive performance, knowledge of vulnerability and capacity, and environmental knowledge.

Chapter 5 – Qualitative Findings

This chapter presents the qualitative findings from the second phase of research for this study. During the first phase of research the quantitative results were used to inform the direction of the qualitative interview questions and the selection of interview participants. In the second phase the qualitative findings help give meaning to the initial quantitative results (Creswell and Creswell, 2018). The interview participants were four senior officers representing the TFS operations division across all four commands. In addition to presenting the findings from analysis of the interview data, this chapter also discusses the participants interpretation and meaning of some of the quantitative data results. The participants were presented with quantitative data results from select survey questions and asked for their interpretation of those results. The overarching themes that emerged based on analysis of the interview data are training, leadership, knowledge, preparedness, firefighter risk perception and SHR building vulnerabilities. This section discusses these themes which help identify which factors limit or support preparedness for fire service personnel.

Training

The critical importance of training in the fire service is widely acknowledged and is viewed as a crucial component of preparedness as training maintains and develops core competencies. Thematic analysis revealed the presence of training deficiencies within TFS. The training deficiencies in the organization was succinctly articulated participant #3 who asserted: "There's a systematic problem with training throughout the whole job." This comment provides a macro perspective of the challenges faced with training across TFS and some of the visible frustration that was felt by participants, participant #1 supported the issue of lack of accessibility of SHR training for firefighters, saying:

> Well there is no specialized training for fighting fires in high-rise buildings, this is one area that is lacking in the whole fire service in general…there's no courses as it is now, So this is something that 's very much needed…and I guess the question is, they don't and they can't get that type of training, so we need to develop that training somehow.

Participant #4 reinforced the need for and responsibility to train TFS members, saying:

> The departments commitment to training…I mean how can you say as a department, we just don't have the time or the resources to train you properly…and a department this big and with such responsibility you know, not just to our crews, but to the citizens we protect.

Lack of specialized knowledge and facilities within TFS were two factors participants felt contributed to training deficiencies. Participant #1 commented about the lack of knowledge and expertise within TFS for SHR training, noting, "There are very firefighters with this type of knowledge, I had to go outside the fire department and do research on these buildings to develop new tactics." Participants noted that the deficiency in developed training courses and material for SHR and HR training was compounded by lack of and need for adequate training facilities to accommodate any SHR program that may be developed. As Participant #1 expressed, "We don't have you know, complicated training facilities or we don't have the systems in our facilities to go train we have to go and imagine this happening and imagine that." The need for more realistic training facilities was expressed by participant #2, who said "We need to have accessible mock-up or props that we can actually pump to at that pressure." Participant #1 noted that current training facilities do not adequately represent the building technologies or modern building design that firefighters regularly encounter, saying, "Most training facilities they are not designed for high-rise firefighting. They are designed for residential house fires." This same participant went on to say, "We train from experiences of past fires and building designs…Were trained to fight fires in 1960 buildings." Participants also suggested these deficiencies were known and that other challenges influenced availability of training.

Organizational structure and lack of resources were identified as factors influencing the ability to deliver training rather then a lack of awareness of the problems that need to be addressed. Participant #4 said, "It's not like they're ignoring it, it's on their radar screen. It's just, if I had to guess I would say they just don't have the resources to, to cover all the things they need to cover." The participant elaborated further on the possibility that a realignment of budgetary priorities across TFS divisions may be necessary to correct deficiencies in training, saying "The training division at TFS should be number two to OPS in terms of budget resources and what we need." Participant #1 suggested that funding may be limited in the future and that it was fortunate that a second HR truck had been purchased and equipped before the pandemic had occurred, saying:

> We're actually lucky right now and it's a good thing that's happened prior to Covid because now there's not going to be any money to spend and buy equipment. The good news is we've already bought the equipment and its already on the high-rise trucks. We just need to, require the training.

While budgetary concerns will likely remain a challenge for TFS into the near future, the ability to conduct training may also be influenced by leadership or the lack there of.

Participant #2 suggested that a lack of leadership was a concern, saying:

> It's the lack of leadership…you know, there was a time not that long ago…I'm in my 25th year, 25 years ago we did stuff every day, there was stuff we did every day that was

> arranged and set up and organized and the district chief knew about it and ensured we did it…we're all guilty, we're all guilty of it [training not being conducted].

Additionally, participants expressed that there are inconsistencies with the amount of informal training being conducted by crews, with some crews doing far more informal training then others, however the level and frequency of training across TFS remains problematic. Regarding the lack of formal training by the training division, participant #3 stated "the only training we do is with our crews and the crews have taken somewhat of a leadership role" [to initiate their own training]. This sentiment was repeated by participant #4 who was impressed by the dedication and success of the crews despite the lack of training, saying:

> But the lack, the lack of training is. My God it like it's really starting to sink into me. I don't know if it's because I'm in the role I'm in now or what, but I'm seeing it and on the other side of it, I'm seeing how well as an organization, how well our people adapt to the lack of it.

This participant suggested, TFS firefighters remain focused and operationally successful despite the lack of formal and informal training being conducted.

Interview participants were also asked to comment on the responses to some of the survey questions relating to training where the results were not definitive. The results from question 6, below, had a median of 3, which suggested respondents were split in their views of the experience of crew training.

Q6. Does this statement reflect your experience? My fire crew is well prepared and trained in how to implement an improvised interior/exterior standpipe system if a standpipe system in a building fails.

Strongly Agree 1	**Agree 2**	**Neutral 3**	**Disagree 4**	**Strongly Disagree 5**
7.6% N=21	27.4% N=76	13.4% N=32	36.1% N=100	15.5% N=43
Median =3	**Mean** =3.27	**SD =**1.04	**Avg** 3.25% N= 277	

Interview participants were asked why they thought respondents had vastly different responses and they offered several different explanations. Participant #1 suggested that the split in respondents' opinions was a result of a training and knowledge gap that led to their confusion comprehending the question, saying:

> I think a lot of firefighters may not understand that question, only because they don't know what an improvised standpipe is…they don't have that experience of doing an improvised standpipe…it comes down to that knowledge base, without that knowledge base, you know, crews don't know what answer to pick right?

The perceived current lack of knowledge and training on improvised standpipe systems and the erosion of this skill set was echoed by participant #2 who reflected on his experience and that of his crew and said, *"*I trained on it many, many years ago. Has my crew trained on it, I'll guarantee they haven't, not even in recruit training.*"* Participant #3 suggested that the split in opinion for this question was a function of bravado, with respondents not being honest and critically reflective of their actual abilities*:*

> I think everybody is going oh wait were not trained, and then you know, I think there are certain people who may not be answering that honestly…I think that comes with our job and I think a lot of us are type A personalities, we feel we can handle just about anything. And they may think they're prepared but they may not even know what they're being prepared for, they may not even know what the problems are

Thus, possible reasons for the mixed response to question six include an erosion in the knowledge base and training of this skill set by fire crews, additionally crews may be displaying bravado and not being honestly reflective of their actual abilities.

The interview participants were also provided with the results from question 15 in the survey, shown below, which indicated that most participants had not received training from TFS in pump operations training for standpipe connections in SHR buildings (> 84 meters).

Q15. How accurately does this statement represent your experience? TFS has provided me with pump operations training for standpipe connections in super high-rise buildings (> 84 meters)

Strongly Agree 1	**Agree 2**	**Neutral 3**	**Disagree 4**	**Strongly Disagree 5**
.7% N=2	1.8% N=5	5.4% N=15	35.4% N=96	58% N=160
Median =5	**Mean** =4.5	**SD =.74**	**Avg** 4.46% N= 278	

Participants were asked to explain factors that influenced access to SHR training for TFS personnel and whether they would ideally expect all TFS personnel to have access to or taken this type of training. While there were a range of views about influencing factors, all participants believed that this training was necessary but inaccessible for many reasons. When whether the participant believed there was a need for access to and completion of this specialized training by personnel, participant #4 stated, “I do. Yeah. 100%.” Participant #3 suggested that the training at least should be accessible and completed by those who encounter SHR buildings in their commands and districts saying, “Yeah. Wow, at least the ones that are being exposed to those hazards, at least the people that work in that area.” Participant #1 commented on the inaccessibility of this training currently and the future direction that this training would take, saying:

> We don't have any access to this training now. I know [anonymous] has made huge leaps and bounds. So now you can go online, it will tell you to pump 1400kpa into every standpipe…that information is actually starting to come out now…we can't give you all the cool techniques…we only give you the basics, here's the kit…that fine tuning that needs to be done at the station with the Captain and crew.

Participant #4, who agreed that there is an expectation for personnel to receive this training, but budgetary concerns and a lack of resources impacts the ability for the training division to deliver programs, said, "they just don't have the resources to cover all the things they need to cover…it [training division] has to take a greater position within TFS…it should be number two." There was consensus among participants that this training needs to be accessible to firefighters, but accessibility is difficult due to resource scarcity, however training is in development and is becoming accessible in an online format.

The data from the quantitative survey also indicated are problems with training. The mean property measurement for survey questions relating to training was 52%, much lower then the other two properties. When measurements were filtered by command, years of service, level of education and by districts that contain the most SHR inventory, the results showed little variation. Deficiencies in training are generally well known throughout TFS operations division, however, the assertion that problems with leadership have contributed to a lack of access to and availability of appropriate training for SHR buildings was unexpected.

Leadership

There was a perception among participants that there are leadership deficiencies within TFS that may be impacting training. Participant #3 suggested that TFS needs effective and decisive direction and communication from senior administrators to acknowledge and rectify training problems within the organization saying,

> [communication] has to come from the top and I think leadership of the department has to recognize that we have a problem here, and they have to make a statement and say were going to address it with this training and come up with a program and get everyone on board

This sentiment was shared by participant #4 regarding the need for senior administration to address problems, who said, “dive into this and proactively say, you know what, this is where we are going, what’s it going to take to make this, to be able to respond well to these.” The lack of direction and communication from senior administration was echoed by participant #2 who suggested that the primary medium for communication of policies was antiquated and ineffectual saying, “the communication in our stations from management or from headquarters is so bad…they send out an FCC [Fire communications communique] they assume everyone reads it.” While this statement suggests that the method and medium of delivery of communication is deemed poor and antiquated, it also points to a potential lack of leadership by officers to discuss these communications with their crews and ensure that everyone is up to date.

Participant #2 asserted that equipment needs, and training deficiencies are not pro-actively addressed by senior administration and are only addressed after being researched and pushed for by the “boots on the ground” firefighters. The Participant said, “Individuals took it upon themselves to establish a committee, the high-rise committee, and they were the driving force behind, you know, a second high-rise truck, the updated equipment on those trucks and then the training…I would say it’s the boots on the ground that have pushed and pushed and got the training and the equipment." The participant suggested that new training and equipment requests have been driven by firefighter initiatives and not from the administrative level.

Two participants believed that the direction and leadership of senior administration was moving in a positive direction. Participant #1 spoke of the leadership provided by senior administration in the development of training for pump operations for HR buildings, saying, "I know that [senior administrator] has made huge leaps and bounds. You can go online; it'll tell you to pump at 1400kpa into every standpipe…that information is actually starting to come out now." A positive future leadership direction for TFS was asserted by participant #4 who stated:

> I know that he's [senior administrator] grabbed the bull by the horns and he's moving in the right direction and I'm hopeful were gonna make some real gains there. Right now, for everybody's sake, for our sake, for the organization's sake as well.

The consideration of leadership problems was not an initial focus in this study and was revealed while attaining the perspective of participants during the interviews. As participants suggested, leadership is needed to develop the required training programs and ensure provision of facilities, as well as to deliver the appropriate knowledge base to firefighters so they can achieve successful operational outcomes.

Knowledge

Interview respondents suggested that knowledge about firefighting in SHR buildings is influenced by the number of SHR building inventory that is in a firefighter's district. They also perceived a need to seek specialized knowledge about SHR buildings from outside sources and to operationalize that knowledge in full mock training scenarios on SHR buildings to gain experience with this type of fire response.

Interview participants suggested firefighters SHR building knowledge is influenced by the level of SHR building inventory in their commands and districts. A higher number of SHR buildings in a district provide more exposure to SHR buildings and thus more experience. Participant #1 explained:

> We do have more buildings in the downtown core, and we do have those ultra high, high-rise buildings in the downtown core. And although we haven't had as many fires in those buildings, when we run alarm calls or medical calls, were getting in these complex buildings…[it] gets us a bit more familiar with these buildings then let's say trucks, you know like 411.

While certain districts have much greater inventory of SHR buildings and have more exposure to them, the knowledge of these building complexities remain limited for firefighters.

The specific knowledge that is needed by firefighters to operate in SHR buildings was described by participant #1 who confirmed that unique knowledge is required when firefighting in SHR buildings compared to typical HR buildings, saying:

> They [crews] need to understand the building envelope [footprint] and they need to understand the building systems because all these buildings are different. Being able to recognize the type of systems in the building will make it easier for firefighters to understand what tactic is needed and what smoke control measures are needed…if we recognize the building envelope and the building systems then we know how this firefight is going to go, right now we don't recognize what's happening with the building envelope…we can use the building envelope and those systems to help contain that fire to

> the fire floor…[the] building is trying to do this for us and that's the key difference between 1960 buildings and these ultra high-rise buildings.

Similarly, participant #2 said, "Firefighters need to know the layout of the building, how many stairwells, where are the stairwells, elevators, how many elevators and then the buildings mechanical system." The complexities of these new buildings and the knowledge needed to work with the buildings systems and building design to achieve success was recognized by participant #4 who stated, "building systems, I really think with SHR's, that it's really these amazing complex building systems that come into play." While working with the building envelope and building systems was unanimously acknowledged by participants, how a fire behaves or can be manipulated in SHR buildings was also recognized as crucial knowledge needed by firefighters. Participant #4 stated, "You know, fire behavior in high-rise buildings…thermodynamics, how the smoke and heat moves in a high-rise building…we need to know that." Fire behaviour, stack effect or how smoke moves above and below the neutral plane in a building is necessary knowledge for firefighters to operate safely and effectively in SHR buildings.

Multiple participants suggested, outside organizations with specific expertise in SHR firefighting should be brought in to share their knowledge. As participant #3 said:

> I think it would be more effective to bring in experts…maybe they're engineers, maybe they're sprinkler designers or people who build elevators, and have them explain what the limitations of some of the systems are in these buildings to firefighters. Everything in these buildings are designed for the people that live in them, they are not necessarily designed for firefighters.

Reaching out to outside sources to increase firefighter's knowledge of the buildings was supported by other participants. For example, participant #1 said, "We should do more tours, tours with either the people that designed them, or the engineer that's managing that building and ask them how do you expect us to fight a fire in the building." Participant #4 agreed, saying "bring in experts and show us … the fire protection and … the fire detection and the suppression systems." Participants felt this approach could be successful in meshing the technical knowledge firefighters need with the practical application of how to best work with the building design and systems during fire operations. Participant #4 asserted "we're familiar with what we have now because you know, we're doing it, but these new buildings that they are constructing it's state of the art equipment that we have very, very limited knowledge on how to operate." Firefighter's lack of familiarity with SHR building design and systems is further impacted by a lack of hands on SHR training. It was suggested that hands on training through full-mock scenarios could alleviate this short fall.

Knowledge is inter-related with training. Participants suggested that full-mock scenarios should be conducted in SHR buildings simulating a fire response to increase operational knowledge. This would allow crews to take a heuristic approach, establishing what tactics may be successful, and to see what barriers to success will likely be encountered. Participant #1 described in detail the need and benefit of conducting scenarios for this purpose, saying:

> We should run yearly full-scale scenarios with the staffing equivalent to a second alarm…within those scenarios do the difficult tasks…live scenario training is really, it's hands on doing kinesthetic repetitive training…your training has to accurately represent the reality of the situation.

This response reinforces the importance of meshing knowledge acquisition with kinesthetic repetition provided by through training.

Findings suggest a firefighter's knowledge base is influenced by the frequency of their exposure to SHR buildings. Knowledge of SHR building envelopes and building systems by firefighters is required and could be enhanced by bringing in outside experts who could provide insight into the design of buildings and their systems. Further, knowledge about something is different than experiential knowledge, mock scenarios are also needed to develop the type of kinesthetic knowledge needed for firefighting. While knowledge is crucial to the operational success of firefighting operations in SHR buildings, preparedness is another capacity for firefighters to respond effectively.

Preparedness

Preparedness is inclusive of material and human resources needed to response to fires in SHR buildings. The findings suggest that TFS has the technical capacity to respond to fires in SHR buildings and has sufficient personnel. However, capacity is reduced because of the lack of trained personnel. TFS has recognized the need to invest in specialized technical equipment to provide the needed capacity to respond to fires in SHR buildings. TFS now has two dedicated HR trucks which carry specialized equipment designed to overcome some of the vulnerabilities in these buildings such as water supply issues from the standpipe system. Participant #1 acknowledged the importance of this new technical capacity for TFS, but noted the training component is still required, saying:

> The good news is we've already bought the equipment and it's on the high-rise trucks. We just need the training…we've come up with a package of four FX

> extinguishers…you pull a pin, you throw it in the unit, close the door, 30 seconds later you re-enter and you see what the extinguisher has done…so we'll be going through all four and that gives us 30 seconds to back up with a portable compressed air foam system…we can fill an apartment with 600 us gallons of finished foam…that is our solution for a catastrophic failure where we can't get any water on the fire.

This added capacity is available on two specialized trucks that are staffed with four dedicated personnel; however, the bulk of firefighting operations remain the work of other apparatus. The state of the current HR kit known as a (Pal Pak) is a limiting factor for preparedness as it doesn't supply the needed water volume and pressure for HR and SHR buildings. As participant #1 explained,

> So unfortunately, due to our current hose and nozzle package, we don't have, we really can't effectively fight fires right now. We're currently using the Pal Pak which is a 38mm hose and fog nozzle. If you look at NFPA 14 and 13a and 1710, it is recommending a 65mm hose line with one and one/eight tip. This helps with low pressure and gives us the volume that we need…it [Pal Pak] doesn't meet any real standard.

Participants perceived that the new equipment would increase capacity to respond to fires in SHR buildings. Using a scale using a rating between 1 (low) and 10 (high) to rate TFS preparedness, participant #1 stated:

> For our ultra-tall buildings [SHR] … I'd have to give us a one, only because of the Pal Pak. By the end of the year, I'd give us an eight on SHR buildings because now we have the proper hose and nozzle package…we need that specialized equipment and specialized training.

Thus, the upgrade in equipment is a significant boost in technical capacity for TFS firefighters responding to SHR buildings, however training is still required.

SHR buildings can present unique challenges that require adequate resources on scene, however not all incident commanders are aware of the resources they may require. As participant #4 explained:

> I mean, developing a response plan to this [SHR]. I mean, what resources do we need? Do we even know what we need at these, these super high-rises?... If the fire is on the 60th floor, what does that even mean? As opposed to a fire on the third floor. You know, like how many more, how many more people do we need based on, based on what, you know?

The uncertainty of what resources may be required by incident command are compounded by a general lack of awareness of the distribution of SHR buildings across commands. Participant #2, when asked about the location of SHR buildings said, “in south command, they have far more super high-rises. I don’t think there’s any actually, I don’t think there’s any in any other commands.” While South command does have the greatest inventory of SHR buildings, these buildings are present in all four commands. This misconception of the size and location of SHR buildings throughout Toronto was reflected in comments by participant #4 who stated, “I don’t think we run a lot of these calls [SHR buildings] throughout the city. Those type of structures you typically find them along the you know, Yonge street corridor or down in a downtown area.” While many SHR buildings are located along the Yonge street corridor which follows the subway line, there is significant stock of SHR buildings in the West and East ends of the city, away from the Downtown core.

There was unanimous agreement among all participants that there are differences in the level of preparedness across commands, with the perception that South command has the greatest level of preparedness. As participant #2 said:

> No, it'll be definitely different, differences in preparedness…there will be people in other commands that have no idea…unless you have exposure to these and what the challenges are, I think you take for granted what you might run into.

The perception of differences between commands with South command being the most prepared was highlighted by participant #1 who noted:

> I can tell you that they're definitely not equal. South command would be the most prepared. But even within South command, I would say district 33 would be the most prepared…now North command has a new high-rise [truck]. So, I would say they would be second and they'll get better just like South command. And East and West command … I would say that they'd be tied for third.

Participants suggested that greater levels of SHR building inventory in a command provided more exposure for firefighters to these buildings, observing that the exposure provided a greater level of experience which ultimately influences preparedness across commands**.** Participant #4 elaborated on the increase of exposure being a factor in greater preparedness, saying, "I would say they're more prepared for it in the South…there isn't as many high-rises in these other commands…So that would probably be the rationale for them being a little bit better, a little more practiced." The increase in practice was explained by participant #1 who described how responding to false alarms or medical calls provided south command firefighters with increased familiarization with SHR buildings, they noted

> So we do have more buildings in the downtown core…and although we haven't had as many fires in those buildings, when we run those alarm calls or medical calls, we're getting in these complex buildings…running alarm calls, running medical calls gets us more familiar with these buildings.

Increased familiarization with these buildings may also influence the preparedness of firefighters to overcome possible water supply issues that they may encounter in SHR buildings and the recognition that the current Pal Pak is not a viable tool for fire suppression.

The interview participants were provided with the quantitative data results from question #9 below, which had a median response of 3 and showed that survey respondents were split in their opinion, with a 28% of respondents choosing the neutral position. The interview participants were asked to give their interpretation of the survey results for the following question:

Q9. Do you agree with this statement? Very tall buildings can present challenges to fire crews who require adequate nozzle pressure for fire suppression. TFS high-rise kits (Pal Pak) provide adequate equipment (low pressure nozzles etc) to overcome low water pressures in buildings.

Strongly Agree 1	**Agree 2**	**Neutral 3**	**Disagree 4**	**Strongly Disagree 5**
2.5% N=7	24.7% N=69	28% N=78	33% N=91	12.2% N=34
Median =3	**Mean** =3.27	**SD =**1.04	**Avg** 3.27% N= 279	

Participant #1 suggested that the large neutral position showed a knowledge gap, that many firefighters were unaware of water supply issues in SHR buildings and the inadequacy of the equipment they were using. He said, "that response shows that the education needs, or the education isn't there." Participant #4 agreed that the large neutral response was the result of a knowledge gap, saying "I think it's inconsistencies…you're getting into a lack of knowledge…you have some crews that are just completely unaware of the new hose that we're using, the 65 and all that." Participant #3 agreed that the large neutral response was the result of a lack of awareness and education, stating "again, the neutral at 28 [%] means that people are unaware, that they haven't been educated on it at all." Participant #2 explained the median of 3 was a case of those who understand the issue and others that do not, saying "There's those that know and those that don't know." Thus, there appeared to be agreement among interview participants that the results suggest there is a knowledge gap about the limitations of standard TFS equipment for fighting fires in high rise buildings. The knowledge and education of water supply vulnerabilities is an important component of firefighter preparedness. The level of knowledge and education of firefighters can contribute to a firefighter's risk perception.

Firefighter Risk Perception

The findings suggest optimism bias influences FF's risk perception and level of preparedness, especially in city areas with low levels of HR/SHR building inventory. Further, a fire crew's knowledge base, experience, and familiarity with SHR buildings appear to influence firefighter's perception of personal risk that could result in injury. As one participant explained, with a lack of training increased perception of risk could be the result of fearing the unknown. Participant #4 stated:

> We haven't had a lot of training in these buildings. So, the fear of the unknown…we are going to get up there, and you know, is it going to behave different? ...is there going to be enough water? … I would say it's the fear of the unknown…I think experience would overcome that [increased risk perception].

A fire crew's knowledge base and experience were cited by participant #2 as a major component of perception of risk related to firefighting with SHR buildings, saying:

> I think number one, lack of knowledge…unless you've done any research, again, research or training on it [SHR buildings], you have no idea, it's going to be by trial and error and sometimes that takes time. And we know time is not our friend on the fire ground.

The participant continued to explain that an experience gap among fire crews will affect their risk perception, saying "[fire crews] not being aware of the challenge ahead of them, like just being unaware because they've had no exposure" (Participant #2). Experience can also come through training and the lack of training was suggested as being a factor influencing risk perception. Participant #3 said, "going back to training right, so you may, you may think something is quite risky because they've never been trained on it." Firefighters exposure to SHR buildings and the level of training they have received can influence the perception of risk.

In discussing risk perception, participants talked about the belief by some firefighters that they will never experience difficulties or even encounter firefighting operations in an SHR building. Participant #3 suggested "[firefighters] blind faith in the building components, that they all function, everything works…it's not gonna happen to me, it's gonna happen to somebody else." This sentiment was expressed by participant #1 who explained how fire crews lack of risk perception has led to complacent behaviour and dangerous fire ground practices. The participant spoke of his conversations and interactions with many fire crews, saying

> You know how many times I've taken the elevator to the fire floor. And say, Well there's a firefighter killed in Texas, there's a firefighter killed here, there's a firefighter

killed there. Look at the NIOSH studies, they took the elevator to the fire floor…well, if I ever get a fire that's that bad, I'll take my thumb off the door close button and the door will close and I'll be safe. They just don't have that experience or have been in a situation where they're going to be in trouble. And it's hard for firefighters to kind of make those connections…they don't know any better…they haven't had that bad experience. They have had good luck.

These views support the notion that optimism bias may be an influencing factor in firefighters risk perception.

The experience of firefighting in SHR buildings and the risk perception firefighters experience was explored in question 5 of the survey, shown below. The result from this question was a median of 3, which showed that respondents were split in their opinion. Further, 25% gave a neutral response (rating of 3). The interview participants were asked to give their interpretation of the survey results for the following question:

Q5. How accurately does this statement reflect your opinion? When fighting a fire in a high-rise building above 30 storeys, I feel well protected from personal injury and well equipped to achieve successful outcomes.

Strongly Agree 1	**Agree 2**	**Neutral 3**	**Disagree 4**	**Strongly Disagree 5**
4.6% N=13	36.6% N=102	25.1% N=70	24.4% N=68	9.3% N=26
Median =3	**Mean** =2.97	**SD** =1.08	**Avg** 2.97% N= 279	

Participant #1 suggested that the reason for the neutral position reflected a lack of awareness, saying "the 70 people that went with neutral, that neutral could really reflect just a lack of awareness of issues in these very tall buildings." Participant #3 concurred that the neutral position was a response to a lack of knowledge and awareness, suggesting respondents were thinking, "Well, I didn't realize this was a problem so I'm kind of like neutral on this because I don't know a lot about it." Participant #4 suggested that those that strongly agree may have received more training than those that disagreed, and this could reflect inconsistencies across commands. The participant suggested,

> It speaks to our inconsistencies across commands on how we respond. And I also would say it speaks to our inconsistencies in training. So the people that would strongly agree that they feel well protected, they might be getting more training in that area…and the people that disagree, maybe they're not…but the fact that it is happening [Median of 3], just speaks volumes to the problem that we have, don't you think?

Participant #2 agreed that those who said they felt truly safe may have an increased knowledge base, however also suggested that the make up of this group may be partially made up of those who feel invincible. This participant suggested "that group that feel totally prepared is made up of young, invincible members and people who have true general knowledge." Thus, interview respondents suggested a firefighter's level of knowledge and experience influence risk perception. Gaps in knowledge and experience may lead to a heightened risk perception if firefighters do not have the necessary knowledge to accurately access risk. As one participant suggested a firefighter might have an increased sense of risk due to a fear of the unknown. The ability for firefighters to accurately access risk is important when conducting operations in SHR buildings with complex designs and operating systems.

SHR Building Vulnerabilities

SHR buildings have complex designs with complex building systems that can complicate operational responses and present firefighters with additional challenges. Some of these challenges include difficult ingress due to premise security. Security can limit access to certain floors in both stairwells and elevators especially in mixed use buildings. The height of SHR buildings can add significant VRTs, delaying rapid mitigation. Added height impacts the ability for firefighters to overcome elevation and friction loss in a standpipe system creating water supply issues for suppression. Many of these buildings have glass wall exteriors which become a hazard with falling glass if they are breached**.** SHR buildings can have extraordinarily complex designs as the result of a blending of an old building with a modern building. Often SHR buildings are mixed-use buildings with both residential and commercial usage. One of the noted complexities with gaining ingress into these types of building was security. As participant #1 explained:

> Premise security. The buildings are becoming more secure. We have more layers of security that we have to go through just to get to the fire location. The building internal layout. So we have large podiums. We have a high-rise building on top of a high-rise building, we have commercial we have mixed-use. So the complexity…

The complexity of security and the internal layout of these buildings was also noted by participant #2, who said:

> You go to certain floors, you can only access certain floors…there are buildings that you can only access certain parts of the building…so you've got complex building designs…so they've included an old building into a new building to protect history, but this is where you run into a whole other thing, you can be in a building that has a completely different address and be connected to another building.

Complex building designs can impede ingress which further adds to the response time and adds precious minutes to the VRT. Participant #1 elaborated on the operational challenges that are caused by VRT, saying:

> You have your reaction time, your reflex time, how long does it take us to get from the lobby up to fight the fire, Toronto averages six minutes. Anytime the incident commander calls for something, he or she has to expect a six-minute reaction time or leg time. That, that is a huge problem.

As illustrated, timely access to a building is a critical factor in a response and security and building design are two factors that can impede access and slow VRT.

The ability for lift capacity is crucial to move personnel and equipment and participants noted this ability to is challenging in buildings that distribute access via different elevators. As participant #2 noted:

> Different elevators, different sizes, some go to certain floors and so this is where your pre-planning comes in, you go to certain floors, you can only access certain floors…the work involved of getting your equipment up there and establishing, establishing, you know, a base sector up a couple floors below the fire floor.

Lift capacity is one of many systems that firefighters are reliant upon to successfully launch an operation in an SHR building.

Firefighters are also heavily reliant on fire pumps and the standpipe system for fire suppression. For some SHR buildings it is not possible for the fire service to overcome the elevation loss and head pressure if a fire pump system fails. As participant #1 explained:

> So with buildings of that height, we are heavily reliant on the building systems. The proper size hose and nozzle package is definitely needed for these types of buildings. If we have a failure of the system that is where we run into problems…if we have a failure, let's say so if the elevators fail, we have a big problem, a fire pump fail, smoke ventilation systems, or there's improper compartmentalization or the EVAC announcement system doesn't work. That's going to give us a real problem.

A failure of systems would be a catastrophic event which would severely impede any chance of a successful operational outcome. While a catastrophic systems failure would have extreme consequences, even when building systems are functioning normally, firefighters can be presented with water flow issues that can impact fire suppression. As participant #1 elaborated,

> We don't follow the NFPA standard, we follow the Ontario building code…when they talk pre and post 1993[NFPA]. They're talking about 65psi and 100psi for standpipe operations. We follow the Ontario building code, which is 65psi. And we go below 65 if the fire department is able to supply the FDC connection…So a lot of people don't know that. So we are actually below the NFPA standard in some of our buildings, were actually below the 65psi. So it's kind of scary if you look at it that way.

Thus, depending on the building, firefighters can experience water pressure in standpipe connections below the OBC mandate of 65psi, adding another operational challenge for firefighters with SHR buildings.

Participants also noted numerous other operational challenges for firefighters in these buildings. As participant #1 explained:

> We have problems, objects falling from heights, the higher the building the more danger the more debris…communications with our radios is a huge problem, premise security…our water supply…the FDC from the dry to the wet side is a problem…the physical demand and physical workload for firefighters is huge…failure of the electrical systems is huge, casualty retrieval is complicated. Fire and smoke spread are something we have to worry about, the effects of wind…catastrophic building system failures.

There are many potential operational challenges for firefighters responding to fires in these complex buildings. Complex internal building designs with premise security that limits firefighter ingress; additional VRT due to the height of the building; impacted standpipe operations due to elevation and friction loss as well as failures occurring at the FDC; falling glass debris from height if windows are breached and an increased fire and occupant load.

This chapter provided findings from the interviews that help in understanding factors influencing preparedness for response to fires in SHR buildings. Further the chapter presented some explanations for the survey results that were difficult to interpret. As illustrated, training, leadership, and knowledge are all factors that influence preparedness. Firefighter's perception of risk related to responding to fires in SHR buildings appear to be influenced by experience/exposure to SHR buildings, knowledge and the level of training received. A firefighter may experience heightened risk perception due to a lack of experience and knowledge, or as one participant suggested, because of "the fear of the unknown" (participant #4). Further, there are inherent vulnerabilities in responding to fires in SHR buildings because of complex internal building designs with premise security that limits firefighter ingress; additional VRT due to the height of the building; impacted standpipe operations due to elevation and friction loss; failures occurring at the FDC between the wet and dry side; falling glass debris from height if windows are breached and an increased fire and occupant load.

Chapter 6 - Discussion

This chapter offers a discussion and interpretation of the study's findings and provides actionable recommendations for the fire service. The recommendations are intended to provide a framework that supports the enhancement of firefighter preparedness and safety. Additionally, this chapter provides an explanation and overview of possible study limitations.

The purpose of this study was to measure the level of preparedness of fire service personnel to inherent vulnerabilities in high-rise residential buildings that could threaten firefighter's life-safety during a fire event. Additionally, this study explored which factors support or limit preparedness. Firefighter preparedness is influenced both positively and negatively by several key properties. The influencing properties for firefighter preparedness consist of technical and environmental/contextual knowledge, specialized/focused training, and firefighter experience. Resource capacity, both material and human, of TFS as an organization also influences preparedness. In turn, other factors appear to influence resource capacity, including organizational priorities, budgetary requirements, leadership and mentoring and the availability of necessary resources (personnel and equipment) available for deployment. TFS capacity is also influenced by the ability to develop training curriculum, implement training programs, and provide training facilities to support that curriculum.

Preparedness Deficiencies

Knowledge

There are two parameters of knowledge that influence firefighter preparedness. One is technical knowledge. Technical knowledge is the specialized or specific knowledge firefighters need to fight fires in SHR buildings, such as the knowledge of water supply vulnerabilities and standpipe operations. The second is environmental/contextual knowledge, knowledge regarding the environment in which they are working. This knowledge includes area familiarization of the building inventories in fire districts and firefighter's familiarity with SHR building envelopes. The analysis of the quantitative findings revealed inconsistencies in the level of technical and environmental knowledge across commands and districts. Respondents were asked if they have any SHR buildings in their fire district as defined by the OBC definition. The commands and districts with the greatest inventory of SHR buildings were chosen for analysis (South command: district 1 & 3, North command: district 1, West command: district 3, East command: district 4). Each command and district showed large variation in their environmental knowledge of building inventory. For example, there are 22 SHR buildings in West command, district 3, and 23 SHR buildings in East command, district 4, however the responses from these two commands and districts were vastly different, with 78% of west command district 3 respondents saying that SHR buildings are present in their district, while 75% of East command district 4 respondents saying that SHR buildings were not present in their district. Environmental and technical knowledge of SHR buildings in districts by firefighters was explored again using the NFPA definition of a very-tall building which adopts slightly different language then the OBC definition for a SHR. Where the OBC defines a SHR by height (>84m), the NFPA defines a very-tall building by the inability of the fire service to overcome elevation and friction loss when pumping into the building standpipe. The results from this question displayed a median of 3, with respondents across all four commands split in their opinion regarding the presence of these buildings in their fire district. When commands and districts with the greatest inventory of SHR buildings were chosen for analysis (South command, district 1 & 3, North command: district 1, West command, district 3, East command, district 4), East command district 4 responded with

50% in agreement that these buildings are present in district 4. This is a different outcome from the OBC definition where 75% of respondents said that these buildings were not located in East command district 4. North district 1, South district 1 & 3 and West district 3 were split in their opinion with a median of 3 in contrast to the OBC definition where respondents mostly agreed that these buildings are in their fire districts. The variation and lack of knowledge regarding the presence and location of SHR building inventory in fire districts was supported by the qualitative findings. Interview participants also had different perspectives of where these buildings may be found, with one participant suggesting that SHR buildings are only located in South command, while another participant believed that these buildings typically are located along the Yonge street corridor. While many SHR buildings are located along the Yonge street corridor which follows the subway line and encompasses both North and South commands, there is significant stock of SHR buildings in the West and East ends of the city, away from the Downtown core. The lack of firefighter awareness to the identification and presence of SHR building inventory in their fire districts points to inconsistencies in environmental knowledge across commands and districts. It is important for firefighters to be aware of the unique characteristics of the buildings in their district and to recognize SHR buildings and the vulnerabilities that these buildings may present in order to achieve successful mitigation and reduce life-safety risk.

One of the largest potential vulnerabilities for firefighters is difficulty with adequate water supply for fire suppression in SHR and HR buildings. There are numerous water supply issues that firefighters may encounter, and one problem is non-field adjustable pressure reducing valves that regulate the water pressure a firefighter will receive when connected to a standpipe; these valves are important, especially on lower floors of a building where the pressure is greatest. If these are set incorrectly the result can be low water pressure that can not be easily corrected or overcome (Stuckey, 2015). Another issue that can impact operations is a failure in the standpipe system, particularly on the dry side at the fire department connections; failures have been documented at pressures well below the maximum rated standpipe operating pressures (Savelle, 2007). A failure of a building's stationary fire pump in SHR buildings is a catastrophic event which requires sole source water supply pumping by fire department apparatus. Depending on what floor the fire is located, it may not be possible for firefighters to overcome the elevation loss and friction loss present to supply adequate water pressure (Friedman, 2014). The most common water supply complications for TFS have been the OBC's minimum pressure requirements because buildings in Ontario are not required to follow the NFPA 14 standards. The OBC mandate only requires buildings to meet a minimum requirement of 450 kpa and 1800 LPM of water flow (TFS Training Note, December 2019). For this reason, firefighters arriving at a building that has properly functioning stationary fire pumps can not be sure what water pressure they will receive from a standpipe system. To overcome this uncertainty, TFS is now deploying a new HR firefighting kit that conforms to NFPA 1710 standards and provides larger water flow rates at lower pressures then the current (Pal Pak) HR kit. Survey responses to this question about firefighter's technical knowledge of water supply issues (question 9), had a median of 3, indicating that respondents are split in their knowledge about water supply and pressures needed to fight fires in HR buildings. Close to half of TFS firefighters agree that water supply and low building pressures are a concern and recognize the inadequacy of the current HR kit (Pal Pak) in use. However, 28% chose the neutral position, possibly being unsure or unaware that water supply issues are a serious concern, and 27% believe that the TFS Pal Pak currently being used by fire crews is sufficient for HR operations. A potential reason for this split in response was explained by an interview participant #4 who stated, "I think it's inconsistencies…you're getting into a lack of knowledge…you have some crews that are just completely unaware of the new hose that we're using, the 65 and all that." The notion that there is a technical knowledge gap about water supply and pressure was also supported by participant #3 who suggested "the neutral at 28 [%] means that people are unaware, that they haven't been educated on it at all." These three questions support the suggestion that there are inconsistencies in both technical and environmental/contextual knowledge across commands and districts. These inconsistencies in knowledge also impact firefighter's risk perception and situational awareness.

Risk Perception

A firefighter's technical and environmental knowledge of HR vulnerabilities will shape their perception of risk and influence the corresponding self-protective actions and behaviours they implement. Increased knowledge of environmental vulnerabilities expands a firefighter's situational awareness and their ability to assess risk with greater accuracy. Survey question 5 explored the personal risk perception of firefighters while performing operations in buildings above 30 storeys. The results showed a median of 3, with respondents split in their perception of personal risk. While 40% of respondents said they felt safe, 25% chose the neutral position and 34% said they did not feel safe. A potential reason for this split in response was explained by an interview participant who suggested that an increase in risk perception could be due to a lack of knowledge and training. Participant #4 said:

> We haven't had a lot of training in these buildings. So the fear of the unknown…we are going to get up there, and you know, is it going to behave different?...is there going to be enough water? … I would say it's the fear of the unknown…I think experience would overcome that [increased risk perception].

The participant continued to explain that an experience gap among fire crews will affect their risk perception, saying "[fire crews] not being aware of the challenge ahead of them, like just being unaware because they've had no exposure" (Participant #4). Experience can also come through training and a lack of training was suggested as being a factor influencing risk perception. As participant #3 said, "going back to training right, so you may, you may think something is quite risky because they've never been trained on it."

These statements support the suggestion that risk perception is influenced by knowledge and experience which can be gained through training. The ability to properly access risk is an important component of situational awareness and can be influenced by optimism bias. Optimism bias can be defined as "a systematic error in perception of an individual's own standing relative to group averages, in which negative events are seen as less likely to occur to the individual than average compared with the group, and positive events as more likely to occur than compared with the group (Weinstein, 1980, as cited by Dalziel & Soames Job, 2006, P. 490). For firefighters operating in a HR building, optimism bias could lead to the underestimation of the potential risks and an overestimation of their personal ability and preparedness. It was suggested that optimism bias could play an influencing role in those respondents who had a lower risk perception. As participant #3 suggested "[firefighters] blind faith in the building components, that they all function, everything works…it's not gonna happen to me, it's gonna happen to somebody else." The participant's statement lends support to the role of optimism bias as an influencing factor in respondents risk perception and assessment of risk. The participant's statement mirrors the definition of optimism bias as explained by Sharot (2011), who described optimism bias as an underestimation of our chances of becoming ill, getting divorced or being in a car accident while overestimating our successes such as stock market gains, the ability to get a project completed on time and within the budget, or our personal job marketability (Sharot, 2011). While experience, knowledge and training influence firefighter's risk perception and their ability to accurately assess risk, optimism bias could lead to the underestimation of the potential risks and an overestimation of a firefighter's personal ability and preparedness. It has been suggested that firefighters with greater levels of experience and education have a higher risk perception. Rodriguez-Garzon et al., (2012) reported a greater level of education and experience leads to a higher risk perception in firefighters, specifically those who are university educated. The current study analyzed risk perception applying demographic filters by education and years of service (experience) to see if these two factors lead to an increase in risk perception. This study did not find an association between greater levels of education and experience and an increase in risk perception among firefighters. While risk perception is influenced by knowledge and experience, it is largely through training that knowledge and experience is developed

Training

Technical and environmental/contextual knowledge is supported or limited by the frequency, accessibility, and quality of training a firefighter receives. As McGrail (2007) noted "Firefighter safety and survival is directly related to the type and amount of training you receive", (p. 12). SHR and HR firefighting training is a focused/specialized training that is not readily accessible for TFS firefighters. The quantitative results indicated that 93% of respondents had not received training in pump operations for standpipes in SHR buildings. A lack of SHR firefighter tactics and training remains a problem for TFS and the fire service in general, as explained by participant #1 who stated:

> Well there is no specialized training for fighting fires in high-rise buildings, this is one area that is lacking in the whole fire service in general…there's no courses as it is now, So this is something that‘s very much needed…and I guess the question is, they don't and they can't get that type of training [firefighters], so we need to develop that training somehow.

Accessibility to specialized training for firefighters requires curriculum development and specialized facilities that is limited or supported by aspects of resource capacity, namely budgetary and organizational decisions. This was supported by the views of participant #4 who stated: ‘‘they just don't have the resources to cover all the things they need to cover…it [training division] has to take a greater position within TFS…it should be number two.” The participant elaborated further, saying “The training division at TFS should be number two to OPS in terms of budget resources and what we need..” While resources to develop curriculum and to run formal SHR training programs may be hampered by resource concerns, online training material is available for several HR specific fire ground skill sets such as improvised standpipe techniques. The preparedness of crews to implement improvised interior/exterior standpipes was explored in the survey which revealed that respondents were split in their perspective of crew preparedness and training in how to implement an improvised interior/exterior standpipe system with 52% saying their crew was not prepared, 13% were neutral and 35% said they were well prepared and trained in this skill set. While this material is available to fire crews through online curriculum, the level of technical knowledge and the frequency at which this training is being conducted remains inconsistent across commands and districts. Participant #4 elaborated on the inconsistencies and lack of training that is being conducted in general throughout the organization, saying:

> But the lack, the lack of training is. My God like it's really starting to sink into me. I don't know if it's because I'm in the role I'm in now or what, but I'm seeing it and on the other side of it, I'm seeing how well as an organization, how well our people adapt to the lack of it.

This statement expresses the lack of both formal and informal training being conducted across commands and districts. Informal captain lead training evolutions with their fire crews is an important and expected aspect of TFS training strategy. The frequency and quality of informal training being conducted may be impacted by leadership.

Leadership

Leadership is an important aspect of an organizations resource capacity. Leadership deficiencies throughout the organization was an unexpected finding that was revealed during the qualitative phase of inquiry. Participant #2 suggested that a lack of leadership has led to an erosion over time of the informal training that was once a regular part of a crew's routine, saying,

> It's the lack of leadership…you know, there was a time not that long ago…I'm in my 25th year, 25 years ago we did stuff every day, there was stuff we did every day that was arranged and set up and organized and the district chief knew about it and ensured we did it…we're all guilty, we're all guilty of it [training not being conducted].

An erosion in the informal day to day training being conducted by crews has ramifications for firefighter preparedness as training is essential to maintain and develop professional core competencies. It was suggested a lack in leadership from TFS administration to provide clear direction and implement necessary training programs and equipment that would increase TFS capacity and preparedness. Participant #3 expressed their opinion of the lack of direction and commitment by the organization to remedy HR training deficiencies saying:

> [communication] has to come from the top and I think leadership of the department has to recognize that we have a problem here, and they have to make a statement and say were going to address it with this training and come up with a program and get everyone on board.

The lack of leadership and commitment by the organization to develop needed training curriculum and conduct training exercises was echoed by participant #4 who suggested that the problem was systemic and deeply rooted saying:

> The departments commitment to training…I mean how can you say as a department, we just don't have the time or the resources to train you properly…and a department this big and with such responsibility you know, not just to our crews, but to the citizens we protect.

These statements suggest that aspects of leadership throughout the organization, and the commitment to provide the needed resources to develop and deliver training are limiting factors that impact firefighter's preparedness. A commitment by the organization to develop and deliver high quality training programs to support preparedness becomes increasingly important as firefighter's operational experience wanes.

Experience

With the introduction of detection and fire suppression systems in HR buildings, in combination with accelerated fire code inspection and enforcement, the fire service has seen a steady decline in the frequency of fire calls which translates into less operational experience. This decline in frequency of fire calls is compounded by an aging work force, senior firefighters with the most operational real-world experience are retiring leaving an experience knowledge gap that must be bridged by increased technical knowledge and training. The Hong Kong Fire Service Department (HKFSD) mirrors what TFS is experiencing with the loss of experienced senior people and the need to fill that knowledge void. As Siu-hang Lo (2010) explained “Fire-fighting safety and efficiency counts as much on expertise as practical experience. However, the decreasing trend of building fire calls over the decade and average retirement rate of more than 100 experienced fire fighters a year creates a knowledge management problem” (P. 20).

The decline in experience due to reduced fire calls with a lack of training being conducted impacts firefighter’s operational preparedness. Firefighter preparedness to respond to SHR buildings varies across commands and districts. It was unanimously suggested among participants during the qualitative phase of research that commands, and districts have different levels of experience with SHR buildings and that South command has the greatest level of experience and therefore preparedness to respond to SHR buildings. South command district 1& 3 have the largest inventory of SHR buildings in the city. Firefighter’s stationed in those districts will naturally encounter these buildings more frequently when running fire alarm activation calls and will have more actual firefighting experience due to larger inventories in their districts. One participant explained the level of preparedness of South command, specifying that even within the command, districts 3 has elevated levels of preparedness in comparison to the rest of the command due to the greater inventory of SHR buildings in the district and a specialized apparatus for HR fire fighting that is located in district 3. Participant #1 explained the reasons for this difference, saying:

> I can tell you that they're definitely not equal. South command would be the most prepared. But even within South command, I would say district 33 would be the most prepared…now North command has a new high-rise [truck]. So I would say they would be second and they'll get better just like South command. And East and West command … I would say that they'd be tied for third.

This statement lends support to the suggestion that the greater the level of SHR inventory in a command and district, the greater the level of field experience firefighters will build, therefore it is logical that districts 1 and 3 in South command would have the most exposure and experience which translates into greater preparedness, with elevated levels of technical knowledge, contextual knowledge and experiential knowledge. The lack of exposure to SHR buildings was suggested by one participant to be the reason for lower levels of knowledge and experience and ultimately preparedness in some commands and districts, participant #2 stated:

> No it'll be definitely different, differences in preparedness…there will be people in other commands that have no idea…unless you have exposure to these and what the challenges are, I think you take for granted what you might run into.

This statement reinforces the notion that experience (exposure) to SHR buildings is a crucial component of firefighter technical and contextual knowledge. With some firefighters having limited real-world exposure to these buildings, experiential knowledge acquisition through training becomes even more crucial. While the Toronto Fire Service currently has challenges before them to promote firefighter preparedness through elevated training and leadership throughout the organization, there are many areas of existing preparedness strengths and new initiatives that must be recognized.

Crew Size

TFS staffs all pumper trucks with a crew size of four, however when responding to a HR, the first in crew quickly diminishes in size. The driver/pump operator remains outside the building to establish a water supply to the standpipe, this reduces crew size to 3 firefighters initiating fire attack. One firefighter must assume the role of elevator control from the crew, reducing the initial attack team to just 2 personnel, a firefighter, and the company officer. The crew of 2 now must connect to the standpipe system and advance a hose line, the company officer is now juggling hats between tactical command and performing at the task level until command is transferred to another officer. In most areas of Toronto, the initial attack crew will be backed up by a crew of 3 from the second or third in apparatus, however in some areas of the city this deployment may not occur as rapidly as desired depending on the distance between neighbouring fire station locations or if apparatus is already committed at a simultaneous event. One of the recent preparedness strengths that greatly increases firefighter safety and the ability to overcome potential water supply issues that are associated with HR buildings is the roll out of the new NFPA 1710 compliant HR standpipe kit and hose package (3x65mm/15m hose, 1’ 1/8” smooth bore nozzle). While this new kit delivers increased capacity for firefighters, it is more labour intensive to deploy, exasperating an already difficult situation for a fire attack crew that consists of just two firefighters. Survey question 7 explored respondent’s perspectives of current fire crew deployment size.

> Q7. The National Institute of Standards and Technology, technical note 1797; report on high-rise fireground field experiments suggested that initial fire attack crews achieve faster results when the initial crew size increases from a crew of 3 to a crew of 6. Do you feel that the typical TFS deployment of an initial crew size of 2-3 is large enough to perform initial fire attack?

Survey Respondents felt that TFS current staffing was inadequate for conducting initial fire attack, with 66% of respondents saying they disagreed.

The NIST study revealed that significant task time reductions occurred when a crew of 3 was up staffed to a crew of 4 during initial fire attack (NIST, 2013). Fire attack (advancing a hose line) is considered one of those essential tasks where speed of deployment and the rapid application of agent to suppress the fire are critical to limit fire advancement and stop the spread of toxic gases that impact firefighter and resident safety.

Preparedness Strengths

The TFS has many existing preparedness strengths and is moving forward with new initiatives that will further strengthen TFS preparedness. New training initiatives and the rollout of HR kits that conform to NFPA standards increases firefighter technical knowledge and provides increased resource capacity to respond effectively to HR fires. The addition of a second fully commissioned dedicated HR specialty truck improves the resource capacity of TFS to respond to the many vulnerabilities that can arise with HR firefighting operations. TFS appears to have adequate fire station coverage across the city. The number, and locations of fire stations throughout the city aids TFS in achieving the NFPA 1710 response time standard to an initial address 76% of the time (Toronto Fire Services, 2018, p. 36). Meeting the NFPA response time standard is a preparedness strength, quick mitigation reduces fire intensity and risk in HR buildings (McGrail, 2007). Recently TFS has adopted a process of professional reflection with the creation of After Action Reviews (TFS, FCC 20-230, July 22, 2020) these reviews are intended to assist TFS with quality improvements for training, resource management, resource capacity and the development of SOG's. Additionally, TFS was recently accredited by The

Commission on Fire Accreditation international (CFAI). Accreditation provides a framework for TFS to seek continual improvement and achieve industry best practices and service delivery.

One area of existing preparedness strength is the number of fully staffed fire stations located through out the city. Toronto is fortunate to have adequate fire station coverage across the city with some limited exceptions outside of the downtown core (Sharp, 2018). With rapidly expanding vertical growth in Toronto, VRT becomes an important response consideration. While NFPA 1710 does not include VRT in their response time recommendations, TFS achieves the NFPA 1710 response time standard of 4 minutes travel response time to all initial event addresses 76% of the time (Toronto Fire Services, 2018, p. 36). On average the VRT time is an additional 5 minutes and 54 seconds (Toronto Fire Service, 2015-2019, Master Plan, P.65). Achieving the NFPA response time benchmark is a preparedness strength as a delayed response means larger, hotter, and more dangerous fire conditions in buildings as a free burning fire doubles in size every 30 seconds (McGraw, 2007). To minimize risk due to the unavoidable additional VRT, TFS has implemented an increase in resource deployment to High-Hazard occupancy buildings built before 2007, increasing the deployment of resources to 28 personnel from a previous dispatch of 19 (TFS, Deployment Review, 2020). This increase in resource capacity for HR buildings brings TFS in line with the NFPA fire protection guidelines for resource deployment to High Hazard occupancies for a first fire attack deployment (Fire Protection Handbook, 2008, as cited by Fire Metropolitan Chiefs 2010, P.8). This increase in staffing also recognizes the NIST Report on High-rise Fireground Field Experiments (2013) recommendations that associated larger crew sizes with more efficiency at accomplishing crucial fire ground (life-safety) tasks such as search and rescue and fire attack (NIST, 2013, p. 133). An increase in on scene resource capacity coupled with the new NFPA compliant standpipe kit and hose pack adds resource capacity for HR firefighting operations, strengthening preparedness. As previously discussed, while staffing remains adequate for an initial fire attack in areas of the city where resources arrive at an event address simultaneously, in other areas of the city, resources have a staggered arrival creating an understaffing issue for an initial fire attack.

TFS is providing the initial training to operations fire crews for the deployment of a new HR hose and nozzle package. The new equipment replaces the current Pal Pak with an NFPA 1710 compliant HR standpipe kit and hose package (3x65mm/15m hose, 1’ 1/8” smooth bore nozzle) that will help to overcome some of the water supply issues in HR buildings. The new equipment will allow for increased water flow rates at reduced water pressure requirements. Participant #1 explained how vital this new equipment is for TFS preparedness, saying:

> For our ultra tall buildings [SHR] … I’d have to give us a one, only because of the Pal Pak. By the end of the year, I’d give us an eight on super high-rise buildings because now we have the proper hose and nozzle package…we need that specialized equipment and specialized training.

The participant felt strongly that this one change in equipment and training increased TFS’s HR operational response, building capacity and preparedness. Additional resource capacity for HR firefighting has been added with the commissioning of a second fully staffed, dedicated HR specialty truck which carries a variety of fire-fighting equipment designed for HR operations, such as portable compressed foam systems and remote release extinguishers (grenades) that can be deployed to help overcome possible standpipe, water supply and infrastructure failures. These two initiatives increase TFS’s resource capacity, strengthening preparedness for HR response.

TFS recently developed a professional reflective process called After Action Reviews (AARS). Critical reflection is the process of enquiry into a profession's conduct, ethics and decision making, this process is common practice in the fields of nursing, education, and policing (Child, 2005). The AAR's are designed to reflect on and document the actions that were taken at emergency incidents with the purpose of identifying opportunity to improve as an organization. The AAR's primary purpose is to review what areas need improvement, specifically identifying training and equipment needs, reviewing resource allocation, and assessing training notes and SOG's (TFS, FCC, 20-230, July 22, 2020). As Child (2005) explained, "instructional methods based on rote learning, chalk, and talk, and show and tell training are insufficient as a means of developing firefighters capable of responding and adapting to the complex demands implicit within increasingly professionalized firefighting labor. Future firefighters will need to be adaptive, reflective and accountable; able to demonstrate discursive and inquisitive capabilities; and engage in reflected actions both on and off the incident ground", p. 558. The adoption by TFS of this reflective process through the creation of ARR's provides a structural framework that identifies and supports current and future preparedness needs. Additional frameworks through the CFAI now provides TFS with an evaluation process to seek continual improvement and achieve industry best practices and service delivery.

Toronto Fire Services was recently granted agency accreditation by the CFAI. The process of accreditation required extensive reflection by TFS through multi-year examinations of current operational practices, which then were evaluated by the CFAI and compared to current industry best practices. The accreditation process involves the evaluation of 256 best practice benchmark indicators which are then assessed by industry experts in a peer-review process (Toronto Fire Services, Annual report, 2018.) This accreditation process is a lengthy and difficult process for an agency to go through and is analogous to ripping off bandages to reveal a wound. While it was suggested that TFS has leadership deficiencies, this is an example of an exceedingly difficult but worthwhile process that requires strong leadership at the administration level. It was suggested by participant #4 that the needed changes to identify and correct preparedness deficiencies have been acknowledged and are underway, saying:

> I know that he's [senior administrator] grabbed the bull by the horns and he's moving in the right direction and I'm hopeful were gonna make some real gains there. Right now, for everybody's sake, for our sake, for the organization's sake as well.

This sentiment of administration moving in the right direction and correcting preparedness deficiencies was shared by participant #1 in respect to much needed HR and SHR training that has been in development and is starting to be made available, saying,

> I know that [senior administrator] has made huge leaps and bounds. You can go online - it'll tell you to pump at 1400kpa into every standpipe…that information is actually starting to come out now."

These statements support the suggestion that while TFS has preparedness deficiencies, the organization has implemented reflective frameworks that evaluate performance with the aim to correct deficiencies. These statements also provide support for a more balanced perspective of leadership deficiencies throughout TFS. This on-going process of organizational reflection is a preparedness strength and a factor the supports firefighter preparedness.

Although TFS has preparedness deficiencies that impact both the level and support of fire service personnel preparedness to inherent vulnerabilities in HR residential buildings. The organization has many strengths that support preparedness and positively influence the properties of technical and contextual knowledge, focused training, firefighter experience and resource capacity. TFS has implemented processes such as CFAI accreditation that will continue to improve preparedness and strive to exceed fire service industry best practices.

Recommendations

This research project highlighted a variety of preparedness concerns, the recommendations being presented address concerns with gaps in firefighters' environmental knowledge and initiatives to improve SHR focused training. Additionally, these recommendations consider increases to crew staff size which improves the efficiency of accomplishing crucial fire ground (life-safety) tasks such as search and rescue and fire attack (NIST, 2013, p. 133).

Recommendation 1 – Crew Sizes

In accordance with the findings from the National Institute of Standards and Technology (NIST) technical report 1797, this study also supports the implementation of increased crew sizes for TFS fire trucks to allow for a minimum of four firefighters for initial fire attack being performed by the first arriving apparatus. This increase in staffing will improve task efficiency as shown by the NIST technical report and provide an appropriate crew size to deploy the new NFPA compliant HR hose kit. While TFS achieves the NFPA 1710 response time standard of 4 minutes travel response time to all initial event addresses 76% of the time (Toronto Fire Services, 2018, p. 36). This does not take into consideration the VRT time that on average adds an additional 5 minutes and 54 seconds to the overall response time (Toronto Fire Service, 2014, Master Plan, P.65). The VRT is an unavoidable reality that places a greater importance on the speed and efficiency of crews to complete priority tasks (fire attack) and make up for the VRT that has been added, a larger initial crew size is a step forward to further this goal. The efficiency of crews to complete priority tasks is not only a function of crew size, but is also a function of effective, hands on repetitive kinesthetic training that mirrors as closely as possible realistic fire conditions, this is important to maintain and develop the core competencies that are essential for successful operational outcomes.

Recommendation 2 – Training for HR and SHR Response

As McGrail (2007) noted "Firefighter safety and survival is directly related to the type and amount of training you receive" (p. 12). Fires in HR buildings require enormous resources in both equipment and personnel. Personnel must be trained to execute specific core competencies in a well rehearsed synchronistic fashion, while being flexible enough to adapt and improvise tactics and approaches as conditions dictate. To achieve this level of competency and adaptability, training methodologies become as important as the subject matter being disseminated. Participants suggested that the most effective way to train for HR and SHR response would be to conduct semi-annual HR scenarios in existing buildings, involving a typical second alarm response compliment of trucks and personnel. As participant #1 suggested, running scenarios provides a pragmatic way to deliver kinesthetic hands-on repetitive training in a realistic environment, saying:

> We should run yearly full-scale scenarios with the staffing equivalent to a second alarm…within those scenarios do the difficult tasks…live scenario training is really, it's hands on doing kinesthetic repetitive training…your training has to accurately represent the reality of the situation.

The participant suggested that training conducted should be as realistic as possible with both the execution of the fire ground tasks assigned and the training facility itself. While it is not logically feasible for TFS to develop a mock-up HR building, TFS can explore partnerships with other city agencies such as Toronto Community Housing Corporation, or private sector sources such as building developers to find existing buildings or buildings that are under construction where scenario training can be conducted. This strategy was implemented by the Surrey Fire Service (SFS) who partnered with ITC Construction group, Pacific Rim Fire Protection and Century Group (Bond &Lehman, 2010). SFS and their partners located a 21-storey HR that was still under construction and unoccupied. This provided a realistic training facility that allowed firefighters to experience pumping into the FDC and flowing water from attack lines at elevation (Bond & Lehman, 2010). A partnership strategy could also be sought for other training opportunities beyond locating and securing viable training facilities. Multiple participants suggested seeking external resources outside of TFS, who have specific expertise in HR and SHR building design, engineering, and fire protection systems be sought to assist in course development and training. Participant #1 suggested that technical and contextual knowledge could be gained through guided building tours with external subject matter experts, saying, “We should do more tours, tours with either the people that designed them, or the engineer that’s managing that building and ask them how do you expect us to fight a fire in the building.” Participant #4 agreed, saying “bring in experts and show us … the fire protection and … the fire detection and the suppression systems… .” Utilizing outside resources to enrich training opportunities for Hr and SHR training should be considered by TFS. Forming collaborative partnerships with other city of Toronto agencies and private sector sources to explore HR building site locations for hands on training scenarios is a viable option to increase TFS preparedness for HR and SHR response.

Recommendation 3 – Environmental and Technical Knowledge and Training

This study highlighted gaps in firefighters' environmental knowledge to the presence of SHR buildings in their fire districts. These knowledge gaps are concerning, as many of these buildings have unique building envelopes and vulnerabilities which can present enormous difficulties for those responding to them. The vulnerabilities and difficulties that may be encountered was explained by participant #1 who said:

> So with buildings of that height, we are heavily reliant on the building systems. The proper size hose and nozzle package is definitely needed for these types of buildings. If we have a failure of the system that is where we run into problems…if we have a failure, let's say so if the elevators fail, we have a big problem, a fire pump fail, smoke ventilation systems, or there's improper compartmentalization or the EVAC announcement system doesn't work. That's going to give us a real problem. (Participant #1)

Gaps in the technical and environmental knowledge to the presence of SHR buildings and the vulnerabilities associated with them impact firefighter's risk perception and their ability to accurately assess risk. The ability to accurately assess risk is an important part of situational awareness which informs the decisions and tactics being made. In the absence of this technical and environmental knowledge, the decisions being made may have disastrous consequences. As Gasaway (2013) explained, situational awareness in (IDLH) environments relies on the intuitive and creative processes of the right brain. The intuitive, gut-based decisions are the culmination of stored images of tacit knowledge and experiences (Gasaway, 2007, p. 11). Those stored images of technical and environmental knowledge that inform decisions must be developed. As Gasaway (2019) asserted, "We don't know what we don't know", (Gasaway, 2019, as cited by

Kinakin, 38:30). In other words, a lack of technical and environmental knowledge may lead to the potential for flawed risk assessments because the knowledge has not been developed. While area familiarization drills are part of TFS training, this study recommends a curriculum-supported training initiative focused on the development of SHR technical and environmental knowledge that is specific to the SHR building inventory in each fire district. With the help of TFS analytics, all SHR buildings (as classified by the OBC definition < 84m) can be identified for each district. Through ELI, the online curriculum platform, technical knowledge courses that highlight SHR vulnerabilities can be delivered to all crews. The technical knowledge courses can then be built upon with the Captain lead drill component which would be designed to build environmental knowledge through building familiarization of the SHR inventory that has been identified for each district. Company officers will be provided a check list of potential vulnerabilities that are associated with SHR buildings for the crew to identify. Where possible the company officer can pre-arrange for the building maintenance or engineer to be in attendance, this is a practical way to implement aspects of recommendation #2, which suggested guided building tours. As Gassaway (2019) suggested, it is important to marry the repetitive kinesthetic hands-on learning with the cognitive knowledge of what, when and why simultaneously (Gasaway, 2019, as cited by Kinakin, 2019, 52:08). This double component training initiative could build both technical and environmental knowledge blending both cognitive and kinesthetic methodologies.

Summary

Firefighter preparedness is influenced both positively and negatively by several key properties. The influencing properties for firefighter preparedness consist of technical and environmental/contextual knowledge, specialized/focused training, and firefighter experience.

Additional influences of preparedness are the resource capacity of TFS as an organization. The term resource capacity encompasses several influencing factors for preparedness. They include TFS organizational priorities, budgetary requirements, leadership, and the availability of adequate resources (personnel and equipment) for deployment. TFS capacity is also influenced by the ability to develop training curriculum, implement training programs, and provide training facilities to support that curriculum.

Limitations

Cultural bias

With any research conducted there exists the possibility that interpretations made by the researcher are subject to cultural bias, even if it is unintentional (Creswell & Creswell, 2018). It is acknowledged that the researcher is a TFS operations division Firefighter and an active member of the Toronto Professional Fire Fighters Association, local 3888. This research has been submitted for third party review to ensure any identifiable bias is nullified.

Data Reliability

The source of the quantitative data was an anonymous Likert survey that was available on-line through the TPFFA. The survey relies on self-reported data that can not be independently verified, the responses must be taken at face value. This is a limitation as it is not possible to know if the 280 responses or 10% of operations firefighters who responded, accurately reflect the views of the entire operations division. For example, if those who responded exhibit a heightened level of engagement or professional development in comparison to those who did not respond, the data may not accurately reflect the entire sample element and could influence results in unpredictable ways. Similarly, it is not possible to generalize from four interviews, rather the interviews provided insight into better understanding some of the quantitative findings as well as some of the contextual factors influencing preparedness capacity within the TFS for fighting fires in HR and SHR buildings.

The qualitative sample size for this study is relatively small N=4. This study employed a combination of non-probability and snowball sampling for interview participant recruitment. This study sought senior officers within TFS that had operational experience with HR and SHR firefighting response. The availability of subject matter experts in this area of firefighting is extremely limited, and further constrained by the selection being limited to just a single organization (TFS). The availability of participants was further impacted by the COVID-19 pandemic which altered participants schedules and limited their availability to conduct interviews remotely.

Conclusion

Firefighter preparedness is influenced both positively and negatively by several key properties. The influencing properties for firefighter preparedness consist of technical and environmental/contextual knowledge, specialized/focused training, and firefighter experience. Additional influences of preparedness are the resource capacity of TFS as an organization. The term resource capacity encompasses several influencing factors for preparedness. They include TFS organizational priorities, budgetary requirements, leadership, and the availability of adequate resources (personnel and equipment) for deployment. TFS capacity is also influenced by the ability to develop training curriculum, implement training programs, and provide training facilities to support that curriculum.

This study found inconsistencies in firefighter's technical and environmental knowledge of SHR buildings located in their districts and to water supply vulnerabilities that can be associated with these buildings. The support to build technical and environmental knowledge is limited by firefighters' access to specialized training. Some of the barriers that limit support for specialized training programs were found to be associated with organizational priorities and a lack of resource capacity to develop and deliver training programs. The frequency of crew training was found to be inconsistent between commands and districts. It was suggested that the frequency of training being conducted has declined due to an erosion in leadership. An erosion in leadership was found to be a limiting factor that has impacted the frequency of training being conducted. Technical and environmental knowledge, experience and training are factors that influence firefighter's risk perception and their ability to assess risk accurately. It was suggested that greater levels of knowledge and the presence of optimism bias are two factors that influence those respondents that reported a lower risk perception. The work of Rodriguez-Garzon et al., (2012) reported, a greater level of education and experience leads to a higher risk perception in firefighters, specifically those who are university educated (p. 768). Greater levels of education were not found to be associated with higher levels of risk perception among respondents.

There was variation in the levels of preparedness between commands and districts, with South command having elevated levels of preparedness compared to the other districts. One factor which supports elevated levels of preparedness is exposure/experience to SHR buildings. Commands with greater levels of SHR inventory have greater exposure to SHR buildings, South command districts 1 & 3 have the largest inventory of SHR buildings compared to the other commands and districts.

Areas of strength that support preparedness can be found in the adoption of reflective processes through the creation of ARR's which provide a structural framework that identifies and supports current and future preparedness needs. Additional CFAI frameworks provide TFS with an evaluation process to seek continual improvement and achieve industry best practices and service delivery. Another area of preparedness strength is fire station coverage, TFS has adequate fire station coverage across the city. The number and locations of fire stations throughout the city aids TFS in achieving the NFPA 1710 response time standard to an initial address 76% of the time (Toronto Fire Services, 2018, p. 36). Meeting the NFPA response time standard is a preparedness strength, quick mitigation reduces fire intensity and risk in HR buildings (McGrail, 2007). To minimize risk due to the unavoidable additional VRT, TFS has implemented an increase in resource deployment to High-Hazard occupancy buildings built before 2007, increasing the deployment of resources to 28 personnel from a previous dispatch of 19 (TFS, Deployment Review, 2020). Providing the initial training to operations fire crews for the deployment of a new HR hose and nozzle package also supports TFS preparedness. The new equipment replaces the current Pal Pak (38mm hose, combination nozzle) with an NFPA 1710 compliant HR standpipe kit and hose package (3x65mm/15m hose, 1' 1/8" smooth bore nozzle) to help partially overcome some of the water supply issues in HR buildings.

To further support improvements in preparedness, recommendations focused on training initiatives that can improve firefighter preparedness for HR fire operations and the necessary fire crew sizes that improve efficiency at accomplishing crucial fire ground (life-safety) tasks such as search and rescue and fire attack (NIST, 2013, p. 133). In accordance with the findings from the National Institute of Standards and Technology (NIST) technical report 1797, this study supports the implementation of increased crew sizes for TFS fire trucks to allow for a minimum of four firefighters for initial fire attack being performed by the first arriving apparatus. This increase in staffing will improve task efficiency as shown by the NIST technical report and provide an appropriate crew size to deploy the new NFPA compliant HR hose kit. To further improve preparedness, recommendations were made for TFS to seek outside resources to enrich training opportunities. Subject matter experts in the fields of engineering and design who have intimate knowledge of HR and SHR building design and systems could enhance both technical and environmental knowledge. By conducting semi-annual full mock scenarios, training is conducted delivers kinesthetic repetitive training in a realistic environment. Realistic training facilities for HR focused training may be acquired by forming collaborative partnerships with other city of Toronto agencies and private sector sources to explore HR building site locations for hands on training scenarios. While the Toronto Fire Service has challenges before them to support firefighter preparedness, there are many areas of existing preparedness strengths and new initiatives that promote HR and SHR preparedness.

References

Annetts, K. (2018, August 20). Toronto has over 400 new Skyscrapers planned and construction in the city is going to get worse. *Narcity*. Retrieved from https://www.narcity.com/ca/on/toronto/news/toronto-has-over-400-new-skyscrapers-planned-and-construction-in-the-city-is-going-to-get-way-worse

Averill, J. D., Moore-Merrell, L., Ranellone, R. T., Weinschenk, C., Taylor, N., Goldstein, R., . . . Butler, K. M. (2013). Report on High-Rise Fireground Field Experiments. https://doi.org/10.6028/nist.tn.1797

Blackwood, K. (2017). *Factors that affect nursing students' willingness to respond to disasters or public health emergencies* (Doctoral dissertation). Oklahoma State University. Retrieved from https://pdfs.semanticscholar.org/ef74/00f00715197a952d23c6120dedf0d86b4b92.pdf

Bond, J., & Lehmann, J. (2010, August 10). High-rise training. *Firefighting in Canada*. Retrieved from https://www.firefightingincanada.com/high-rise-training-6614/

CBC (2017, June 15). Stringent provisions are in place: Canadian cities well prepared for high-rise fires, say fire officials. Retrieved from https://www.cbc.ca/news/canada/fire-highrise-canada-cities-london-1.4160877

Chow, C. L., & Chow, W. K. (2009). Fire safety aspects of refuge floors in supertall buildings with computational fluid dynamics. *Journal of Civil Engineering and Management, 15*(3), 225-236. https://doi.org10.3846/1392-3730.2009.15.225-236

Chow, W., Fong, N., Liu, C., Tai-Keung, T., & Tsz-Kit, Y. (2013). Fire safety strategies for supertall buildings in Hong Kong. *Council on Tall Buildings and Urban Habitat*, *1*, 26-

31. Retrieved from http://global.ctbuh.org/resources/papers/download/264-fire-safety-strategies-for-supertall-buildings-in-hong-kong.pdf

Collins, K. M., Onwuegbuzie, A. J., & Jiao, Q. G. (2006). Prevalence of Mixed-methods Sampling Designs in Social Science Research. *Evaluation & Research in Education, 19*(2), 83-101. https://doi.org/10.2167/eri421.0

Creswell, J. & Creswell, D. (2018). *Research design - qualitative, quantitative and mixed methods approach (fifth edition)*. London, UK: SAGE Publications

Creswell, J. W., & Tashakkori, A. (2007). Editorial: Differing Perspectives on Mixed Methods Research. *Journal of Mixed Methods Research, 1*(4), 303-308. https://doi.org/10.1177/1558689807306132

Dane, F. C. (2018). *Evaluating research: Methodology for people who need to read research*. Thousand Oaks, CA: SAGE Publications.

Dixon, J. (2015, Oct 1). The Normalization of Deviance. *FireHouse.* Retrieved from https://www.firehouse.com/safety-health/article/12109412/firefighter-safety-the-normalization-of-deviance

Feilzer, M. Y. (2009). Doing Mixed Methods Research Pragmatically: Implications for the Rediscovery of Pragmatism as a Research Paradigm. *Journal of Mixed Methods Research, 4*(1), 6-16. https://doi.org/10.1177/1558689809349691

Friedman, A. (2014*). High pressure pump operations for high-rise buildings*. City of Toronto. Retrieved from: Tinker, I. (2018, June 20). Email attachment

Gaillard, J. C., Cadag, J. R., & Rampengan, M. M. (2018). People's capacities in facing hazards and disasters: An overview. *Natural Hazards, 95*(3), 863-876. https://doi.org/10.1007/s11069-018-3519-1

Gasaway, R. (2007). Making Intuitive Decisions Under Stress: Understanding Fireground Incident Command Decision-Making. *International Fire Service Journal of Leadership and Management*, 1, 8-18. Retrieved from https://d1wqtxts1xzle7.cloudfront.net/30885521/IFSJLM_Vol1_Num1.pdf?1362669192=&response-content-disposition=inline%3B+filename%3DReview_of_Van_Wart_M_1998_Changing_publi.pdf&Expires=1610308836&Signature=SLKLu05XCTcYeWY3bJVzGiZcBN5VKqGdjN6DcsZmS5p2HKqX6YYiaFs67Y5IrOeFZ0h1BGE3dBkwdM-B~-7NXjLvV3TbEDfKpCOWEP3FRD~HdNkaosreQZ7cuDy8NdrfQVmm7jRiiYgtrsqKBE485gfN3gnUzFs7M3xfYwbLldQRG6BMXfeSVH0iSp8XBCimXZwr5~EO~M61e9JE9X4bZfXnJC3tHgD7vgc5tf6Xv0QgijAZosKjEpHdydyYhYaEcXEjhwJjvQrggpdwhEYaZs5eksVYr87zBtJY6-zraqjFJ22BUBtRk6Pkpu~lIfwCkf6kCH5pibRtpCIlVueChA__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA#page=10

Gasaway, R. (2013, April 22). Situational Awareness. *Firefighting in Canada*. Retrieved from https://www.firefightingincanada.com/situational-awareness-15223/

Gerges, M., Mayouf, M., Rumley, P., & Moore, D. (2017). Human behaviour under fire situations in high-rise residential building. *International Journal of Building Pathology and Adaptation*, *35*(1), 90-106. https://doi.org/10.1108/ijbpa-09-2016-0022

Guest, G., Bunce, A., & Johnson, L. (2006). How Many Interviews Are Enough? *Field Methods, 18*(1), 59-82. https://doi.org/10.1177/1525822x05279903

Hataley, T., & Leuprecht, C. (2014). Asymmetric decentralization of the administration of public safety in the Canadian federal political system. *Canadian Public Administration 57*(4), 507-526. Retrieved from https://onlinelibrary-wicom.ezproxy.royalroads.ca/doi/full/10.1111/capa.12091

Henstra, D. (2013). Chapter 1: Introduction: Multilevel governance and Canadian emergency management policy. In D. Henstra (Ed.), *Multilevel governance and emergency management in Canadian municipalities* (pp.3-24). Montreal: McGill-Queen's University Press. Retrieved from https://ebookcentral-proquest-com.ezproxy.royalroads.ca/lib/royalroads-ebooks/reader.action?ppg=12&docID=3332624&tm=1536780994665

Ivankova, N. V., Creswell, J. W., & Stick, S. L. (2006). Using Mixed-Methods Sequential Explanatory Design: From Theory to Practice. *Field Methods*, *18*(1), 3-20. https://doi.org/10.1177/1525822x05282260

Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed Methods Research: A Research Paradigm Whose Time Has Come. *Educational Researcher*, *33*(7), 14-26. https://doi.org/10.3102/0013189x033007014

Kaplowitz, M. D., Hadlock, T. D., & Levine, R. (2004). A Comparison of Web and Mail Survey Response Rates. *Public Opinion Quarterly*, *68*(1), 94-101. https://doi.org/10.1093/poq/nfh006

Kinakin, A., (2019, July 31). *Situational Awareness: You don't know what you don't know* (No. 51) [Audio podcast]. Tactical Breakdown. Retrieved from https://omny.fm/shows/tactical-breakdown/situational-awareness-you-dont-know-what-you-dont?in_playlist=tactical-breakdown!tactical-breakdown

Leavitt, W. M., & Kiefer, J. J. (2006). Infrastructure Interdependency and the Creation of a Normal Disaster. *Public Works Management & Policy*, *10*(4), 306-314. https://doi.org/10.1177/1087724x06289055

Lo, Shane Siu-Hang. "Fire Fighting in High-Rise Buildings: the Role for Engineers." *Proceedings of the Institution of Civil Engineers - Civil Engineering*, vol. 163, no. 6, 2010, pp. 020–026., http://dx.doi:10.1680/cien.2010.163.6.20.

Macleod, G. (2018). The Grenfell Tower atrocity. *City*, *22*(4), 460-489. https://doi.org/10.1080/13604813.2018.1507099

Mcconnell, N., Boyce, K., Shields, J., Galea, E., Day, R., & Hulse, L. (2010). The UK 9/11 evacuation study: Analysis of survivors' recognition and response phase in WTC1. *Fire Safety Journal*, *45*(1), 21-34. https://doi.org/10.1016/j.firesaf.2009.09.001

McGillivray, G. (2018). Speaking in code: A brief overview of building code in Canada. *Cat tales,12*, 3-4. Retrieved from https://issuu.com/iclr/docs/cat_tales_nov_dec_2018

McGrail, D. M. (2007). *Firefighting operations in high-rise and standpipe-equipped buildings*. Tulsa, OK: PennWell Books

Millian, D. (2017, May 23). Toronto high-rise living by the numbers. *CBC.* Retrieved from https://www.cbc.ca/news/canada/toronto/toronto-highrise-living-by-the-numbers-1.4127019

Ontario Building Code. (2012). *MMAH supplementary standard sb-4.* Ontario. Retrieved from http://www.buildingcode.online/276.html

Ontario Ministry of Community Safety and Correctional Services, (2011). Glossary of Terms. Retrieved from https://www.emergencymanagementontario.ca/english/emcommunity/response_resources/GlossaryOfTerms/glossary_of_terms.html

Prati, G., Pietrantoni, L., Saccinto, E., Kehl, D., Knuth, D., Schmidt, S. (2012). Risk Perception of Different emergencies in a Sample of European Firefighters. *Work, 45*(1), 87-96, https://doi.org/10.3233/WOR-121543

Rodríguez-Garzón, I., Martínez-Fiestas, M., Delgado-Padial, A., & Lucas-Ruiz, V. (2015). Perception of Occupational Risk of Firefighters in Quito (Ecuador). *Fire Technology, 52*(3), 753-773. https://doi.org/10.1007/s10694-015-0494-x

Savelle, G. M. (2007). High pressure pumping operations at high-rise fires. *National Fire Academy*. Retrieved from: https://www.hsdl.org/?view&did=682661

Schoonenboom, J., & Johnson, R. B. (2017). How to Construct a Mixed Methods Research Design. *KZfSS Kölner Zeitschrift Für Soziologie Und Sozialpsychologie, 69*(S2), 107-131. https://doi.org/:10.1007/s11577-017-0454-1

Sharp, L. (2018). *Growing pains: Exploring the implications of urban vertical growth on emergency fire service delivery in Toronto, Ontario* (master's report). Queens University, Kingston. Retrieved from https://qspace.library.queensu.ca/handle/1974/24291

Sharot, T. (2011). The Optimism Bias. *Current Biology, 21* (23), 941-945 https://doi.org/10.1016/j.cub.2011.10.030

Statistics Canada (2017). Measuring the economy region by region. Retrieved from https://www.statcan.gc.ca/eng/blog/cs/economy

Stuckey, M. (2015). *Firefighters and highrises*. Denver, CO: Outskirts Press.

Tactical Breakdown (Producer). (2019, July 31). Situational Awareness: You don't know what you don't know? [Audio podcast]. Retrieved from https://omny.fm/shows/tactical-breakdown/situational-awareness-you-dont-know-what-you-dont?in_playlist=tactical-breakdown!tactical-breakdown

The Economist (2017, June 24). Tall buildings are becoming more common. They need not be dangerous. Retrieved from https://www.economist.com/international/2017/06/24/tall-buildings-are-becoming-more-common.-they-need-not-be-dangerous

Toronto Fire Service. (2015). *Master Fire Plan 2015-2019.* Toronto, ON. Retrieved from https://www1.toronto.ca/City%20Of%20Toronto/Fire%20Services/Shared%20Content/Files/2015-2019_Master_Fire_Plan_WEB.pdf

Toronto Fire Service. (2017, November 26). *Fire in your High-rise*. City of Toronto. https://www.toronto.ca/wp-content/uploads/2020/11/91c5-20-00237-20-03398-FireHighRise-NOV26-web.pdf

Toronto Fire Service. (2017). *2017 Annual Report.* Toronto. ON. Retrieved from https://www.toronto.ca/wp-content/uploads/2018/04/900e-Annual-Report-2017-.pdf

Toronto Fire Service. (2018, April 4). *Training note, 800, miscellaneous equipment, 805, standpipe kit and hose packs, 101. 1. 9, standpipe operations*. Toronto, ON.

Toronto Fire Service. (2018). 2018 *Annual Report*. Toronto. On.

Toronto Fire Service. (2019). 2019 *Annual Report*. Toronto. On. Retrieved from https://www.toronto.ca/wp-content/uploads/2019/04/8e80-A1902231_TFSAnnualReport2018_WEB.pdf

Toronto Fire Service. (2019, December 20). *Residential High-rises 20 Storeys and Higher*. Toronto. On.

Toronto Fire Service. (2019) Becoming a firefighter. *City of Toronto*. Retrieved from https://www.toronto.ca/home/jobs/information-for-applicants/recruitment-initiatives/toronto-fire-services-careers/becoming-a-firefighter/

Toronto Fire Service. (2019, March 25). *Training note, 100, firefighting knowledge and skills, 106, fireground operations, 106. 22, Pal Pak deployment*. Toronto. ON.

Toronto Fire Service. (2019, Dec). *Training note, 100, firefighting knowledge and skills, 101, buildings, 101.1 high-rise buildings, 101.1.5 standpipe operations*. Toronto, ON.

Toronto Fire Service. (2020, July 22). *Advisory, FCC 20-230*. Toronto, ON.

Toronto ranked 9th for the most Skyscrapers in the world. (2019, February 4). *Toronto Storeys.* Retrieved from https://torontostoreys.com/2019/02/toronto-ninth-most-skyscrapers-in-the-world/

Urban Fire Forum. Fire Metropolitan Chiefs (2010) *Fire service Deployment -Assessing community vulnerability.* Retrieved from https://www.nfpa.org/-/media/Files/Membership/member-sections/Metro-Chiefs/UrbanFireVulnerability.ashx?la=en

van Duijne, F & Bishop, P. (2018). Introduction to Strategic Foresight. Future Motions. Retrieved from http://www.futuremotions.nl/wp-content/uploads/2018/01/FutureMotions_introductiondoc_January2018.pdf

Warren, M. (2018, July 18). Race is on to build the tallest Toronto high rise. *The Star*. Retrieved from https://www.thestar.com/news/gta/2018/07/18/race-is-on-to-build-the-tallest-toronto-highrise.html

Zmud, M. (2008). Public Perceptions of High-rise Building Emergency Evacuation Preparedness. *Fire Technology*, *44*(4), 329-336. https://doi.org10.1007/s10694-008-0057-5

Appendix A

Exploring Inherent Vulnerabilities in High-rise Residential Buildings: Life Safety Implications During a Fire Event.

Royal Roads University Masters Thesis Research Project

Informed Consent for Local 3888

Researchers:

Chris Coulthard

Disaster and Emergency Management Program

Royal Roads University

Royal Roads, University 2005 Sooke Road Victoria, British Columbia, Canada V9B 5Y2

chris.coulthard@royalroads.ca

Supervisor:

Dr. Jean Slick

Associate Professor and Program Head of Humanitarian Studies

Royal Roads University

2005 Sooke Road Victoria, British Columbia, Canada V9B 5Y2

Jean.Slick@RoyalRoads.ca

Invitation and purpose:

Dear TPFFA members, my name is Chris Coulthard, I'm the acting captain of pump 226 on B platoon. I invite you to participate in this research project that is exploring the levels of awareness and preparedness of (TFS) fire service personnel to inherent vulnerabilities that could impact life safety during a fire event in high-rise and super high-rise residential structures. This research is being conducted as part of my thesis project for the Masters of Disaster and Emergency Management program at Royal Roads University. As professional fire fighters in the fifth largest department in North America, your participation in this survey is extremely valuable due to your breath of experience, knowledge and diverse expertise. The goal of this study is to create actionable recommendations that can improve our safety and protect the lives of the residents we serve.

Participant involvement:

Voluntary participation involves answering a short set of on-line survey questions, the questions are evaluated using a Likert 5-point scale, 1. Strongly agree, 2. Agree, 3. Neutral, 4. Disagree, 5. Strongly disagree. The survey should take no longer then 10 minutes to complete and submit.

Nature of the questions:

The questions asked are specific to firefighting operations in high-rise structures, they have been chosen to ascertain the level of awareness and preparedness of personnel to various vulnerabilities that exist in these structures that could affect life-safety for both residence and fire personnel.

Potential benefits: While there are no immediate benefits to local 3888 members, the goal of this research is to create actionable recommendations that will inform practice and ultimately lead to a safer fire ground for us and improved life safety for the residence we serve.

How participants will be informed of results:

Once this research has been completed the findings will be published in our associations (TPFFA) publication Fire Watch. All results will be explained as they relate to the entire research project.

Potential risks to you:

There are no apparent risks to anyone who wishes to voluntarily answer this survey. This survey is completely anonymous, the information obtained is for research purposes only and has no possible repercussions for participants. This will not affect your standing with our association or with our employer, the City of Toronto.

Privacy, confidentiality and anonymity:

This survey is completely anonymous, no identifiable information such as name, or employee number is collected. Some survey platforms utilize IP addresses to ensure that participants are not completing the survey multiple times, however no IP address for this survey will be used by the researcher to collect data. This survey is using Survey Monkey as a delivery platform, Survey Monkey stores data in both Canada and the United States. There is a chance that information if stored in the US could be accessed by the US government under the Patriot Act, however your identity would remain anonymous.

How your information will be protected and stored:

All survey data received is anonymous and will only be accessible by the researchers mentioned in this study, all information gathered is password encrypted, individual responses to questions will not and can not be shared with anyone but this research team.

Your rights as a research participant:

Your participation is completely voluntary, you may discontinue this survey at anytime prior to hitting the submission button at the end of the survey. By clicking the submission button at the end of the survey, you are giving your consent to participate in this survey. This survey is anonymous, therefore once you have submitted the survey it is not possible for the researchers to know the identity of the individual respondent.

Questions:

Please feel free to contact the researchers if you have any questions or concerns regarding this research. C.Coulthard: chris.coulthard@royalroads.ca Dr. J. Slick: Jean.Slick@RoyalRoads.ca

Appendix B

Local 3888 Fire Survey

What is the level of preparedness of fire service personnel to Inherent vulnerabilities in high-rise residential buildings that could threaten life-safety during a fire event?

These questions are to be answered using a 5-point Likert scale, 1. Strongly agree, 2. Agree, 3. Neutral, 4. Disagree, 5. Strongly Disagree.

Measurable Properties

Knowledge

Q.3

When providing sole source water supply to fire crews on the 58th floor of a building, a pump discharge pressure of 480psi (3309 KPA) is required to provide adequate nozzle pressure. **Do you agree that this is a safe operating pressure for TFS crews to work at with current TFS issued hose and appliances?**

Q.8

Vertical response time is the added time it takes fire crews to reach the fire floor after arriving at the initial event address, **do you agree that this additional increase in response time in a high-rise structure increases the risk to both residents and fire personnel during a fire?**

Q.10

How accurate is this statement? National Fire Protection Association (NFPA 14) requires a minimum of 100psi (689) KPA of nozzle pressure (post 1993), attained from the two most remote outlets on any floor.

Q.11

Do you agree with this statement? The Ontario building code stipulates what pressure a Fire Department may place on a standpipe system in the event of a buildings fire pump failing?

Q.12

Do you agree with this statement? Buildings in Ontario do not have to adhere to NFPA standards but must adhere to the minimum standards set by the Ontario Building Code

Q.14 NFPA 20 defines a Very Tall High-rise building as a building that is so tall that it is impossible for the fire department apparatus to pump into the fire department connection at the street and overcome the elevation loss and friction loss in order to achieve 100 psi at the most remote 2.5” (65mm) hose outlet. **Do you feel that this definition applies to buildings in your first run fire district?**

Preparedness

Q.1

Do you feel this statement is accurate? If stationary fire pumps fail, Toronto Fire Services (TFS) can establish an adequate water supply through FD connections and successfully deliver adequate nozzle pressure for suppression crews on the 58th floor?

Q.2

Do you feel that this statement is accurate? TFS has high-pressure pumping capabilities that will provide adequate water supply and nozzle pressure through a standpipe system to floors above 50 storeys?

Q.5

How accurately does this statement reflect your opinion? When fighting a fire in a high-rise building above 30 storeys, I feel well protected from personal injury and well equipped to achieve successful outcomes.

Q.7 The National Institute of Standards and Technology, technical note 1797; report on high-rise fireground field experiments suggested that initial fire attack crews achieve faster results when the initial crew size increases from a crew of 3 to a crew of 6**. Do you feel that the typical TFS deployment of an initial crew size of 2-3 is large enough to perform initial fire attack?**

Q.9

Very tall buildings can present challenges to fire crews who require adequate nozzle pressure for fire suppression. **TFS high-rise kits provide adequate equipment (low pressure nozzles etc) to overcome low water pressures in buildings. Do you agree with this statement?**

Training

Q.4

Do you agree with this statement as it pertains to your experience? I have received and participated in training evolutions that provide me with the necessary tactics and skill sets to remain safe and achieve successful outcomes while fighting a fire in a high-rise structure.

Q.6

Does this statement reflect your experience? My fire crew is well prepared to implement an improvised interior/exterior standpipe if a standpipe system in a building fails.

Q.13

Does this statement reflect your day-to-day experience? As a crew we regularly conduct informal training sessions focused on high-rise deployment which could include topics such as, pumping to the standpipe, elevator control, ventilation, and alternative techniques if a standpipe system fails.

Q.15

How accurately does this statement represent your experience? TFS has provided me with pump operations training for standpipe connections in super high-rise buildings (> 84 meters)

The next questions are demographic questions and do not follow a Likert scale.

Demographics

1. **How many years of service with TFS have you completed**? 1-5, 5-10, 10-20, 20-30, 30+

2. **Do you identify as** 1. Male, 2. Female, 3. Non pronouns 4. Other

3. **What is your age category**, 1. (20-30), 2. (30-20), 3. (40-50) 4. (50-60) 5. (60+)

4. **What command and fire district do you work in** #1, North, (1,2,3,4) #2, East, (1,2,3,4) #3, (1, South, (1,2,3,4) #4, West (1,2,3,4)

5. **What is the highest level of education that you have obtained**? 1.High School 2. Trade School/Community College 3. University degree. 4. Masters degree 5. PHD

6. The Ontario Building Code (OBC) deems a building that is greater than 84^ m in height a Super High-rise. **Do you have any buildings in your first run fire district that meet this definition? Yes/No**

Appendix C

Exploring Inherent Vulnerabilities in High-rise Residential Buildings: Life Safety Implications During a Fire Event.

Interview Research Consent Form

Researcher:

Chris Coulthard

Disaster and Emergency Management Program

Royal Roads University

Royal Roads, University 2005 Sooke Road Victoria, British Columbia, Canada V9B 5Y2

chris.coulthard@royalroads.ca

Supervisor:

Dr. J. Slick

Associate Professor and Program Head school of Humanitarian Studies

Royal Roads University

2005 Sooke Road Victoria, British Columbia, Canada V9B 5Y2

Jean.Slick@RoyalRoads.ca

Statement of research purpose

The intent of this research project is to explore the level of awareness and preparedness of TFS personnel to inherent vulnerabilities in high-rise residential structures that could impact life safety during a fire event. The city of Toronto is experiencing tremendous vertical growth with the construction of extremely tall residential structures, these structures pose significant operational challenges for TFS personnel responding to fire events. The desired outcome of this research is to develop actionable recommendations that will improve the life-safety of firefighters responding to high-rise fires and for the building residents.

Participants

Dear _________

My name is Chris Coulthard, I am the acting captain of pump 226 on B platoon. I am conducting research for my thesis project for the Masters of Disaster and Emergency Management program at Royal Roads University. I ask for your consideration to participate in this research project, as your experience, knowledge and perspective can provide important information which will contribute to a more thorough and in depth understanding of TFS preparedness for response to super high-rise buildings. If you wish to contribute to this research project, your participation will consist of an interview with the principal researcher for approximately 45 minutes. All interviews will be conducted via skype at a time of your choice; no interviews will be conducted in city of Toronto buildings or TPFFA locations. The questions asked will explore your perspective, opinion, and experience of the current TFS operational response to high-rise fire incidents and training initiatives.

Your participation is completely voluntary, you may withdraw your participation at anytime, including after the interview has been conducted. No withdrawal explanation or rationale will be asked of you or required. If you choose to withdraw at anytime, any information that has been gathered will be immediately destroyed and removed from the research project.

There are no known risks to your participation in this study. Your contribution will remain confidential and anonymous. No names or identifiable descriptions will be used in this thesis project to maintain anonymity. Each interview participant will be assigned a code number to protect your identity. Further, no information about the interview participants will be shared with the Toronto Fire Service or the Toronto Professional Firefighters Association. The final thesis or recommendations arising from this thesis may be published in local 3888 Fire watch magazine or shared at a conference. Further, recommendations from this study may be shared with TFS administration.

All information gathered will be secured via computer password encryption on the researcher's computer and will remain confidential, only the researcher will have access to this data.

Audio recordings of the interview will be used after the interview concludes to assist the researcher with the transcription and coding of data. All the interview research material will be destroyed once this research project is completed and has been submitted and archived by the Royal Roads University Library.

Any questions regarding this study or your participation in this study may be asked at anytime and are encouraged. Your consent to participate is required by the researcher, if you choose to participate a copy of this consent form will be made available for your retention.

Your participation would be greatly appreciated, if you agree to participate in this study, I ask for you to sign this form consenting to participate in a 45-minute interview that will adhere to the above guidelines.

Date: ______________

Signature: ________________

Participant

Date: _________________

Signature: __________________

Researcher

Appendix D

Interview Questions

Introduction

Research overview:

The intent of this research project is to explore the level of awareness and preparedness of TFS personnel to inherent vulnerabilities in high-rise residential structures that could impact life safety during a fire event. The city of Toronto is experiencing tremendous vertical growth with the construction of extremely tall residential structures, these structures pose significant operational challenges for TFS personnel responding to fire events. The desired outcome of this research is to develop actionable recommendations that will improve the life-safety of firefighters responding to high-rise fires and for the building tenants.

Definitions:

NFPA 20 defines a **Very Tall High-rise** building as a building that is so tall that it is impossible for the fire department apparatus to pump into the fire department connection at the street and overcome the elevation loss and friction loss in order to achieve 100 psi at the most remote 2½-in (65 mm).

The **OBC** defines a Super High-rise building as a building that is > 84 m in height.

I would like to start by asking you some questions about TFS preparedness to respond to fires in high-rise and super high-rise structures.

1. How prepared do you think TFS is to effectively respond to fires in high-rise structures under 20 stories. Can you rate TFS's preparedness for this task on a scale of 1-10, 1 being low and 10 being high?
2. How prepared do you think TFS is to effectively respond to fires in super high-rise structures. How would you rate TFS's preparedness for this task on a scale of 1-10, 1 being low and 10 being high?
3. What factors influence the difference in preparedness between high-rise and super high-rise occupancies if any?

I now want to ask you some questions relating to operational readiness across commands

4. How would you rate the level of TFS preparedness for super high-rise response across the four commands? Are they all equally prepared or are their differences across commands?
5. Can you think of additional differences in operational readiness for responding to fires in super high-rise buildings between the four commands?

I now want to ask you some questions related to risk for crews in super-high-rise buildings.

6. What factors increase risk to fire crews in super high-rise operations?

7. What factors might influence a crew's perception of risk?
8. What steps can the fire service take to mitigate the risk for crews working in super high-rise buildings?

I now want to ask you some questions about the knowledge required when responding to fires in super-high-rise buildings.

9. What specific knowledge do firefighters need when conducting fire operations in a super high-rise building?
10. What are the ways firefighters gain this specialized knowledge in the TFS? What factors do you think can positively or negatively influence firefighters base of knowledge?

I now want to ask you some questions about technical capabilities for responding to fires in superhigh-rise buildings

11. What additional technical capabilities does TFS need to operate in buildings over 84 meters in height?
12. What would strengthen TFS technical capabilities to respond to (operate) during a fire that is above 50 stories?

Appendix E

Interview Questions Related to Survey Response Results

I now want to ask you some question related to the survey responses. There were four questions in the survey where the results were more challenging to interpret. I would like to get your thoughts about how you interpret the responses received.

1.The results from Question 5 revealed a median of 3, showing that respondents were split in their opinion. Further, 25% gave a neutral response (rating of 3). What do you think contributed to this neutral response?

Q5. How accurately does this statement reflect your opinion? When fighting a fire in a high-rise building above 30 storeys, I feel well protected from personal injury and well equipped to achieve successful outcomes.

Strongly Agree 1	Agree 2	Neutral 3	Disagree 4	Strongly Disagree 5
4.6% N=13	36.6% N=102	25.1% N=70	24.4% N=68	9.3% N=26
Median =3	**Mean** =2.97	**SD** =1.08	**Avg** 2.97% N= 279	

2. The results for Question 9 also had a median of 3, showing that respondents were split in their opinion. Further, 28% gave a neutral rating. What do you think contributed to this neutral response?

Q9. Do you agree with this statement? Very tall buildings can present challenges to fire crews who require adequate nozzle pressure for fire suppression. TFS high-rise kits (Palpak) provide adequate equipment (low pressure nozzles etc) to overcome low water pressures in buildings.

Strongly Agree 1	Agree 2	Neutral 3	Disagree 4	Strongly Disagree 5
2.5% N=7	24.7% N=69	28% N=78	33% N=91	12.2% N=34
Median =3	**Mean** =3.27	**SD** =1.04	**Avg** 3.27% N= 279	

3. The results from Question 6 had a median of 3 showing respondents were split in their reflective experience of crew training, why do you think respondents have vastly different reflections?

Q6. Does this statement reflect your experience? My fire crew is well prepared and trained in how to implement an improvised interior/exterior standpipe system if a standpipe system in a building fails.

Strongly Agree 1	**Agree 2**	**Neutral 3**	**Disagree 4**	**Strongly Disagree 5**
7.6% N=21	27.4% N=76	13.4% N=32	36.1% N=100	15.5% N=43
Median =3	**Mean** =3.27	**SD =**1.04	**Avg** 3.25% N= 277	

For Question 15, which was about training for pump operations for standpipe connections in super high-rise buildings, most respondents said they had not been provided with this type of training.

4. What factors influence access to super high-rise training for TFS personnel? Would you ideally expect all TFS personnel to have access to or taken this type of training?

Q15. How accurately does this statement represent your experience? TFS has provided me with pump operations training for standpipe connections in super high-rise buildings (> 84 meters)

Strongly Agree 1	**Agree 2**	**Neutral 3**	**Disagree 4**	**Strongly Disagree 5**
.7% N=2	1.8% N=5	5.4% N=15	35.4% N=96	58% N=160
Median =5	**Mean** =4.5	**SD =.74**	**Avg** 4.46% N= 278	

Appendix F

TFS Analytics, 2019, Residential High-rises 20 Storeys and Higher

2019-12-20_Residen
tial High-rises 20 stc

https://drive.google.com/file/d/1GT5GeBVSdKggXKgD1_WxnTbh0SVevKW9/view?usp=sharing

Appendix G

Survey Invitation/Consent/Survey as viewed in Survey Monkey

PDF Survey for print.pdf

https://drive.google.com/file/d/156GlRpWsIKEM8Yso0uslZU8qOZ6wsmks/view?usp=sharing

Appendix H

TFS Analytics 2020, Commands and Districts.

https://drive.google.com/file/d/1d610BipaggCKv1VOGDcQafyGpEKPcB0R/view?usp=sharing