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ABSTRACT. Practitioners are continuing to develop egress modelling software for the design of the built environment. These models require data about human behaviour and factors for calibration, validation, and verification. This study aims to address the specific data and knowledge gap: emergency egress of the elderly. Such data is difficult to collect given privacy and consent concerns, with strong relationships generally being required between residences and researchers. Through the observation of nine fire drills at six Canadian long term care and retirement homes, specific evacuation actions and behaviour were observed for 37 staff members and information about the evacuation of 56 residents was collected. These drills demonstrated that emergency egress in long term care and retirement homes is highly staff dependent with 72% of residents recorded requiring full assistance at all stages of movement in evacuation, and that the type of announced/unannounced drill and level of resident care will affect the type of data collected. The development of travel speed and pre-movement is discussed subject to limitation with qualitative behavioural insights of residents that were observed. This study provides valuable methodological discussion on how to conduct behavioural studies in similar highly restricted research environments. Specific attention is given to understanding the considerations that must be made when using fire drills as data sources, and the impact that these can have on using such data for modelling. This study may inform the initial setup and programming of evacuation models from an actions and behavioural perspectives of staff members and residents.

Keywords: Fire drills, Aging Populations, Dependent behaviour, Evacuation, Behavioural data, Movement time

1. Introduction

A demographic factor that has potential to have significant impact on the time required for emergency egress is that the global population is aging.[1] In Canada, the 2016 census showed that seniors outnumbered children for the first time in the country's history.[2] By 2036, seniors are projected to comprise 23%-25% of Canada's population.[3] This change will affect the requirements of the built environment. Aging and elderly populations require more time and assistance to evacuate in emergencies due to the increased prevalence of physical and mental disabilities.[4,5] The Society of Fire Protection Engineers (SFPE) identified the collection of data relating to demographics, specifically vulnerable populations, as the priority theme in its 2018 Research Roadmap.[6] This demonstrates that there is a need for understanding of the behaviour, actions and dependencies of vulnerable populations, such as the elderly, in fire events.

In places such as long term care (LTC) and retirement homes, which specifically cater to this demographic, the role played by care staff can have a substantial impact on the nature of the evacuation process.[7] This can be seen in a number of prominent and deadly fires in LTC and retirement-type homes. Devastating fires (ex. Rosepark Care Home in Scotland in 2004 and in the L'Isle-Verte Senior's Residence in Canada in 2014) have resulted in significant loss of life.[8,9] There have been eight fires in Canadian residences dedicated to the care of the elderly within the last nine years alone with life loss (Table 1).

Table 1
Recent Fires in Canadian Long Term Care, Retirement and Seniors Homes[30-39]

Date	Place	Location	Fatalities
Mar-18	R J Brooks Living Centre	Bancroft, Ontario	1
Sep-17	Extendicare Port Hope Long Term Care Centre	Port Hope, Ontario	0
Jul-17	Oasis Residence	Terrebonne, Quebec	1
Nov-16	Domaine des Trembles	Gatineau, Quebec	0
Mar-16	Villa Carital	Vancouver, British Columbia	0
Dec-15	Medicine Tree Manor	High River, Alberta	0
Jun-14	Extendicare Starwood	Ottawa, Ontario	0
Jan-14	L'Isle-Verte Seniors Residence	L'Isle-Verte, Quebec	32
Aug-12	Retirement Home	Edmonton, Alberta	1
May-12	Place Mont-Roc home	Hawkesbury, Ontario	2
Apr-12	Long Term Care Home	Langley, British Columbia	1
Apr-11	Rainbow Suites Retirement Home	Timmins, Ontario	1
Apr-10	St. Joseph's Residence	Winnipeg, Manitoba	0
Jan-09	Muskoka Heights Retirement Home	Orillia, Ontario	4

In order to be representative of real-life emergency situations that can inform building design, egress models must represent various elements of human behaviour and take into account the wide range of factors that can influence how and when people will evacuate in diverse situations and environments. These models require calibration, validation and verification. They rely upon access to data covering a range of populations and environments. Data of this nature can come from a variety of settings, can include a wide spectrum of demographics, and can represent varying levels of credibility for using and developing egress models and subsequent design. Herein, qualitative and quantitative behavioural data was collected through the observation of nine fire drills at six different LTC and retirement homes in Ontario, Canada. Given the high dependence of residents on staff members in these homes, the study focuses on the actions and behaviours of the staff members and their interactions with residents during fire drills. The paper highlights the nuances of conducting fire drills in LTC and retirement homes and the complexities of collecting data from such drills. The paper details the process that was followed to build relationships with LTC and retirement homes, to observe and collect data from fire drills at these homes. Additionally, this study discusses the limitations to be considered when using fire drills as a data collection method. The methodology herein tailors to how similar and future studies by other researchers and practitioners may be conducted within restricted research environments. The study is Canadian focused but certain conclusions and material will extend to broader use. While the datasets are subject to various limitations noted herein, practitioners may find this study useful to inform the initial setup and programming of their evacuation models from an actions and behavioural perspective of staff members and residents. This manuscript is the first in a series by the authors which is intended to be followed by a modelling verification and validation study which is beyond this current manuscript's scope.

2.0 Theory

2.1 Legal Fire Drill Requirements

In this study, the observed retirement homes had three levels of care. These levels range from independent, assisted and memory care. In independent care, there is little to no supervisory staff needed for residents. Assisted care offers staff assistance with day-to-day activities. Memory care assistance offers extended care for residents with neuro-diverse requirements such as early stage dementia or derivatives. These residents often have difficulty with recognition and can easily be confused. For their safety, these residents receiving memory care assistance are located on a secured floor, with staff assistance available. LTC home residents tend to require physical or cognitive assistance and have restricted mobility. Enhanced monitoring and care is provided with 24-hour nursing.

The two types of care homes are both required to have fire safety training and procedures per the National Fire and Building Code of Canada (NBC and NFC herein) in addition to the provincial codes.[10,11] The procedure of a fire drill is the responsibility of the building management.[12] The

procedure should address the potential building fire hazards with respect to the residing occupants, note building safety features, indicate the target number for non-staff occupant participation during the drill and the number of trained staff involved. Procedure should follow the fire department regulations and confirm that the emergency systems comply with the NBC.[12] The NFC also addresses that the frequency of the fire drills depends on the occupancy type. For elderly care homes, the staff are required to participate in a fire drill once a month and the staff participation must be recorded. In LTC homes, three fire drills are required every month, one on every shift (morning, afternoon, night).[11,13] Both LTC and retirement homes are required to have one fire drill per year observed by a city fire marshal. This drill must represent the worst-case timing scenario - the least number of staff that would be present in the home - the night shift. It also requires that all residents in the fire drill wing be evacuated to a place of relative safety e.g. to an adjacent fire compartment, and not necessarily to outside the building. The code allows staff members to stand in and act in the place of residents.[11,13]

2.2 The Role and Purpose of Fire Drills

A drill can be defined as "an exercise involving a credible simulated emergency that requires personnel to perform emergency response operations for the purpose of evaluating the effectiveness of the training and education programs and the competence of personnel in performing required response duties and functions".[14] Drills are often used to evaluate the performance of individuals in a simulated emergency environment so as to gauge how they could perform during a realistic emergency. Drills can also be seen as training and educational activities to teach people how they should act in an emergency situation.[12] In both cases, drills provide the opportunity to address performance, be it an individual act, role or procedure, or the interactions between different groups, individuals, environments, and emergency scenarios. Drills can also provide opportunities to gather valuable information about evacuee behaviour and procedural design.[15] Given that conducting "experiments" in the traditional sense of the word is generally not possible for ethical and safety concerns – particularly with vulnerable populations – drills, along with other models, can provide a limited opportunity to better understand aging populations' behaviour in fire. Egress drills are commonly used tools. However, their benefit, effectiveness and limitations are not widely understood as discussed in depth elsewhere.[12] This is a critical consideration when using drills as a means of data collection for research. It is important to understand that drills are a simulation, a model of an emergency situation. Practicality, safety, cost and ethics can limit their value.[12] Researcher influence can also impact the realism of a drill and the quality of the data collected and should therefore be managed carefully to minimize its impact.[16] For the modeller using this data it is critical to know the limitation and applicability of the data to keep it within context and understand its impact on the practitioner's uncertainty.

2.3 Egress Data and Evacuation Modelling

Over the past few decades, evacuation modelling software has been developed for applications in crowd dynamics, pedestrian movement and evacuation processes.[17] These models are used by various fields and disciplines, and as such they play an important role in understanding and representing human movement and evacuation behaviour. There exist many different egress models, ranging from hydraulic calculations to adaptive agent-based approaches.[18] These models vary in the way that they configure buildings, populations, and procedures.[19] Practitioners have reviewed and summarized the features and capabilities of current egress modelling software.[20,21]

Models rely on an understanding of the situation being simulated and appropriate data input. This data is not only used for creating egress model simulations, it is also necessary for the verification and validation of the tools themselves.[22] Data can come from a variety of sources including simulated emergency evacuations such as fire drills. Much of the data available in publicly accessible literature has been compiled and can be found in the fifth edition SFPE Handbook.[23] An understanding of human behaviour in fire and the dependencies between groups and their care takers are important when using and interpreting the data available. Additionally, data collection context, techniques and processes can have a large impact on the nature of the data collected and therefore need to be considered when looking to use the data in a computer model specifically when dependent behaviour is sought to be understood.

3.0 Methodology

Data relating to fire drills and procedures was collected in collaboration with three LTC homes and three retirement homes. The characterization of the buildings used for the nine drills is summarized in Table 2 and 3. The drills are numbered in the order that they were observed. Early research focused on LTC homes (Drills 1-4, 6) while the more recent studies focused on retirement homes (Drills 5, 7-9). The first four drills were monthly drills in which resident participation was not mandatory while the latter five drills were legally required annual fire marshal-observed drills. In total, six different homes agreed to have drills observed by researchers, and nine individual drills were observed (three drills at one home, two at another, and one drill at each of the other four homes).

Semi-structured, formal conversations were had with a staff member responsible for organizing fire drills and training staff at each of the participating homes. Monthly or annual fire drills were observed in person with notes being taken by hand during the drill. Sections 3.1 and 3.2 detail the methodology for the data collection.

Table 2
Summary of participating long term care and retirement home locations where data was collected

	Drill 1[a]	Drill 2	Drill 3[a]	Drill 4	Drill 5[b]	Drill 6[a]	Drill 7[b]	Drill 8	Drill 9
Number of Storeys	3	7	3	2	5	3	5	5	6
Number of Residents	161	193	180	192	127	190	125	N/A [c]	N/A [c]
Long Term Care Home	X	X	X	X	-	X	-	-	-
Retirement Home	-	-	-	-	X	-	X	X	X

[a] Drills 1, 3 and 6 were observed in different wings at the same location at the same level of care but at different dates so occupancy differs.

[b] Drills 5 and 7 was observed at the same location at different levels of care location at the same level of care but at different dates so occupancy differs.

[c] Exact occupancy not available but > 100.

3.1 Building Connections and Conducting Conversations

The first stage of the research involved building a relationship of trust with LTC and retirement homes. Convenience sampling was used for the study, with as many homes in study region being contacted as possible (based on the information that was available online). Four rounds of written requests were sent out to managerial staff at the homes describing the project and inquiring about their willingness to talk about the home's fire safety practices, policies and evacuation procedures. It was made clear that the authors would answer questions or discuss any concerns that the home representatives had prior to agreeing to a meeting. Table 3 details the response rate for each round of meeting requests. Formal conversations were had in person at the homes with the head staff member responsible for organizing and overseeing fire drills and fire safety training and responses were written down by the researcher (general information, not exact quotes). The pre-determined questions focused on general building information, fire detection systems, active and passive systems, fire strategies and staff procedures, resident level of care as well as general demographics and resident population characteristics.

Table 3
Response rate for each round of meeting requests

Round of Meeting Email Requests	Request Timeframe	Type of Home	Number of Homes Contacted	Number of Homes that Responded	Number of Homes that Agreed to Participate	Number of Homes Where Meetings Were Conducted	Number of Homes Where Drills Were Observed
1	Sept. 2014	Long Term Care	8	4	3	2	1
2	Sept. 2015	Long Term Care	7	4	4	4	3
3	Jan. 2016	Retirement	7	2	1	1	1
4	May 2017	Retirement	15	6	4	3	3

In total, meetings were conducted at seven different LTC and retirement homes. One LTC home where a meeting was conducted could not be reached to arrange a fire drill observation. At homes where multiple drills were observed, follow-up conversations were had prior to observing subsequent drills so as to update any information that had changed since the previous meeting.

3.2 Fire Drill Observation and Data Collection

Following the meetings, the participating homes were asked if they would be willing to allow members of the research team to observe one of the homes' required fire drills as part of this research study; six different homes agreed. The authors were invited to observe drills that were pre-arranged by the different homes based on monthly or yearly fire drill requirements. Information such as floorplans, staff fire safety procedures and anticipated number of participants were acquired in advance of each drill and were used to prepare a guide which was given to each observer.

The method of observing each fire drill followed a similar process so as to maintain compatibility and allow for comparisons to be made. Each drill was observed in person from within the designated fire wing (outside the room compartments). This method of data collection was necessary given that informed consent of residents living with dementia could not practically be obtained for using cameras for data collection. Additionally, filming nursing staff during the fire drills was forbidden as third-party evaluation by film was prohibited by their unions. Research ethics were also more easily obtained in this method of data collection. It is acknowledged by the authors that this method of observation does not allow for all events that may occur during a drill to be recorded and analyzed. While the authors acknowledge this can result in a loss of important data, the willingness of the homes to allow the drills to be observed in the first place was in part due to the fact that cameras were not being used.

At each home, the authors met with the drill coordinator for a pre-drill discussion on the details of the drill. If the drill was a worst-case scenario annual drill, the drill coordinator would also hold a pre-drill discussion with the staff members participating to review procedures, assign roles, and answer questions (participating staff members were briefed for Drills 5 – 9). The drill observations took place within the building wing where the evacuation was taking place. Three to four researchers (led by at least one of the authors, but also including those on their research team) attended each fire drill and were positioned along the corridors of the fire drill area to limit interference with staff procedures. The number of researchers in attendance at each drill was determined based on maximizing the amount and quality of data collected, and by minimizing the impact of the observers on the drill (based largely on the geometry of the floorplan – hallway length, linear vs. non-linear layout – and whether an observer could remain in the same location throughout the course of the drill while being able to record the necessary data). For the first four drills which took place at LTC homes, each observer was responsible for recording general observations of participating staff and residents along with the corresponding times. For Drills 5 – 9, the timestamps of specific actions, including when staff members entered the wing and when residents or staff entered a room, left a room, and entered the safe zone, were the focus of the observation. Behaviours exhibited and actions undertaken by both staff and residents were also noted, along with the times that they were observed. Written notes were kept during the drill and synchronized stopwatches were used by observers to note key timestamps. For these later drills, the observation task distribution between the researchers depended on several factors including the geometry of the building wing being evacuated, the level of care being provided (and corresponding level of resident dependency), and the number of participating staff and residents. For Drills 5, 6 and 9, each researcher recorded the actions of one staff member. This was deemed the most effective method given that the residents in Drill 5 and 6 had a high dependency on staff (memory care floor or long term care home) and would therefore not evacuate on their own, and for Drill 9 there were only a few residents living on the evacuation floor. It should be noted that in contrast to Drills 5 and 9 where the number of observers equalled the number of participating staff members (3:3), there were more staff participating in Drill 6 than there were observers (8:3). It was determined that in order to collect data to the degree of specificity required while not unduly interfering with the drill by having too many observers present, it was necessary to focus closely on a select number of staff. Therefore, each researcher observed one staff member. This meant that the same amount of data was collected as in the other drills, but the proportion of data collected to potential data was smaller. For Drills 7 and 8, researchers focused on recording actions observed in specific sections of the wing. This was deemed the most effective method as the drills took place on floors where residents were more independent and autonomous and therefore were expected to evacuate without extensive staff assistance. This method allowed the researchers to observe and record the actions of both the staff and the residents (both autonomous and non, herein we define autonomous as residents who left their room on their own ability and moved to the safe zone on their own

ability, with or without prompting, with or without walkers, wheel chairs etc). Given the floorplan geometry, this method also allowed the researchers to remain in one place throughout the drill, limiting their impact on the drill. Following each drill, the researchers observed the post-drill discussion held by the drill coordinator with the participating staff (and the fire marshals if present). After leaving the homes, the researchers then met to discuss the drill and to consolidate the raw data each person had collected. Table 4 details the conditions of each drill including the number of participating staff and residents, the working shift during which the drills took place, and the duration of the drill. Table 5 shows the frequency and probability of observed staff actions and behaviours during the drills, and Table 6 shows pre-evacuation times and percent evacuation times for 5 of the observed drills. These tables will be discussed in later sections of the paper.

Table 4

Summary of fire drill conditions

	Drill 1	Drill 2	Drill 3	Drill 4	Drill 5	Drill 6	Drill 7	Drill 8	Drill 9
Type of Drill Observed	Monthly	Monthly	Monthly	Monthly	Annual	Annual	Annual	Annual	Annual
Working Shift	Day	Evening	Evening	Evening	Night	Night	Night	Night	Night
Time of Drill	2:00 pm	3:30 pm	3:00 pm	3:30 pm	3:30 pm	10:00 am	1:30 pm	2:00 pm	10:30 am
Number of Staff	15	7	9	7	3	8[a]	3[b]	3	3
Number of Staff Stand-Ins	0	0	0	0	3	11[c]	1	0	4
Number of residents participating	3	0	2	2	10	14	22	14	6
Number of residents that did not evacuate	0	1	0	0	0	0	0	4	0
Number of residents recorded	3	0	2	2	10	5	18	10	6
Autonomous residents recorded [e]	3	0	0	0	1[d]	0	11	1	0
Drill Timing to "all clear" (mm:ss)	6:00	5:00	4:52	3:23	13:33	9:08	14:28	15:05	7:38

[a] 8 staff participated in the drill, data was collected for 3 of them

[b] 3 staff participated in the drill, data was collected for 2 of them

[c] 11 staff stand-ins participated in the drill, data was collected about 7 of them

[d] Resident evacuated on their own, but were returned to their room and then evacuated by staff

[e] Autonomous is defined as residents who left their room on their own ability and moved to the safe zone on their own ability, with or without prompting, with or without walkers , wheel chairs etc.

Table 5

Frequency and Probability of Observed Staff Actions and Behaviour

Action or Behaviour	Overall Frequency From All Nine Drills # of Staff Observed (# of Drills Observed In)		Probability Based on Total Number of Actions (%)	Probability Based on Total Number of Staff Observed in all Drills (%)
Pre-Drill Actions				
Normal (unaware of drill about to occur)	23	(3)	9.7%	62.2%
Staged (aware of drill about to occur)	14	(5)	5.9%	37.8%
Perception of Initial Stimulus (Drill Start)				
Ambiguous - Observe behaviour of others	0	(0)	0.0%	0.0%
Unambiguous - Alarm, intercom message, staff radio devices	37	(8)	15.7%	100.0%
Seek and Disseminate Information, Investigate				
Already in fire wing when drill starts	10	(6)	4.2%	27.0%
Travel to and enter wing where the fire is located	27	(7)	11.4%	73.0%
Search for the fire (checking rooms)	10	(2)	4.2%	27.0%
Go right to fire room (do not search other rooms)	6	(6)	2.5%	16.2%
Communicate location with collogues via handheld radios	5	(2)	2.1%	13.5%
Raise the Alarm / emergency message via intercom system	1	(1)	0.4%	2.7%
Seek information from other staff members	5	(3)	2.1%	13.5%
Seek information from fire marshal or drill coordinator	1	(1)	0.4%	2.7%
Initial Securing of Environment				
Bring fire extinguisher into wing	7	(5)	3.0%	18.9%
Locate/entire fire room	14	(7)	5.9%	37.8%
Simulate fighting fire using fire extinguisher	1	(1)	0.4%	2.7%
Place towels under fire room door	2	(2)	0.8%	5.4%
Clear all obstacles out of hallway	8	(1)	3.4%	21.6%
Close resident room doors (pre-evacuation)	2	(1)	0.8%	5.4%
Resident Evacuation				
Check rooms for residents (initial check)	16	(6)	6.8%	43.2%
Assist residents with pre-movement actions (in resident rooms)	3	(2)	1.3%	8.1%
Verbally prompt residents to evacuate (not req.to walk with)	2	(1)	0.8%	5.4%
Guide and walk with residents to safe zone	14	(7)	5.9%	37.8%
Guide/assist resident back into room (still within fire wing)	1	(1)	0.4%	2.7%
Aide another staff member in evacuating a resident	3	(2)	1.3%	8.1%
Close room doors upon exit of room	4	(3)	1.7%	10.8%
Do not close room doors upon exit of room	2	(2)	0.8%	5.4%
Re-Checking Rooms and Marking as Clear				
Use Evacucheck or hanging marker to indicate cleared room	9	(5)	3.8%	24.3%
Re-Check evacuated rooms (once)	5	(2)	2.1%	13.5%
Drill Closure				
Stand around	3	(1)	1.3%	8.1%
Say that all residents have been evacuated, in bed	1	(1)	0.4%	2.7%

Table 6
Drill Evaluations of Only Recorded Residents

Drill	Pre-evacuation Times Avg [Min – Max]	Time which Percentage of People Evacuated [MM:SS]			
		25	50	75	100
5	5:36[0:47 – 10:16]	4:52	5:37	8:27	11:19
6[a]	2:02[0:46-3:13]	1:19	2:45	2:47	3:38
7	3:09[0:32-10:39]	1:20	3:16	8:14	12:16
8	6:53[2:25-11:42]	5:28	7:10	10:15	13:55
9	3:53[1:29-5:32]	4:37	6:52	7:03	7:32
Average	4:18				

[a] only 5 residents of 14 are recorded.

4. Results

4.1 Formal Conversation Data

Though each home had different architectural designs and features, the buildings were typically organized in the same way. In the LTC homes, this meant that each floor was compartmentalized into wings or units, which were straight hallways that generally branched off a central core. The elevators were centrally located, and fire rated stairwells were located at the end of each unit. The wings were separated by fire rated doors, creating compartmentalized units. This enabled horizontal evacuation to take place during emergency situations. In the retirement homes, this compartmentalization was only seen if the home had a floor or wing designated for the care of residents with dementia. Most floors of the retirement homes consisted of rooms branching off a main hallway. Horizontal evacuations were still the first stage of an evacuation in the retirement homes, however residents would be evacuated to the stairwells.

In the LTC homes, the average age of residents was 75 to 88 years. Based on their knowledge about the residents, it was estimated by the staff members participating in the initial meetings that between 88-100% of residents would require some form of assistance to evacuate horizontally given the number of residents with cognitive and/or physical disabilities. While the need for assistance was less in the retirement homes, in one building for example, over 90% of the residents would still require assistance to go down the stairs. Staffing levels were consistent among both the LTC and retirement homes - that the least number of staff were present during the night shifts.

The formal conversations provided information on the fire evacuation procedures and practices at each home. Each home had a fire plan that was updated annually and reviewed by the fire department. The official procedures varied from home to home, however they were similar in

nature and are published in publicly available policy literature. The REACT fire response procedure (Remove those in danger, Ensure door is closed, Activate alarm, Call 911, Try to extinguish the fire) was used by three homes, with another home using the RACE method (Rescue, Alarm, Contain the fire, Extinguish). The representatives at two homes did not cite a specific reaction acronym, however the approach they described closely resembled the REACT method.

In addition to the initial fire safety training they received as part of their orientation upon being hired, employees were required to participate in annual training and fire drills. During the monthly fire drills, the residents were not required to participate as it was viewed more as a way for the staff to practice the steps that they would need to go through in an actual fire evacuation. In both the LTC and retirement homes, this involved locating and evacuating the fire room (and any connecting rooms) followed by the rooms on either side and the one directly across the hall from the fire room: these occupants are considered most at risk during the initial stages of a fire. This was referred to as the critical triangle (Figure 1). The rooms were then to be progressively evacuated, starting with those in closest proximity to the fire room. All doors were to be closed after each room was evacuated. Each home had a way of designating which rooms had already been evacuated. Some homes used Evacuchecks which were tabs attached to the doorframe of each room that could be flipped once the room had been checked, other homes hung a tag on the door handle (Figure 2a and 2b).

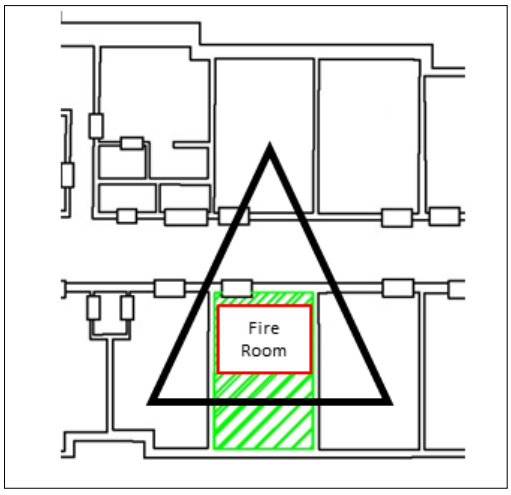


Figure 1. Visualization of the “critical triangle” that determine what are weighted to be evacuated first.

Figure 2. (a) Evacucheck before evacuation (b) after evacuation

In the LTC homes, where some residents were bedridden, several different methods of physically assisting residents during real evacuations were described. One home could use mechanical lifts to move bedridden residents into a wheelchair, another home moved the beds themselves into the hallway and into the safe zone. The two other LTC homes used what was known as the blanket method, where bedridden residents were wrapped in their sheets, guided to the floor and then pulled into the safe zone. As the participating retirement homes did not have any bedridden residents given the level of care they provided, such methods were not necessary. Additionally, it was also expressed by the LTC home representatives that while the staff were searching for the fire, they were supposed to close any open resident room doors as well as clear the hallway of all obstacles (wheelchairs, nursing carts, etc.). In the LTC homes, the staff were also expected to make a "Code Red" announcement over the intercom at the start of the drill to inform all staff in the building that a fire had been detected. In contrast, staff at the retirement homes were notified of the fire emergency via handheld radios instead of over the intercom system. During both LTC and retirement home fire drills, one staff member was expected to simulate calling emergency services and one staff member was required to remain on a floor or wing that provided physical and/or cognitive assistance.

It is important to note that not all the actions and procedures discussed above are tested during fire drills. While these actions describe what staff are supposed to do during an actual fire, however, for various reasons discussed in later sections of this paper, not all are expected to be done during the monthly fire drills (they are required for the annual, fire marshal observed drill).

4.2 Drill Observations

Sections 4.2.1 – 4.2.9 provide summaries of the nine observed drills, where only critical information is provided. The significant times recorded for each observed action and behaviour are written in mm:ss format. The drill floorplans (Figures 3 – 11) may show more residents and staff stand-ins than are noted in the description (the location of all participating residents and staff stand-ins were disclosed prior to some of the drills, including those who did not end up

participating or were not observed during the drill). Rooms labelled “Room #” represent resident rooms that were or would normally be occupied by a resident (including rooms from which residents were not evacuated during the drill). Rooms labelled “Vacant Room #” indicate rooms where residents were not living at the time. Research observer locations are shown in each drill figure. Table 4 summarize the parameters for each drill.

4.2.1 Drill 1 (Long Term Care Home – Day time working shift)

Fifteen staff members participated in the drill. Three residents participated and evacuated without any assistance from staff. The other residents in the wing either remained in their rooms or had left just before the drill started.

The floorplan of the wing where the drill took place can be seen in Figure 3. The drill started with the activation of the fire alarm and an announcement over the intercom indicating "Code Red". After 30 seconds, the staff at the nursing center began discussing if they should call emergency services. They were told by another staff member not to as it was "just a drill". At 0:50, one resident evacuated the wing through the main exit instead of the one adjacent to their room. The fire room was located after 1:20 and staff begin to clear the hallway. At 2:20, a staff member was assigned to simulate calling emergency services. Once the hallway was cleared, the staff began checking resident rooms, closing doors and marking the rooms as clear. Two residents from the same room evacuated the wing at 3:39. Ten seconds later, one of those residents returned to their room. Staff announced that the evacuation was complete at 4:15 and “all clear” was announced at 6:00. The post-drill debriefing followed. During the debriefing, staff members discussed their confusion about what they should do during an evacuation (when to call emergency services, which exits to use, what to do at night when they are short-staffed). The drill coordinator then reviewed the steps according to the home's fire safety plan with the staff.

4.2.2 Drill 2 (Long Term Care Home – Evening time working shift)

The second fire drill took place on the evening staffing shift. It was expected that three to four residents would participate, though none did. According to the home's fire safety plan, the residents who were bedridden would be kept in their beds and then moved out of the wing.

However, this was not something that was intended to be simulated during fire drills.

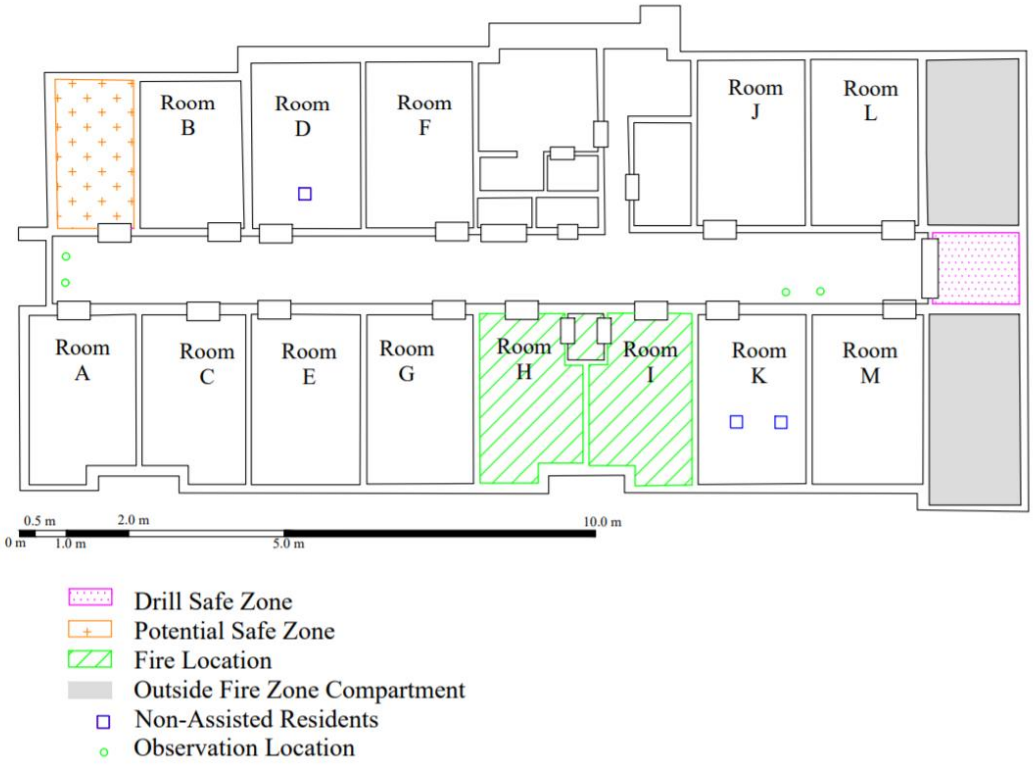


Figure 3.Drill 1 Floorplan

The floorplan of the evacuated wing can be seen in Figure 4. The fire alarm indicated the start of the drill, after which "Code Red" was announced over the intercom. The first staff member entered the wing at 0:19 and entered the designated fire room at 0:32. During the 24 seconds that the first staff member was in the fire room, two additional staff entered the wing. Upon leaving the fire room (not closing the door to the room all the way), the first staff member moved back down the hallway. Ten seconds later, a second staff member checked the fire room, leaving 10 seconds later and closing the door. At 2:00, a green checkmark was placed on the fire room door and the door of the room next to it, and a fourth staff member entered the wing. Three additional staff members entered the wing at 2:12, with one asking if the fire room had been checked. At 3:00, one staff member said that all the residents were in bed and another staff member finished checking a room and stood outside the room with the door open (a resident was inside the room). At 3:11, the drill coordinator announced the end of the drill and the staff began to move into the hallway outside of the wing. The post-drill debriefing began soon afterwards, and "all clear" was announced over the intercom at 5:00. A key point

that the staff discussed during the post-drill debriefing was that there needed to be a better way for staff within the fire wing to communicate with those outside the wing as there was no way to know how many staff should be sent to assist with the evacuation.

Figure 4.Drill 2 Floorplan

4.2.3 Drill 3 (Long Term Care Home- Evening time working shift)

The floorplan of the wing where the third drill took place can be seen in Figure 5. The drill coordinator activated the fire alarm in the room that was to act as the fire room. The coordinator remained in the room until located by one of the participating staff members, as their presence indicated that it was the fire room.

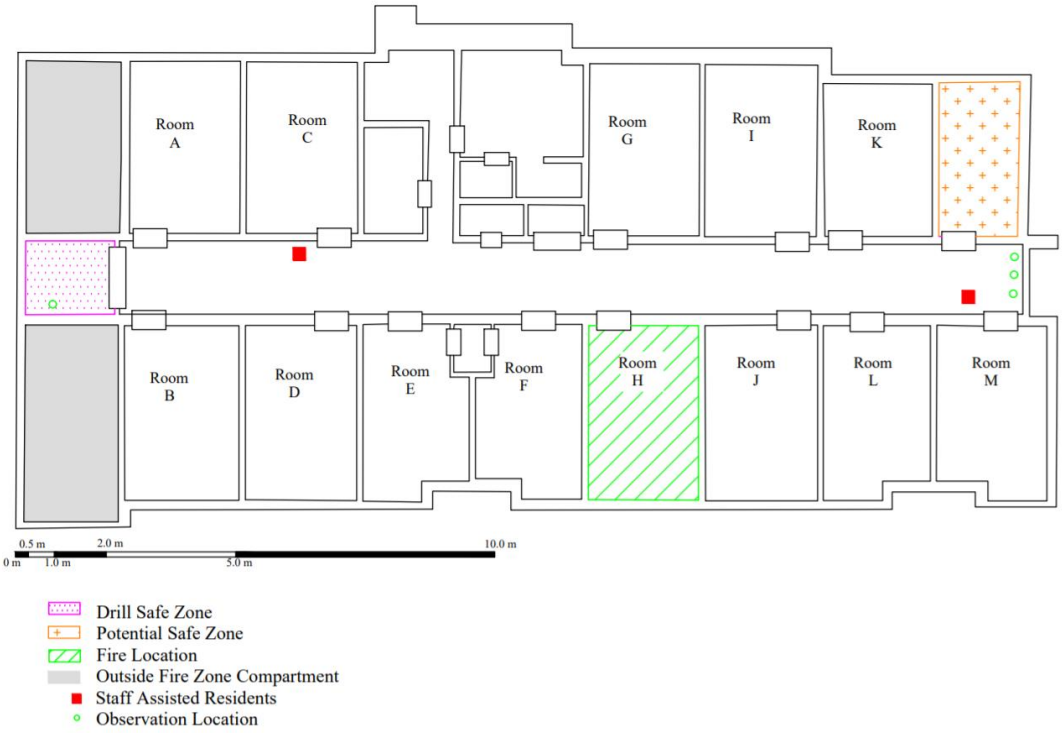


Figure 5. Drill 3 Floorplan

When the alarm sounded, one staff member was already in the wing. "Code Red" along with the fire wing location was announced over the intercom at 0:20. A second staff member entered the wing 10 seconds later. Seven more staff entered near 1:00. At 1:10, a staff member began moving a resident toward the main safe zone (1:31) and a resident at the far end of the hall was moved back into their room to allow staff to conduct the complete egress procedure for all rooms. At 1:27, the fire room was identified by one of the staff members. At 2:00, the staff started clearing the hallway in the fire wing, and soon after the door to the fire room was closed. During the drill, two non-participating residents in the safe zone tried to enter the fire wing and were stopped by staff members outside the wing. Two staff members re-entered the fire room at 2:30, leaving soon after and closing the door as another staff member asked if they checked to see if anyone was in the room. Soon after, a custodial staff member (not part of the drill), moved a cleaning cart from the hallway and into the safety zone, leaving it directly on the other side of the fire doors. The hallway was clear at 3:00, and 15 seconds later, a staff member opened the fire room door again. At 4:00, the Evacucheck was flipped on the fire room door, after which staff members began flipping Evacuchecks on other resident room doors. The drill ended with “all clear” announced at 4:52, 20 seconds after the drill coordinator ended the drill. The drill was followed by a staff debriefing. A participating staff member discussed her confusion on how to use the Evacuchecks.

4.2.4 Drill 4 (Long Term Care Home – Evening time working shift)

It was the home's policy that mechanical lifts be used for bedridden residents as the home had a no-lift policy for the employees. During the fourth drill, the staff were expected to simulate using the lifts (taking one to the resident room but leaving it outside the door). The drill coordinator mentioned that the home had adopted a new procedure approximately one and a half years ago, and that the staff were still adapting to it. Specifically, the staff were now expected to check and evacuate all rooms in the wing as opposed to just the critical triangle. The drill coordinator also mentioned that fire drills were being used as both a training and evaluation tool. The floorplan of the wing where the drill took place can be seen in Figure 6.

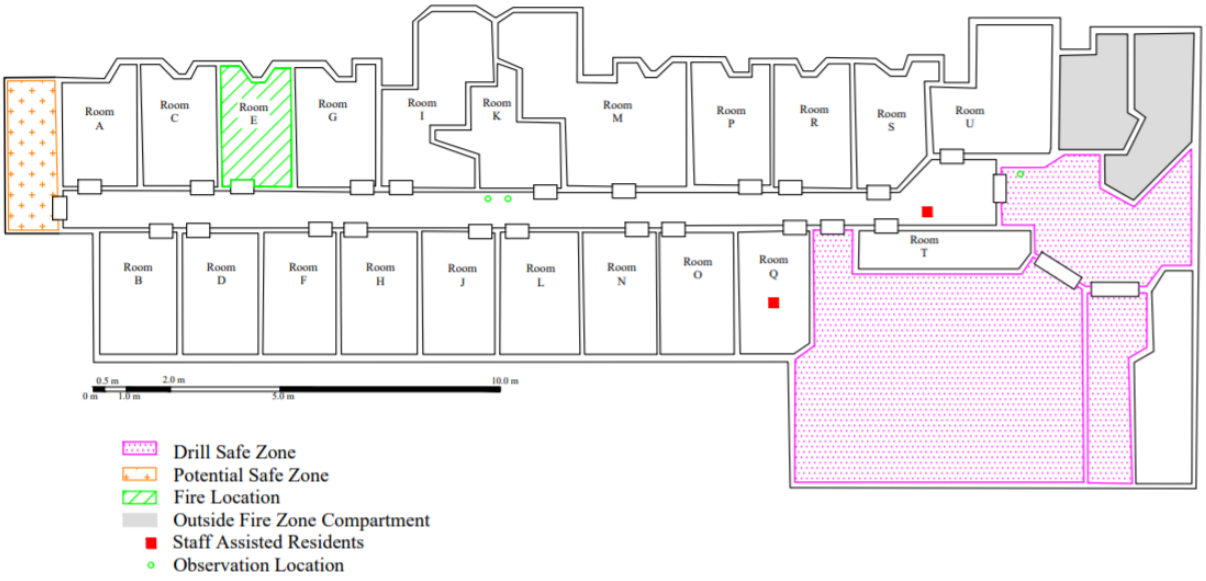
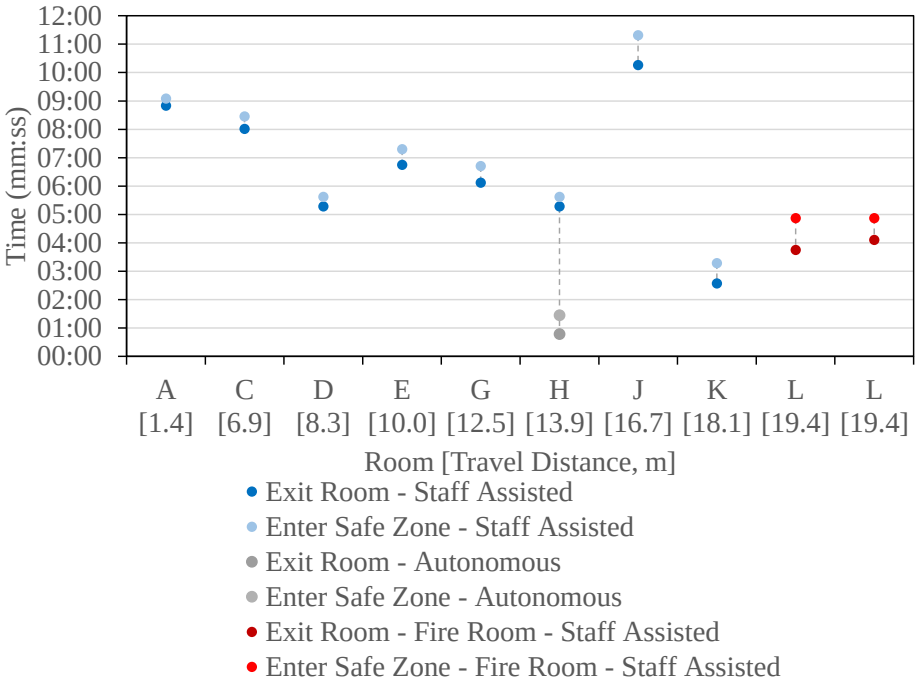


Figure 6. Drill 4 Floorplan

The fire alarm signaled the start of the drill and 15 seconds later a resident in a wheelchair was moved from the hallway to the safe zone. A second resident was also evacuated from the hallway to the safe zone at 1:00 after two staff members spent 15 seconds debating where to take the resident. The door next to the fire room was closed at 1:41, followed by the door to the room across from the fire room. At 1:50, a third staff member entered the wing, and 12 seconds later a towel was placed at the base of the fire room door. During the following minute, four additional staff members entered the wing, standing around and waiting for something to do. At 3:12, a staff member left the wing to say that everything was done. At 3:23 "Code Red All Clear" was announced. During the drill it was noted that key elements of the home's fire emergency procedures were not executed. Examples included not simulating lift use and neglecting to close the doors and evacuate all resident rooms. In the post drill debriefing, the staff expressed that the drill generally went well, and the drill coordinator briefly discussed the tasks that were missed (using the lifts and evacuating all resident rooms).

4.2.5 Drill 5 (Retirement Home – Night time working shift)

In addition to the three staff, ten residents participated in the fifth drill along with three additional staff members standing in place of residents. The floorplan of the wing where the drill took place can be seen in Figure 7. All participating residents were evacuated to the section of the hallway separated by the fire doors; the stairwell at the other end of the hall was not used.



(a)

(b)

Figure 7. (a) Drill 5 Evacuation Timeline (b) Floorplan

There were initial difficulties with the staff's hand-held notification system, so the fire room was not entered until 2:02. During that time, a resident left their room independently and made

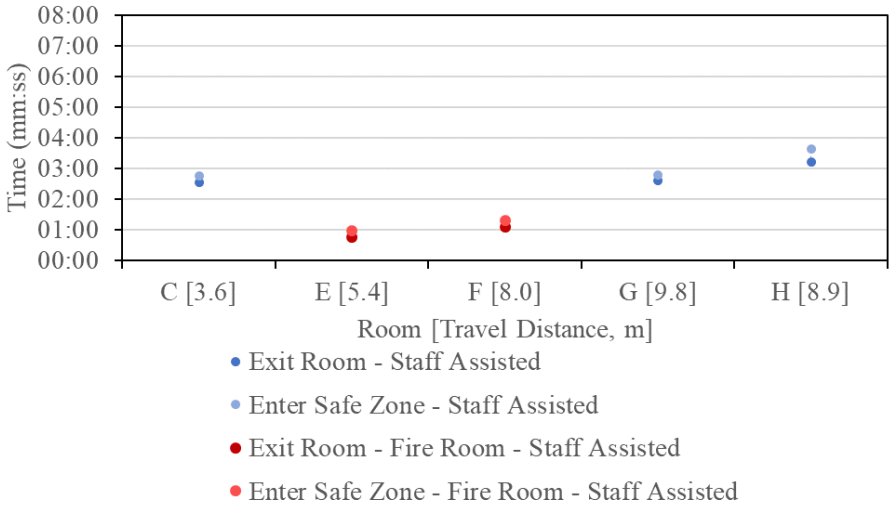
their way towards the safe zone before being prompted by one of the observing staff members to go back to their room (the reasons for this are unknown). Two staff members initially entered the fire room, but one left 30 seconds later to begin evacuating the room beside it. At 3:45, the first resident in the fire room was assisted into the hallway but tried to get back into the room. The second resident in the fire room entered the hallway at 4:06 and both residents then travelled with a staff member to the safe zone. Two staff members continued to evacuate the rooms, starting with those in closer proximity to the fire room. The third staff member entered the wing at 5:44 (they had been on the main floor meeting the fire marshal as would happen during a real fire). Once all of the rooms had been checked and the residents and staff stand-ins had been evacuated, the rooms were then rechecked and tagged to show that the rooms were clear. During this second check, a resident was found hiding in their room, 10 minutes after the drill started. It is not clear why the resident was hiding. This resident was then evacuated, and the remaining rooms were double checked and tagged. The drill lasted a total of 13 minutes and 33 seconds.

4.2.6 Drill 6 (Long Term Care Home – Night time working shift)

The sixth drill was observed in the same long term care home as the first and third drill, and was an annually required worst-case scenario drill. Each of the three observers were responsible for watching one staff member. As with the previous worst-case scenario drill, all the staff were aware that a drill would be taking place. During the pre-drill discussion with the drill coordinator and participating staff, the details of the evacuation were explained, roles were assigned, and staff questions were answered. Eight staff were assigned to evacuate the wing and 11 staff were designated to act as resident stand-ins. The residents chosen to be replaced by staff members were pre-determined based on their requiring a personal lift to get out of bed or their history of uncooperative behaviour. During the pre-drill discussion, the participating staff members were given the opportunity to practice the blanket evacuation method that was to be used to evacuate the staff stand-ins replacing bedridden residents. During this time, the research team selected three of the participating staff to focus on during the drill.

The floorplan of the drill location can be seen in Figure 8. The fire alarm was set off by the drill coordinator from within the designated fire room. The first staff members to respond started checking the rooms to locate the fire. Once the fire room was identified at 0:34, the evacuation started with that room and the one connected to it via a shared washroom, and then proceeded to the critical triangle. One staff member was the designated site manager and this person was in charge of directing all of the other staff. This person did not help with the physical checking of the rooms or the evacuation of residents, with the exception of assisting ambulatory residents who only needed guidance. After the evacuation of the critical triangle, the other rooms were also evacuated. From the start of the alarm to the drill being deemed complete by the organizer and the observing fire marshal, the drill lasted 9:08. In addition to the 11 staff

members, 14 residents were evacuated from the wing. During the post-drill debriefing, one of the key points discussed was how physically strenuous the blanket method evacuation was, especially after it had been done several times. The staff expressed concern over the feasibility of the night staff being able to evacuate certain residents in this manner.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H [8.9]
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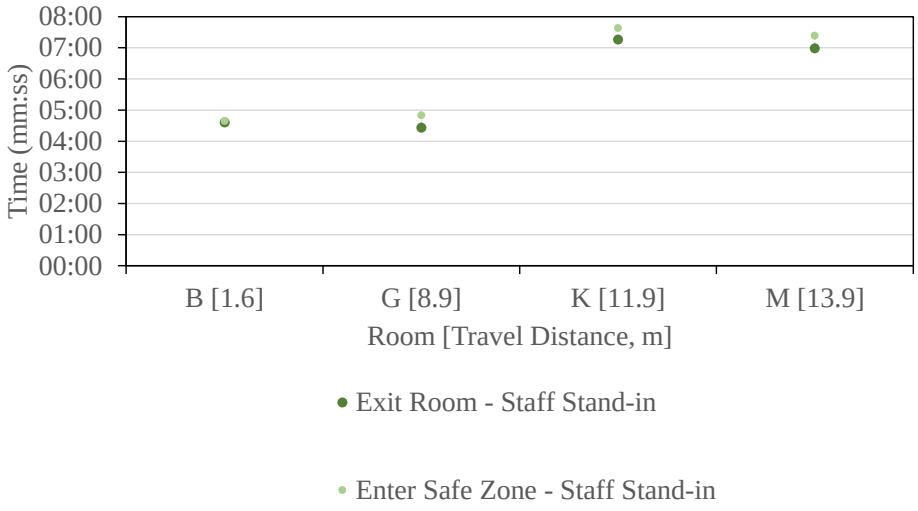
Exit Room - Staff Assisted
Enter Safe Zone - Staff Assisted
Exit Room - Fire Room - Staff Assisted
Enter Safe Zone - Fire Room - Staff Assisted

(a)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00:00
Time (mm:ss)
B [1.6]
G [8.9]
K [11.9]
M [13.9]
Room [Travel Distance, m]
Exit Room - Staff Stand-in
Enter Safe Zone - Staff Stand-in

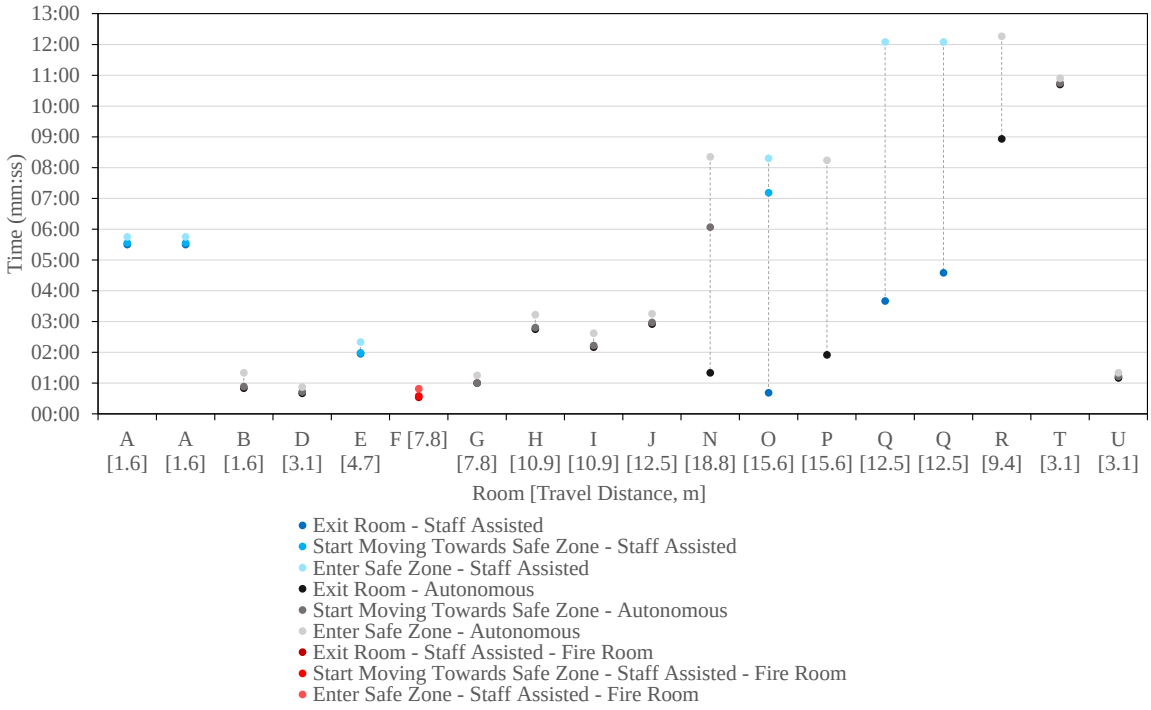
(b)

(c)

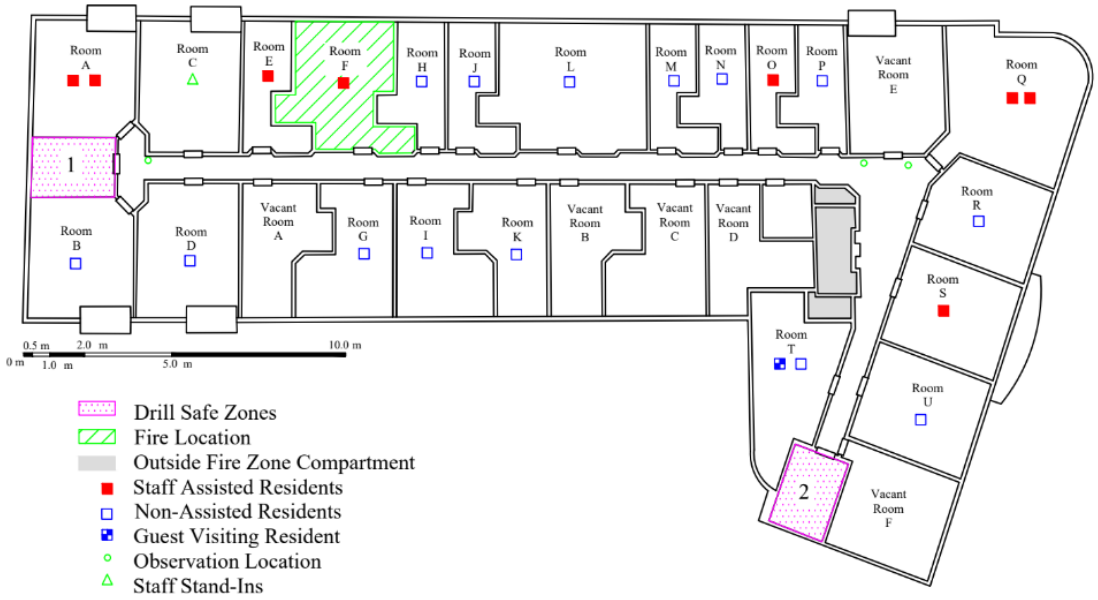
Figure 8. Drill 6 (a) Evacuation Timeline – Residents (b) Evacuation Timeline – Staff Stand-ins (c) Floor plan.

4.2.7 Drill 7 (Retirement Home – Night time working shift)

In contrast to the fifth drill which was observed on a memory care floor at the same home, this drill took place on an independent care floor without fire separation doors. This meant that all residents on the floor were meant to be evacuated to the stair-wells. A total of twenty-two residents participated in the drill along with one staff stand-in, two staff members who aided in the evacuation of residents and one staff member who had to remain on the memory care floor (as per the home's policy). All three staff participated in the pre and post-drill briefings and were considered to have taken part in the fire drill. Four additional staff members who would not typically participate in a worst-case scenario drill were located in the safe zones for resident safety and supervision. The longer hallway was divided into two sections shown on the floorplan in Figure 9. Residents on one half of the wing were evacuated to Stairwell 1 and residents from the other side were evacuated to Stairwell 2. The residents and staff were informed in advance of the date and time the fire drill would occur.



(a)



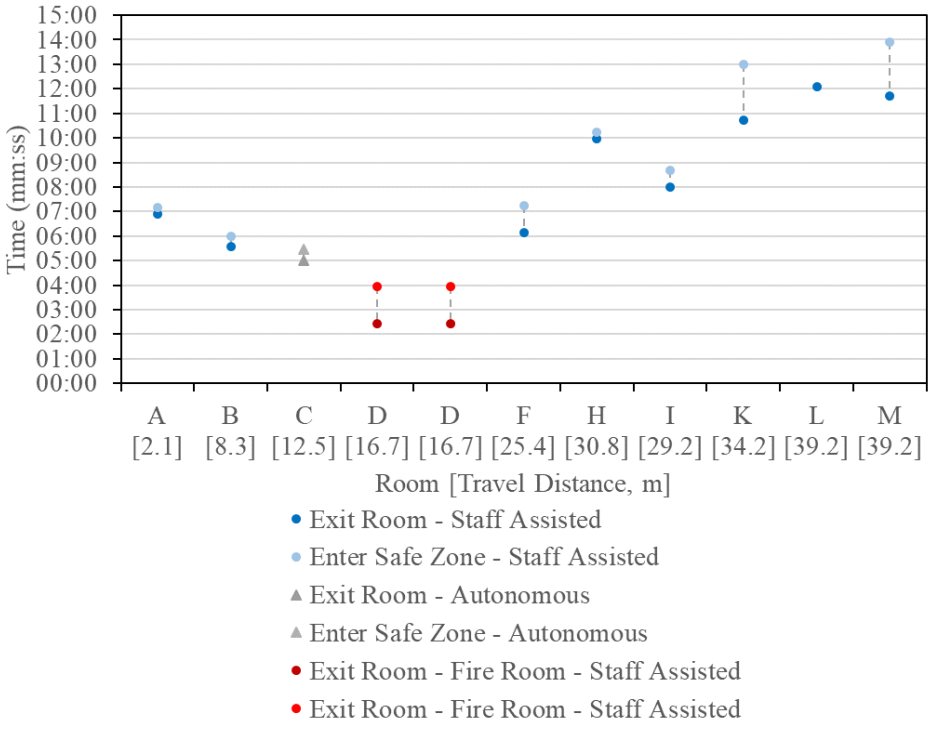
(b)

Figure 9. Drill 7 (a) Evacuation Time line (b) Floor plan.

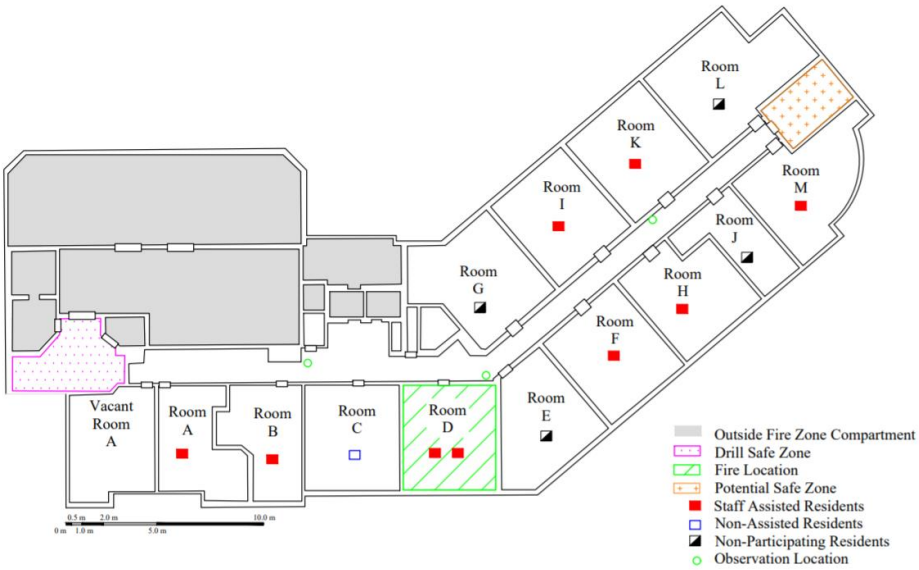
The alarm was sounded for 5 minutes at the start of the drill, then was silenced as to not disturb the rest of the building and occupants. The fire alarm was first sent to the responding nurses' communication phones, which they responded to before the audible alarm was heard by the fire marshal or observers. The evacuation followed the critical triangle method. The resident in the fire room required staff assistance and was observed to have exited the room at 0:32, pushed in a wheelchair by the staff member, and then entered the safe zone at 0:49. Two ambulatory residents evacuated on their own once the audible alarm began. Most other residents evacuated when instructed by the staff member, but some were confused about the procedure. Those residents exited their room and sat on their walkers, awaiting staff assistance to the safe zone. One room housed a married couple in which the spouse would not leave without the other resident who insisted they finish showering before evacuating. The second staff member, who had attended the fire command center, entered the fire drill wing at 4:05. Occupied and vacant rooms underwent two checks before an "All Clear" marker was placed on the door handle, indicating the room was empty. There was one wheelchair-bound resident who independently initiated evacuation once the alarm sounded but was not observed to have entered the safe zone and was later seen re-entering the floor via elevators. The drill ended at 14:28. A key finding was that although this drill occurred on an independent care floor, a majority of residents still required verbal cues from staff to initiate evacuation and some even thought it was the staff's responsibility to guide each resident to the safe zone. This highlighted the important leadership role of staff in these establishments even if the residents were perceived as independent.

4.2.8 Drill 8 (Retirement Home – Night time working shift)

The eighth observed drill was held on an assisted living floor that was not secured; it had two wings separated by a fire door to create compartmentation shown in Figure 10. As this was an annual worst-case scenario drill, the staff of the building were notified of the fire drill details in advance while the residents were notified of the date but not the time that the drill would occur. The researchers had been told that 17 residents would be participating in the drill, however, on the day of the drill they were informed that only 14 would be participating. Of these 14 residents, four did not end up evacuating during the drill (two refused to evacuate and two were told by staff that they did not have to evacuate) and therefore data was collected for 10 residents. Three on-duty night staff were in charge of evacuating the residents. Additionally, four observing administrative staff, two maintenance staff and two fire marshals were also in attendance on the fire floor along with the three research observers and the two drill coordinators. The floor was separated into two fire safety zones by a fire door to which the residents were evacuated past into the safe zone following the critical triangle method.



(a)



(b)

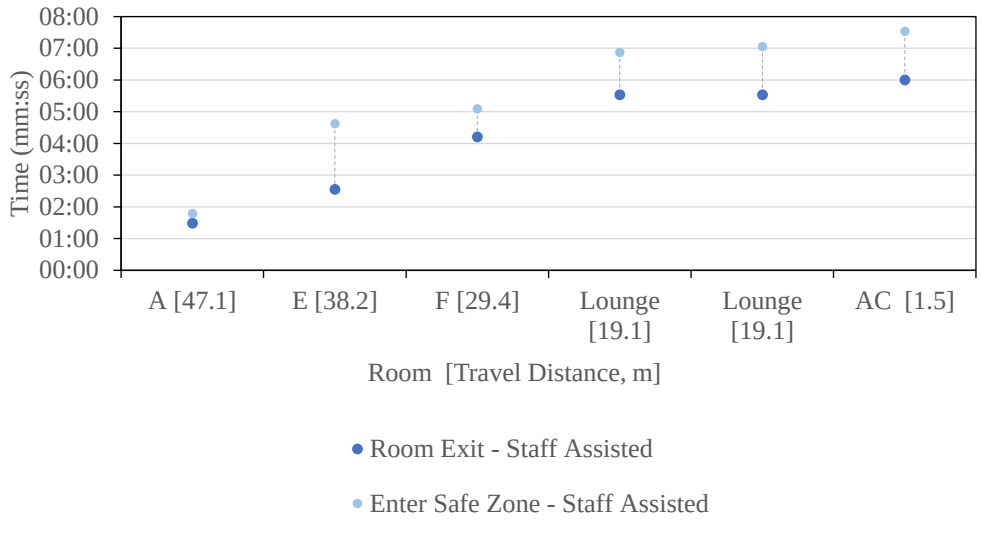
Figure 10. Drill 8 (a) evacuation Timeline (b) Floorplan

On arrival, staff members were overheard discussing the proper procedures for the drill. This was a silent drill therefore the fire marshal indicated the start of the drill. One staff member

was required to go to the fire control center to discover where the fire was located while the other two entered the fire wing and awaited the fire location. Once the location was known, the first staff member evacuated the fire room while the second staff member began notifying the resident in the adjacent room of the evacuation. The residents occupying the fire room were confused and exited the room at 2:25 and then entered the safe zone at 3:57. A resident who did not require assistance other than a verbal cue then evacuated to the safe zone. The third staff member re-entered the wing almost 8 minutes after the drill started. For both occupied and vacant rooms, one check was conducted before the room was declared empty of residents and a marker was hung on the door. One staff member was repeatedly reminded to properly close the door after exiting the room with a resident or after the check. The second staff member encountered two non-participating residents and instructed a third resident that participation was not necessary. This staff member then proceeded to jog with said resident's walker to the safe zone in an attempt to emulate the evacuation actions. At 11:30, visitors entered the fire drill zone via elevators and stood in the lobby area. The fire marshal did not require staff to evacuate a wheelchair-dependent resident to the safe zone if it caused undue stress to the resident. The last resident who entered the safe zone did so at 13:55 and the drill was deemed complete soon after. In the post-drill discussion, the fire marshals emphasized that the building was sprinklered and had compartmentation therefore firefighting actions by staff were not required.

4.2.9 Drill 9 (Retirement Home – Night time working shift)

Having just recently opened, this home had been receiving occupants two months before the fire drill was observed and had approximately 50% occupant capacity at the time of observation. This was the first annual fire marshal-attended drill the retirement home underwent with resident participation. This included three on-duty staff, four staff stand-ins and six residents on a secure memory care floor which required a pass code to exit into the stairwells, one of which was used as the safe zone. The floor had 33 rooms; only ten were occupied, as shown in Figure 11. Some residents were notified in advance of the drill and were moved to alternate floors. Staff stand-ins were put in their place with the respective mobility assistance devices.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Time (mm:ss)
A [47.1]
E [38.2]
F [29.4]
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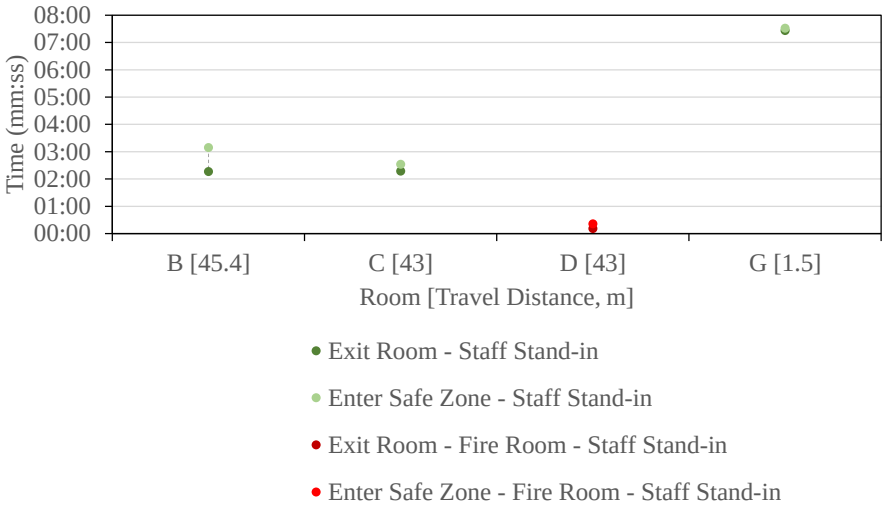
Lounge [19.1]
AC [1.5]
Room [Travel Distance, m]
Room Exit - Staff Assisted
Enter Safe Zone - Staff Assisted

(a)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Time (mm:ss)
B [45.4]
C [43]
D [43]
G [1.5]
Room [Travel Distance, m]
Exit Room - Staff Stand-in
Enter Safe Zone - Staff Stand-in
Exit Room - Fire Room - Staff Stand-in
Enter Safe Zone - Fire Room - Staff Stand-in

(b)

(c)

Figure 11. Drill 9 (a) Evacuation Timeline – Residents (b) Evacuation Timeline – Staff Stand-ins (c) Floorplan

This was a silent drill where no audible alarms were used, but the staff went through the motions of going to the fire command center (located at the Nurse's Office on the same floor) and using the mobile communication phones to relay the location of the fire. The fire room had a staff stand-in using a walker and was evacuated by staff at 0:21, entering the safe zone at 1:43. The second staff member began evacuating residents 59 seconds after the drill began. The third staff member realized they were supposed start the drill on a different level and went into the elevator lobby, then "re-entered" the fire wing at 1:19. The staff followed the critical triangle evacuation procedure similar to previous drills. A couple of residents were in the communal lounge area at the time of the drill and exited the lounge at 5:32, entering the safe zone at 6:52 and 7:03. All residents required staff guidance from their initial locations to the safe zone. All the rooms were checked twice before an Evacucheck marker was flipped up, indicating that the room was cleared. The last resident was evacuated from their room and

exited the wing at 7:32. The drill ended soon after, at 7:38. Observers noted issues with the room doors not fully closing and the lack of fire separation doors on all floors of the building. In the post-drill discussion, the fire marshal suggested that the residents in the fire wing should be evacuated but residents from the rest of the building could stay in place due to the building's compartmentation design. This highlighted the reliance on compartmentation from the building design for the fire safety plan.

5.0 Discussion

5.1 Observed Trends in Behaviour and Actions

Through the observation of the nine fire drills discussed above, several similarities and differences in resident and staff actions and behaviours were identified. A high level of staff dependence was observed. Table 5 provides the types of staff actions and behaviours observed as well as their frequency and probability of occurrence based on those observed and subject to limitation (see Section 5.3). For consistency, only the actions of the staff members who were the primary focus of the observers are included. Drill 1 was excluded as the recorded actions were not associated with specific staff members and therefore could not be tallied. Table 5 shows there are several actions that were observed in multiple drills and by numerous staff members. Examples include entering the fire wing, locating/entering the fire room, checking rooms for residents and guiding residents to the safe zone. The observed actions were influenced by the type of drill being observed and in part due to the requirements of relevant legislation. For example, the number of staff members who evacuated residents was quite low in the first four drills (all monthly drills), especially compared to the percentage of overall staff participating in the drill. This is likely a reflection of the fact that during these drills the staff are not required to evacuate residents. While they are supposed to evacuate residents who are willing and able to participate, it was seen that this was not often done, be it for reasons of not disturbing the residents or because the staff were unaware that they were supposed to. As the staff during the worst-case scenario drills knew the location of the fire room prior to the drill, they were not observed spending time looking for the fire while the staff in the monthly drills generally did. It is also important to note that while Table 5 groups the observed actions into categories and appears to follow a linear progression from drill start to drill end, there is evidence of observed actions occurring multiple times at various times during the drills. For example, staff seeking information from each other occurred at various times throughout the drills.

Less data was collected for residents as they did not egress independently for most instances and focus was instead on staff interactions. Some observations included residents seeking information by coming to stand at their doors prior to being evacuated, residents waiting for other residents before evacuating (e.g., couple), finishing tasks (e.g., showering), bringing belongings with them (e.g., tea), and hiding. The action of hiding requires more careful study to allow design to account for this in the future. It was also observed that many residents, even

those in retirement homes where nursing care is not provided, required assistance to evacuate (40 of the 56 residents who were recorded). In some cases, this meant that the staff had to guide and walk with them to the safe zone. In other cases, this meant verbally prompting residents who were waiting at their bedroom doors. In both cases, the staff had a large impact on the evacuation of residents as the worst total egress times seemed to be most affected by low staff and high proportions of residents as per Table 4. For each drill the number of residents is low, and in some cases staff stand-ins were present limiting the quantifiable value of the drills. Further limitations of this data are articulated within Section 5.3 of this paper.

5.2 Evacuation Timeline and Order

Figures 7 – 11 show the observed room exit and safe zone entrance times, as well as the distance travelled (only to a point of safety, not the entire building) for participants in Drills 5 through 9. Given the high dependency on staff, the pre-evacuation times were largely determined by when a staff member assisted or prompted a resident to evacuate. Staff acting as Stand-ins for residents are presented in separate figures (7-11) where data is available (figures 8 and 11), as they were not credible movement profiles that represent residents, but are still important to include for the purposes of recounting the actions and workload of the assisting staff and to illustrate that they have limited credibility in their use for training in real drills illustrating faster movement speeds than the aging population data. These figures show a general trend of evacuating residents based on their proximity to the fire room, which was in line with the critical triangle method and evacuation strategy mentioned earlier. The variation in time spent between exiting a room and entering the safe zone is also clearly visible in the graphed data. It is important to note, however, that this does not always correspond to the movement time and speed of an evacuee. As was observed during Drill 7 and can be seen depicted in Figure 9, a number of residents exited their rooms independently or with prompting and then remained in the hallway outside of their rooms until they were prompted again or guided to the safe zone by a staff member. It is therefore important to make sure that when using data from a fire drill it is clear whether or not this is represented in the data. True autonomous behaviour is a very gray concept when considering elderly populations. Figures 7 –11 show residents who required a staff member to walk with them to the safe zone (this was defined as staff-assisted for this study) and residents who reacted and evacuated entirely on their own or required only verbal prompting (defined as autonomous herein). The residents were classified this way to be able to see potential differences in the time spent walking from a resident room to the safe zone. This classification is useful for recording movement times (and therefore “agent” speeds when geometry is considered); however, it does not articulate the number of residents who relied upon any form of interaction with staff – which will also be important in modelling. In that case, the number of staff-assisted residents would be higher.

Figure 12 illustrates pre-movement times of residents and residents with staff only. It does not include staff stand-in values. Table 6 and Figure 12 are provided with specific limitation, in that:

they implicitly include the movement of staff with residents; building geometry is not included; and that they are only based on collected resident data which is of low sample number. In all but two drills, staff were always present when the drill began. The latest time for the first staff member to enter the fire wing was 0:24. This tabulated information, based on drills with resident engagement may be useful in table form for practitioners developing preliminary models or algorithms but additional data should be collected (see Section 5.4) prior to use. The measured average speeds (only for residents or residents being assisted – we have not computed speed values for staff stand ins as the data would not be appropriate to be mixed – inclusion would result in a higher movement speed) recorded in the drills (which reflect changes in speeds due to acceleration/deceleration based on measured linear distance from the floor plans and time door to door as taken at the drills) were derived as follows based 56 data sets of resident and assisted resident distance and time data: Average 0.33 m/s, minimum 0.02 m/s, maximum 1.81 m/s, mean 0.3 m/s. This movement profile is subjected to additional limitations which are described in detail within Section 5.3. The authors caution that these data sets do not include anthropometric aspects of movements which should also be studied in a more holistic data collection and modelling study, but these current values do provide practitioners a valuable data set that can be utilised in conjunction with preliminary modelling of care and retirement homes. Subsequently we have limited the scope of this profile generation as it is in need of additional building particularly as it implicitly includes the assistance and non-assisted residents in its calculation. The manuscript does provide the requisite information for practitioners to build preliminary models with exact data given for each resident as well as exact measured floor plans with travel distances noted that can be incorporated into a preliminary model. The quantifiable data is conservative in that the speeds are generally slower than those reported in existing literature for non-autonomous movements such as the SFPE handbook. While limited in value, this data yields a starting point for comparison in future studies and for specific modelling development of case specific movement scenarios or algorithm development (assisted movement for example). Preliminary models may also be commenced focusing on programming behavioural actions as observed. The authors plan future work to study the generation of appropriate models. Figure 12 provides the reader with a visualization of the evacuation timeline of Drill 5 through 9, though inherently does not include the effect of differences in architecture between each drill in different buildings which would be used for travel velocities it is also based on low participation in the drill and limited by low recorded data where some residents were not recorded.

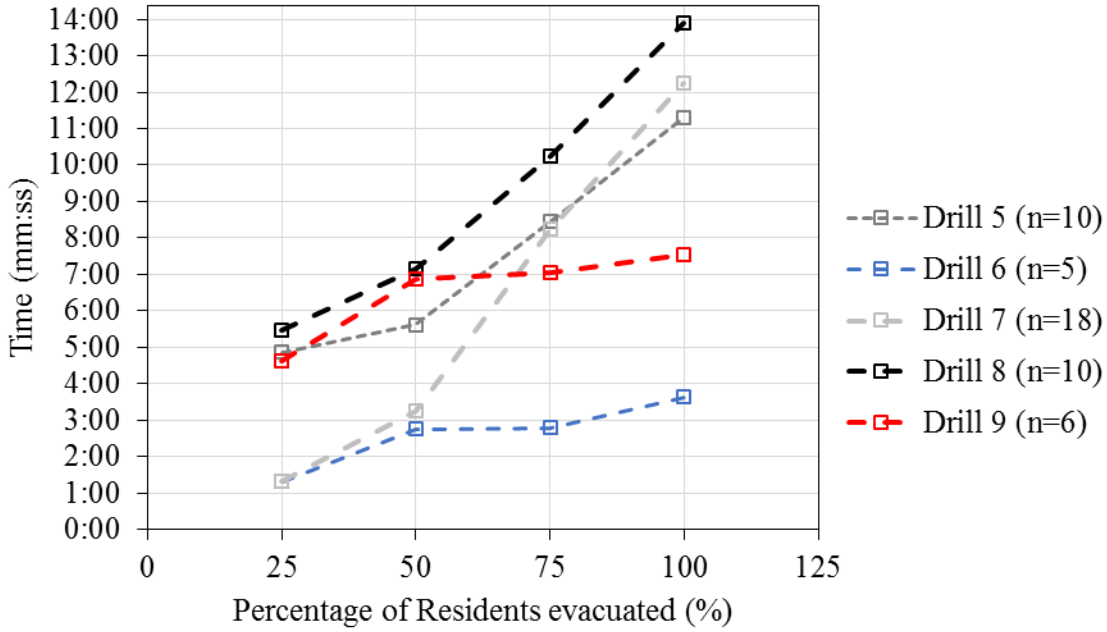

Figure 12: Evacuation Profile assuming implicit staff and resident behaviour (see Table 6 and Section 5.3 for limitations)

5.3 Limitations for Using Fire Drill and Movement Data

It is evident in looking at these drills that there are numerous modifications that are made (intentionally or unintentionally) during a drill that would not be possible given an actual fire event. In some drills, more staff were noted to have played a role in the drill than were supposed to. These staff were observed closing doors to resident rooms, tagging doors and supervising residents in the safe zone. In reality, during the night shift which these drills were supposed to be simulating, these additional staff would not be present to assist. While it is understandable why these staff would be present during a drill for additional resident safety, it is not representative of a real fire. During such an event, the on-duty staff would be responsible for evacuating the residents as well as monitoring them within the safe zone. Additionally, the impact to pre-evacuation and preparation times, as well as the potential increase in resident resistance to evacuation as a result of being woken up and potentially wanting to get dressed or gather belongings, is not represented in these worst-case scenario drills.

Another trend that was seen during all but one of the observed fire drills was that of residents evacuating (either assisted or autonomous) to only one safe zone, regardless of their proximity to the second (typically the stairwell). While it makes sense why this would be done for ease and convenience during a simulation, given the mobility and mental state of many residents (e.g., having residents wait in a hallway is easier and more practical than a stairwell), it is not

representative of all of the safe zones that residents would be evacuated to in an actual fire. Often not all residents were evacuated, even during worst-case scenario drills. In the observed monthly drills (Drills 1-4), it was seen that very few residents were evacuated at all. In the later drills where more residents did participate, staff stand-ins generally took the place of residents who would have greater difficulty evacuating (uncooperative, reduced mobility, etc.). As was seen in Drill 8, a staff member jogged from a resident room to the safe zone with a walker, "simulating" the evacuation of that resident. Given the mobility impairment of this resident, this was not an accurate representation of the resident's evacuation. These resident exemptions or replacements not only affect the time required to complete the drill (pre-evacuation time, walking speed) but also have a large impact on the realism of the drill. It is understandable why LTC and retirement homes do this, to better ensure the immediate safety of their residents and staff as well as reduce the level of disruption caused to both. However, this does have an impact on the credibility of potential data and the use of these drills for training and evaluation of staff in such homes.

The roles played by the drill coordinators and fire marshals present during the drills were also seen to impact the drills. During the worst-case scenario drills, the observing fire marshals and/or drill coordinators were observed to interact with or prompt the participating staff members. This ranged from telling staff that they should be tagging the evacuated rooms to telling staff that they did not have to evacuate residents to the safe zone, as was seen in Drill 8. In this specific case, the fire marshal said that the only important time that the staff were being evaluated on was the time required to prepare the residents and bring them into the wing hallway (not take them to the safe zone). This information not only impacted the subsequent actions of the staff who then did not finish evacuating a resident (therefore impacting the accuracy of the drill's representation of a "real" fire event), it also contradicted what had been observed during the other worst-case scenario drills. In most of the post-drill discussions with the staff, the fire marshals and/or the drill coordinators commented on the impact of fire compartmentalization and sprinklers, stating that in the case of a fire, the staff would have plenty of time based upon the fire rating of the structure (door rating for example) to evacuate residents. In relation to this, no comment about the impact of smoke on tenability in relation to the safe egress time, nor difference in real to standard fire was discussed. The impact of staff and resident actions, such as doors being left open or the fire room being entered multiple times, are not made clearly apparent.

Looking specifically at the considerations warranted by the differences between the earlier and later drills observed in this study, it can be seen that each have advantages and disadvantages. The first four drills in this study were largely influenced by their type (monthly drills not requiring resident participation) and the residence type (long term care homes where residents were highly dependent on staff). In the case of these four drills in this study, the observation style also had an impact (focused on general observations, less on evacuation timestamps). These four observed drills did not provide the type of data that could easily be incorporated

into an egress model (pre-evacuation times, walking speeds, etc.). However, they did serve to provide an understanding of general fire evacuation procedures in these homes. Additionally, as the staff and residents were not informed of the drill prior to it occurring, the initial response to the alarm reflects more closely their response to an actual fire. This realism can fade once the drill coordinator and observers were observed and no fire or smoke is found.

Drills 5 through 9 in this study have their own set of opportunities and challenges that need to be understood when looking to use the collected data. Primarily they showed low overall participation by the residents. While there were some autonomous resident evacuations observed, staff verbally prompting residents to evacuate or physically preparing them for evacuation and walking with them to the safe zone was a very prominent occurrence. This showed that even in retirement homes where residents do not require the same level of daily care as in LTC homes, staff still play an important role in fire evacuations. This information is valuable for models as it shows the importance of modelling the impact of staff and it provides examples of times associated with different staff actions. With respect to the general limitations of annual, fire marshal-observed, worst-case scenario drills, there are a couple key considerations. The staff who will be participating in the drill are aware of the drill before it happens. As these drills are being used for official evaluation by the fire department/province, the homes are also allowed to "practice" the drill before it is observed. While this is beneficial in that it ensures that staff (and potentially residents) are better prepared should a real fire occur, it reduces the realism of the drill (showing the conflict of using drills as training and evaluation tools). Staff stand-ins also affect the realism of the drill, given that they will not react or move in the same way as actual residents – for this reason we do not consider this data within the calculation of any movement profile in this paper.

5.4 Future Work

Research into fire evacuations in LTC and retirement homes, and the inclusion of human behaviour in fire into egress models in general, needs to continue so as to further develop models that are more representative of actual evacuations. The use of the Protective Action Decision Model (PADM) developed by Lindell and Perry holds great potential for being used to create a conceptual model of human behaviour based on data such as that collected in this study.[24,25] The PADM shows the process of decision making during emergencies, describing the steps and factors that influence the adoption of protective actions (in the case of a building fire, evacuating or seeking refuge for example).[25,26] Such a conceptual model could then be used to support the creation of computational models for use within egress software, therefore creating more accurate and realistic models of evacuations of the built environment.

Validated and verifiable models can be explored with the pre-movement and movement data herein with limitation as noted in Section 5.3. Figure floorplans can be scaled appropriately and built with incorporation of the incorporating the movement (pre-movement and movement) profiles derived from the data collected. As sample numbers are low, the authors suggest that

prior to detailed modelling studies that additional data be collected where anthropometric data is also collected.

These models must also begin to incorporate the impact of toxicity and smoke as it has been shown to have a large impact on evacuees.[27] The presence of smoke can not only affect visibility, but also response time and movement speed.[28] Our understanding of toxicity and smoke plays a role in building compartmentalization, which, as seen in this study, is very much relied upon in residences such as LTC and retirement homes. Some studies have also shown that certain health conditions, such as cardiovascular disease, can impact one's susceptibility to smoke.[29] This may therefore have a great impact on residents of LTC and retirement homes and should be studied further.

6.0 Conclusion

This study of nine drills in Canadian LTC and retirement homes has shown that valuable data can be collected from the observation of fire drills. Information about residents, the interactions between staff and residents, the type of actions that are undertaken by staff during the evacuation process and the general procedures that are followed was collected. This information provides a better understanding of evacuations in such care homes and acts as a source of data that can be used to help inform egress modelling software. These drills demonstrated that emergency egress in long term care and retirement homes is highly staff dependent with over 72% of residents requiring full assistance in evacuation.

This study has also shown that there are a number of important considerations that must be made when choosing to conduct this type of data collection or when using data collected by such means. The use of in-person observation and written note-taking can be used in cases where cameras are not welcomed or allowed. When specific observation objectives are defined, and the observers can focus on specific staff and/or resident participants, valuable data can be collected from places that would otherwise not have allowed researchers access. However, if the scope of information sought is too broad or the situation overwhelms the observation and recording capacities of the observers, the completeness of the data collected can be reduced.

The critical point of this methodology is its ethics implications; residents in care homes like these may have conditions such as dementia, which can make it difficult for them to consent to being included in the datasets via other methodologies such as video recording. The methodology herein tailors to how similar and future studies may be conducted within restricted research environments , however; also notes the various caveats which can influence the usefulness of the data that would be collected.

It is easy to see that data from actual fire events would provide the most accurate data, and that collecting data from such events is important in further developing our understanding of human behaviour during such events. However, this data can be very difficult to come by. Over

the course of this study, the researchers made continual efforts to reach out to the owners of local LTC and retirement homes that had experienced real fires in recent years for camera based and real event data. To date, all of these invitations have gone unanswered. Given the difficulty of being able to access such data, fire drills pose a more readily available source of evacuee behaviour information of vulnerable populations. Through drill observation, important information about the behaviours and actions exhibited by staff and residents in care homes and the procedures that are supposed to be followed during fires can be obtained.

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