Housing evacuation of mixed abilities occupants

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Housing Evacuation of Mixed Abilities Occupants

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EXECUTIVE SUMMARY

A joint research project was undertaken by the National Research Council of Canada (NRCC) and Canada Mortgage and Housing Corporation (CMHC) to study evacuation drills in mid-rise apartment buildings with mixed abilities occupants. The study collected real data on time and movement during evacuation drills in four buildings. The buildings involved were located in Ottawa, Montreal, Toronto and Vancouver. These different locations reflected provincial variations in fire safety procedures. Each fire drill was organized, supervised and carried out with the full participation of the local fire department.

Before each evacuation drill, NRCC staff met with the residents identified as having some limitations to discuss their knowledge of the building evacuation procedures and their ability, or inability, to participate in the drill. The initial goal of these meetings was to better prepare for the drill and to inform the fire department of problems that could occur during the exercise. These meetings, however, became information sessions to reassure occupants about the drill. Many older residents and people with disabilities wondered if the firefighters would carry them down the stairs or down a ladder. These occupants then received further explanation as to how the firefighters would perform the horizontal evacuation. One week before each drill, all occupants were informed in writing of the evacuation drill. The message, distributed to each door, did not specify the exact day or time of the evacuation drill, however, it highlighted the importance of the exercise and described the participation of NRCC, CMHC and the local fire department. It specified that researchers would observe the drill and that video cameras, positioned in hallways and staircases, would record the drill.

Each drill took place on a weekday between 6:45 P.M. and 7:30 P.M. in order to have the largest possible number of occupants at home, yet before bedtime for most people. The evacuation drills were carried out during the summer and early fall of 1993; for each evacuation, the weather was sunny and warm. During each drill, data were gathered concerning the following: the time to respond to the alarm, the understanding of voice communication instructions (if present), the direction of movement, the time for all occupants (including disabled persons and elderly) to reach a safe area, the overall evacuation behaviour of disabled persons as well as other occupants, and the time to totally evacuate the building. The data collected, using video cameras, recorded the location, time and frequency of movements, from which various statistical calculations were performed. During the evacuation drill, the research team remained outside the building in such a way as to not interfere with either the building occupants or the firefighters.

Firefighters arriving at the scene followed their usual procedures and participated in the evacuation of occupants. People with limited mobility were moved horizontally by firefighters to a safe area. Mobile occupants, still in the building, were asked to leave by the nearest exit. When the firefighters judged that the situation was satisfactory, the Captain gave the "all clear", the alarms were reset and occupants went back to their apartments.

After the evacuation drill, a questionnaire was distributed to each apartment. Occupants were asked if they had heard the fire alarm and the P.A. messages; interviewees were also asked to list the chronology of their actions and describe their evacuation movements.

A series of statistical analyses was conducted on the data gathered using the video cameras. The time to start the evacuation, to move to safety and to totally evacuate the

building were studied. Analysis of variance was used to compare buildings and to assess the impact of gender, age and physical limitation. The speed of movement on stairs was also analyzed.

Results show that the time to start the evacuation is highly dependent on the ability of occupants to hear the alarm. The time to move to safety appears similar for buildings of comparable architectural design, while the overall evacuation time is dependent on the time at which occupants start to evacuate. In two of the buildings studied, some occupants could not hear the fire alarm in their apartments. Consequently, these occupants started their evacuation only when the arriving firefighters knocked on their doors, providing a mean time to start the evacuation of 9:02 min for these two buildings and a total time to evacuate the building of 25 min. The other two buildings, where the alarm was audible to most occupants, provided a mean time to start the evacuation of 2:49 min, and of 13 min to totally evacuate the building. Questionnaires showed that the time delay before leaving their apartments was used by the occupants to get dressed, gather valuables, find children or find pets. In buildings where a longer time to start was observed, there was, consequently, a longer time to totally evacuate the building.

The characteristics of gender, age and limitations presented little impact on the timing and movement during evacuations. Some older occupants tended to move slower on stairs than other adults. Such occupants, however, did not impede the evacuation of others since the hallways and staircases were never crowded and faster occupants were able to overtake slower ones. Occupants with serious mobility limitations also did not impede the evacuation of others since they usually stayed in their apartments to be rescued by firefighters.

Occupants in three of the four buildings showed a comparable mean speed on the stairs. Among all occupants, they travelled between .41 m/s and .47 m/s on non-crowded stairs. Gender did not play a role in the differences in speed while evacuating the buildings. Those over 65 travelled significantly slower than younger people during the evacuations. Children aged 2 to 5 were also significantly slower; going down the stairs one step at a time, holding the handrail at a height over their shoulder.

Most occupants tended to evacuate in groups. The majority of these groups were couples. Children, for the most part, evacuated in groups which included an adult. These group formations likely delayed the speed of movement of the whole group because members tended to assume the speed of the slowest person. In most cases, the slowest person was a young child or an elderly person. Older occupants also tended to stop to converse rather than maintain the same speed during the evacuation. Occupants tended to use either the most central staircase, located in their familiar path of travel to exit the building, or a staircase that led to a familiar area, such as the main entrance, rather than a staircase close to their apartments.

Recommendations are made regarding the audibility of alarms. Such alarms should be tested to make sure every occupant can hear it from every area of the building. Compensatory alarm systems should be provided for occupants with hearing limitations. All occupants with some limitation should be informed of the emergency procedures and what is expected from them in case of a fire emergency. Training should be provided through annual evacuation drills, to ensure that every occupant recognizes the fire alarm, knows the different means of egress, and understands the general fire evacuation procedures. These measures will improve fire safety for residents of mid-rise apartment buildings with mixed abilities occupants.

1.0 INTRODUCTION

The 1991 National Census of Population in Canada showed that 4.2 million Canadians reported some level of disability [1]. This number represents 15.5% of the total population. Among all people with disabilities, 93.7% are living in private households while 6.3% are living in special institutions. Within the group of people with disabilities between the ages of 15 and 64, 97.9% are living in private households.

Canada is also experiencing an increase in the number of people over the age of 65. The proportion of such elderly people has risen from 10.7% of the total population in 1986 to 11.8% in 1992. Over one-third of these elderly people are living in private households.

Clearly most disabled people and many people over the age of 65 are living in standard types of housing in Canada. Consequently, it could be expected that approximately 20% of the residents in standard housing are people with some sort of limitation on movement, perception or cognitive capacity.

In the last decade, there has been great concern with regard to providing accessibility for most people to a large range of buildings. The housing sector was one area where the need for accessibility was acknowledged and where a serious attempt to provide accessibility has been observed. Several agencies in Canada, such as the Canada Mortgage and Housing Corporation, have strongly encouraged the creation of accessible housing throughout the country. More and more apartment blocks now contain accessible entrances or ramps. Most buildings have accessible elevators and, occasionally, a few units are specially designed to accommodate occupants with disabilities.

Due to economics and the growing number of people with limitations, it would be unrealistic, in the near future, to expect the construction of only new specialized buildings where people with disabilities can reside. Furthermore, most people with disabilities and the elderly are determined to stay autonomous and live as long as possible in standard types of housing. It is not surprising, therefore, that more and more housing projects contain occupants with mixed abilities. Mixed abilities occupancy implies that residents are a mix of family groups, elderly people and people presenting some level of disability or limitation.

While accessibility is offered in more housing projects, the question of egressibility is now becoming a subject of concern. Egressibility can be defined as the possibility of leaving a building or reaching an area of safety in case of an emergency such as a fire. The egressibility concept does not mean that every occupant should egress in the same fashion or through the same route; rather, it intends to promote equivalent opportunity of life safety for everyone [2].

At the National Research Council of Canada, researchers in the National Fire Laboratory of the Institute for Construction (IRC) are developing a Fire Risk Evaluation and Cost Assessment Model (FIRECAM), which is a tool to assess the relative fire safety of building designs for all people. To account for possible increases in evacuation times as a result of the presence of people with disabilities and elderly people, data are needed on such users' evacuation timing and movement. It has previously been assumed that the presence of people with mixed abilities will increase egress time, however, no quantitative data exist to determine the overall change in fire safety resulting from evacuations involving such user groups.

The increasing tendency to find occupants with mixed abilities in standard housing raises new issues regarding life safety. This is the reason why the National Research Council of Canada (NRCC) and the Canada Mortgage and Housing Corporation (CMHC) undertook this joint research project to study evacuation drills in mid-rise apartment buildings with mixed abilities occupants.

2.0 OBJECTIVES

The general objective of this project was to collect real data on evacuation times and the movement of occupants in apartment buildings. Further, it was important to observe the impact of occupants with mixed abilities on the overall building evacuation. The study also took into account the fire department strategies, the evacuation procedures and the building design in assessing the evacuation.

It is important to understand that the goal of the research was not only to study the evacuation of disabled persons, but to gather data on the time and the manner in which occupants with mixed abilities leave their apartment buildings. The research, thus, aims at improving fire safety for all occupants of a building.

The benefits for the occupants and for society in general are the development of evacuation procedures that take into account the reality of people with mixed abilities. More realistic procedures regarding, for example, the time required for the evacuation of such a building, may enable the fire department to be better prepared and potentially save lives. Problems associated with evacuation must also be identified to help develop design and architecture solutions that increase safety for all concerned.

The results of this research will no doubt be included, along with results of other projects, in updates to fire safety regulations and in the National Building Code of Canada. The results will also be used in the computerized Fire Risk-Cost Assessment Model (FIRECAM), currently being developed by NRCC's National Fire Laboratory.

3.0 GENERAL METHODOLOGY

The research involves collecting real data on evacuation time and movements by occupants of apartment buildings. The buildings chosen for this project are mixed-occupancy buildings, i.e., they include families, seniors and people with physical limitations or handicaps.

The buildings selected for this research were identified by CMHC who obtained permission from the owners so that IRC could observe a fire drill. The buildings selected met the following two criteria: 1) 4 to 10 storeys with elevators, 2) mixed-occupancy, i.e., a minimum of 20% of occupants having limitations, in order to reflect Statistics Canada's 1991 census results. The mid-rise buildings chosen each had about 100 apartments, with 1 to 4 persons per apartment. As specified in all fire safety procedures, the drill assumes that all occupants leave the building or reach an area of refuge, which means the movement of approximately 200 people for each exercise.

The project involved four buildings, one in Ottawa, one in Montreal, one in North York (metro Toronto) and one in Vancouver. These different locations reflected some provincial variations in fire safety procedures. Each fire drill was organized, supervised and carried out with the participation of the local fire department.

Before each evacuation drill, the residents with some limitations were consulted to discuss their knowledge of the building evacuation procedures and their ability or lack thereof to participate in the drill. The initial goal of these meetings was to better prepare for the drill and to inform the fire department of problems that may occur during the exercise. However, these meetings rapidly became information sessions to reassure occupants about the drill. Many older residents or people with disabilities wondered if the firefighters would carry them down the stairs or down a ladder. These occupants received further explanations as to how the firefighters would perform the horizontal evacuation.

A week before the drill, all occupants were informed in writing of the evacuation drill. The memo was distributed to each door. The message did not specify the exact day and time of the evacuation drill, however, it highlighted the importance of the exercise and described the participation of NRCC, CMHC and the local fire department. It specified that researchers would observe the drill and that video cameras, positioned in some hallways and staircases, would record the drill. The name of the principal investigator and a phone number were included.

Each drill took place on a week day between 6:45 P.M. and 7:30 P.M. in order to have the largest possible number of occupants at home, yet before bedtime for most people. The evacuation drills were carried out during the summer and early fall of 1993; for each evacuation the weather was sunny and warm.

During each drill, data were gathered concerning the following: the time to respond to the alarm, the understanding of voice communication instructions (if present), the direction of movement, the time for all occupants (including disabled persons and elderly) to reach a safe area, the overall evacuation behaviour of disabled persons as well as other occupants, and the time to totally evacuate the building. The data collected through video cameras recorded the location, time and frequency of movements, from which various statistical calculations were performed. During the evacuation drill, the research team remained outside the building in such a way as to not interfere with either the building occupants or the firefighters.

Firefighters were on location throughout the drill. They were assessing the exercise and participating in the evacuation of occupants. People with limited mobility were moved horizontally by firefighters to a safe area. Mobile occupants still in the building were asked to leave by the nearest exit. When the firefighters judged that the situation was satisfactory, the Captain[1] gave the "all clear", alarms were reset and people went back to their apartments.

After the evacuation drill, a questionnaire was distributed to each unit. Occupants were asked if they had heard the fire alarm and the P.A. messages; interviewees had to list the chronology of their actions and describe their evacuation movements.

4.0 METHOD AND RESULTS FOR EACH BUILDING

Four mid-rise apartment buildings were studied. Although the four buildings present many similarities, it is important to look at each building individually.

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[1]The title of "Captain" is used in this report to identify the firefighter responsible for the evacuation on the site of the exercise although the real title of this person within the fire department might be different.

4.1 Building 1 – Ottawa

Building Description

The Ottawa building, or Building 1, is a 7-storey masonry building, built in 1983 and containing 88 units. Figure 1 shows a typical floor plan of the building. Two elevators are located at the centre of the building dividing the building into two wings; A and B. The building has four exits leading to the outside.

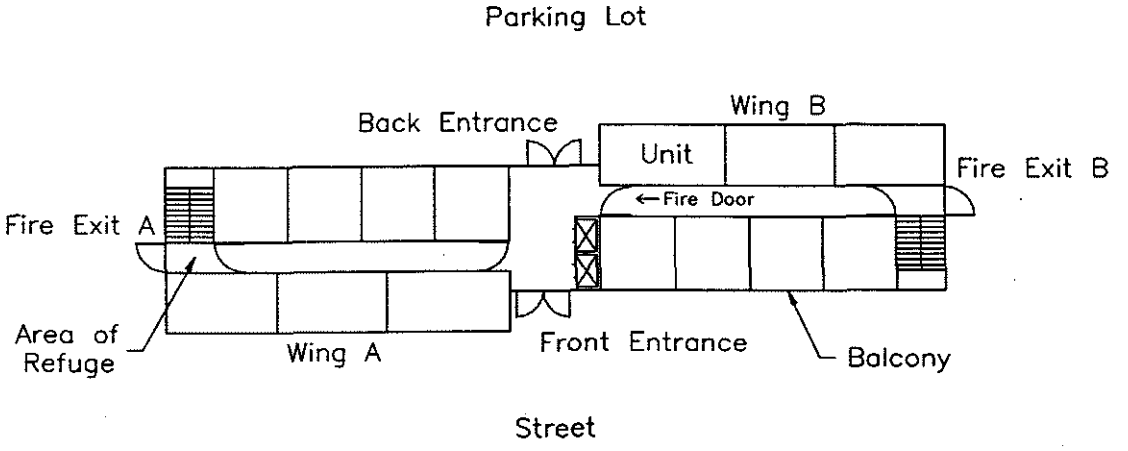

FIGURE 1: Plan of Building 1

The building is built on a slope (Figure 2) so that the Front Entrance is on the 2nd floor and the Back Entrance is on the 1st Floor. Fire Exit A is on the 1st floor and Fire Exit B is on the 2nd floor. Six units have patio-doors at ground level giving direct access to the outside. All units and areas of the building, such as the laundry room and the garbage chutes, are accessible to wheelchair users.

The building has two pressurized staircases located at the ends of the corridors. The staircases have, on the landing at each level, an area of refuge large enough to accommodate two wheelchairs. These staircases are rarely used since most people used the elevators on a daily basis. The building is equipped with a two-stage fire alarm system. This means that, upon activation of a manual pull station or a fire detector, an alert signal (intermittent rings) sounds throughout the building. The signal changes into a full fire alarm (non-stop ringing) after 5 minutes. Every unit has a fire alarm system speaker in the bedroom to enable every occupant to hear the alarm. The building is also equipped with a public address system that allows the firefighters or people in authority to convey messages to the occupants. The P.A. system is linked only to speakers located in the corridors and staircases and not to the units. Upon activation of the fire alarm, the two fire-doors, located on each floor between the corridors and the elevator lobby, close automatically thus creating separate compartments.

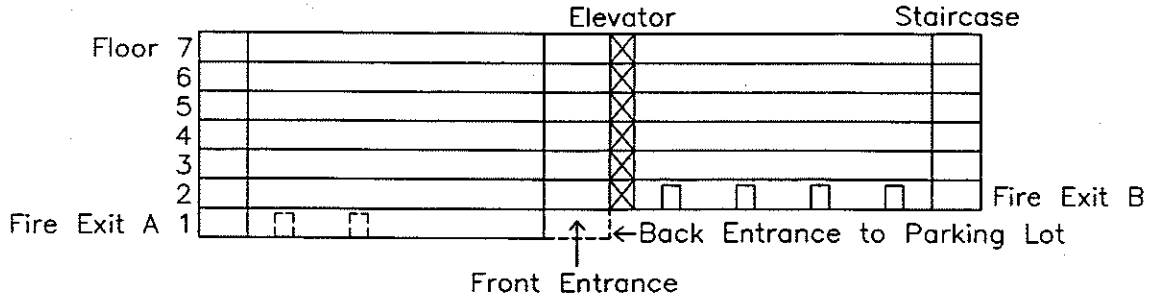

FIGURE 2: Elevation of Building 1

The fire alarm system is directly linked to the fire department which is located 1.5 km away. The fire alarm control panel is located in the entrance lobby of the Back Entrance. At the panel, the firefighters find the alarm control unit as well as a handset for the public address system, the master key for the building and the fire-list of people needing assistance to evacuate.

Building Occupants

At the time of the evacuation, there were130 residents living in the building of whom some 55 presented some limitations or disabilities. Nine of them were seniors, 25 were wheelchair users, and 21 were people with other disabilities. There were also 46 adults and 29 children ranging in age from infants to teenagers. It is important to mention that, at the time of the study, only 36 people were registered on the fire-list. This means that, among the 55 occupants that reported some limitations, 19 of them thought that they would have no problem evacuating by themselves, they refused to be listed, or they forgot to ask to be listed.

Procedure

As this building is a co-operative project, occupants were met at a general meeting a few weeks before the evacuation. The evacuation study was explained to the them and questions were answered by the principal investigator. Members voted unanimously to participate in the study.

All building occupants received a memo (Annex 1) in their mail-box telling them that an evacuation would be taking place in the coming weeks. The note also told them that video cameras would be positioned throughout the building to film the drill.

Most people who were on the fire-list were visited for an informal discussion that turned into an information session about fire safety at home and evacuation procedures. A resident on the 4th floor was instructed on pulling the alarm-bar at a pre-determined time when notified by the principal investigator.

To record the evacuation, 10 video cameras were positioned in the staircases and outside the building. The cameras were started before the beginning of the evacuation and were stopped after the drill was finished.

A fire scenario had been planned with the local fire department. A platoon of eight firefighters with two trucks were on location at the start of the evacuation. According to the scenario, the fire was located on the 4th floor in Wing-A. Four minutes after the fire

alarm activation, four firefighters proceeded to undertake a horizontal evacuation. This was meant to either move occupants with disabilities on Floors 4, 5, 6, and 7 towards Wing-B of the building (two compartments away from the fire location), to instruct people to leave the building, or to go to their balconies as a safe area. This kind of partial evacuation, involving the evacuation of the fire floor plus 2 or 3 floors above the fire floor is the usual procedure used by the Ottawa Fire Department for mid-rise buildings.

During the drill, the Captain who remained near the control unit, gave instructions to occupants over the public address system. He told the occupants where the incident was located and what occupants with disabilities were expected to do. Similar messages were used in previous evacuation studies [3]. When the firefighters judged that everyone had reached a safe location, they gave the "all clear" signal and the evacuation was over.

After the evacuation drill the post-evacuation questionnaire (Annex 2) was distributed to all units.

Results

The pre-evacuation meetings were held with 22 occupants, representing 61% of the occupants registered on the fire-list. Each person interviewed said that he/she had heard the fire alarm before and could recognize it immediately. All of these persons, except one, had been through the evacuation procedures before, due to either false alarms or drills. They all reported knowing what to do when the alarm sounded; that is to say, 8 people said they would stay in their unit and wait to be rescued, 9 would go to their balconies, 4 would go to the areas of refuge in the staircases, and 1 would go out directly through the patio-door. The interviews were good opportunities to reassure some occupants who were worried about the drill, as some were wondering if the firefighters would carry them down the stairs or down a ladder. These occupants received further explanations about horizontal evacuation, compartmentation and moving to a safe area.

A few occupants called the principal investigator because they were worried about their pets. Some were afraid that their dogs or cats would get over-agitated by the sound of the alarm bells, others were wondering if they should bring their birds outside. After discussion, it was agreed that dogs would be brought outside on leashes or otherwise left in the apartment.

The evacuation was carried out July 8, 1993. It was one of the warmest and most humid days of the summer (38°C). Upon activation of the alarm-bar at 19:07:11, by an occupant on the 4th floor, all the fire safety systems came into action immediately; the fire alarm sounded, the fire doors in the corridors closed automatically, the two elevators were recalled to the first floor, and the fans started for the staircase pressurization. Firefighters entered the building at 19:10:10.

The evacuation timing is presented in Table 1. The data have been analyzed to differentiate three times: a) the Time to Start, b) the Time to Exit, and c) the Time to Move. The Time to Start the evacuation is the elapsed time between the fire alarm sounding and the moment the person left his/her unit. The Time to Exit is the elapsed time from the fire alarm sounding and the time when the person crossed one of the outside 4 exits. Finally, the Time to Move is the time each person took to leave the building from the Time to Start, to the Time to Exit, without considering the distance travelled.

TABLE 1
Evacuation timing for Building 1

Time Intervals	Time to Start		Time to Exit		Time to Move	
	Frequency	%	Frequency	%	Frequency	%
0:00-1:00	11	26%	4	10%	30	77%
1:01-2:00	14	33%	14	33%	9	23%
2:01-3:00	7	17%	7	17%		
3:01-4:00	4	10%	8	19%		
4:01-5:00	3	7%	6	14%		
5:01-6:00	0	0%	0	0%		
6:01-7:00	1	2%	1	2%		
7:01-8:00	0	0%	0	0%		
8:01-9:00	0	0%	0	0%		
9:01-10:00	0	0%	0	0%		
10:01-11:00	1	2%	0	0%		
11:01-12:00	0	0%	1	2%		
12:01-13:00	0	0%	0	0%		
13:01-14:00	0	0%	0	0%		
14:01-15:00	1	2%	0	0%		
15:01-16:00	0	0%	1	2%		
Total	42	100%	42	100%	39	100%

Only 59 persons representing 45% of the residents participated in the evacuation drill. Although some people might have been away on holidays or not at home at the time, it was a low participation rate. It should be mentioned that this building has had an average of 12 false alarms per year, one occurring 2 months before the study. These false alarms seem to discourage participation. Also, there was a good number of people standing on their balconies throughout the evacuation, looking down at the action in the parking lot. According to some residents, the number of people who participated in the drill represented the average number of people that usually left the building when the fire alarm sounded on previous occasions.

As presented in Table 1, the Time to Start to evacuate, varied from the time the fire alarm sounded to over 14 minutes. It was of particular interest to further break down the Time to Start, as this gave a more detailed picture of the occupants who started within the first minutes. Close study of the videotapes show that the first person evacuating left between 0:31-0:45. This person, who left his unit at 0:34, was a visually-disabled person. Ten persons left between 0:46-1:00 minute. Table 2 presents the Time to Start, the Time to Exit, and the Time to Move, in increments of 15 seconds, for the first 5 minutes of the evacuation.

The Time to Exit varies from the first few seconds of the evacuation for the people located in the lobby to over 15 minutes after the alarm. Most people, representing 94% of the evacuees, had left the building during the first 5 minutes after the alarm. Due to the low occupant density in the building, there was no queuing to enter the staircase and no crowds in the stairs. Therefore, the Time to Exit was dependent only on the starting time, the speed of travel and the distance to travel.

TABLE 2
Movement for the first 5 minutes

Time Intervals	Time to Start		Time to Exit		Time to Move	
	Frequency	%	Frequency	%	Frequency	%
0:00-0:15	0	0%	0	0%	17	44%
0:16-0:30	0	0%	0	0%	0	0%
0:31-0:45	1	3%	0	0%	7	18%
0:46-1:00	10	26%	4	10%	6	15%
1:01-1:15	9	23%	4	10%	6	15%
1:16-1:30	2	5%	2	5%	1	3%
1:31-1:45	0	0%	4	10%	2	5%
1:46-2:00	3	8%	4	10%		
2:01-2:15	1	3%	4	10%		
2:16-2:30	1	3%	2	5%		
2:31-2:45	0	0%	0	0%		
2:46-3:00	5	13%	1	3%		
3:01-3:15	1	3%	2	5%		
3:16-3:30	3	8%	2	5%		
3:31-3:45	0	0%	2	5%		
3:46-4:00	0	0%	2	5%		
4:01:4:15	0	0%	2	5%		
4:16-4:30	0	0%	1	3%		
4:31-4:45	1	3%	1	3%		
4:46-5:00	2	5%	2	5%		
of all	93%		93%		100%	
Total	39	100%	39	100%	39	100%

The two Fire Exits and the Front and Back Entrances were not used equally. Fire Exit A accommodated 25% of the evacuees, Fire Exit B, 56%, the Front Entrance, 7% and the Back Entrance, 12%. Fire Exit B was favoured over Fire Exit A because, according to the scenario, the fire was on 4th floor-Wing A. Consequently, occupants were directed by the firefighters towards the other end of the building and to Fire Exit B. Only the people who were already in the front lobby left through the Front Entrance. Similarly, only the people who were in the lobby at the back left through the Back Entrance. This latter access is the usual way in and out of the building and should have been well used during the evacuation according to the affiliation model [4]. This was not the case because there was no staircase leading to the Back Entrance or the Front Entrance and no one could use the elevators that had been recalled to the ground floor, so most people used the fire exits. However, affiliative behaviours were observed since most people, after leaving by Fire Exit A or B, gathered close to the Back Entrance before re-entering the building through this entrance at the end of the exercise.

The Time to Move was calculated from the moment a person left his/her unit to the time that person reached an outside exit. The results showed that the evacuation time does not vary considerably among evacuees. In fact, the majority took about 1 minute to travel the distance between their units and an outside exit, regardless of the location of their starting points.

The average time to walk down one floor was 16.1 seconds, 0.47 m/s. This descending time was similar to some office buildings studies where crowds slow down people to a rate of one floor every 14 to 34 seconds, or 0.66 m/s and 0.23 m/s [5]. One visually-disabled occupant suffering from arthritis had an average time of 24 seconds going down one floor (0.31 m/s). Even though his speed was a bit slow, it had no impact on the evacuation time of other people since there were no crowds in the staircase.

According to the fire-list, 23 people in need of assistance to evacuate were living in units on the 4th, 5th, 6th or 7th floors. Only 7 occupants were actually moved to an area of safety. What happened was that most people with disabilities went to their balconies when the alarm sounded. This attitude is not surprising since it is the appropriate response according to the evacuation procedure. Also, some people explained after the drill, that they wanted to watch the activity outside. Furthermore, since the temperature was 38°C, it felt good being out on the balcony! One of the consequences was that when the firefighters knocked at the doors of people on the fire-list, the occupants couldn't hear them due to the loud alarm inside and their location on the balcony. The few disabled people who answered their doors were directed to an area of refuge by the firefighters. This horizontal evacuation took less then 10 seconds for each person, since these people were in wheelchairs and firefighters could quickly roll them to a safe area. Moving the disabled people did not impede the evacuation of other occupants since most people were already outside when the firefighters started the horizontal evacuation approximately 4 minutes after the alarm. The "all clear" was given at 19:23:16, exactly 16:05 after the sounding of the fire alarm.

The post-evacuation questionnaire was filled out by 41 occupants, representing 57% of all the units. Everyone mentioned that they had heard the alarm and its sound was loud enough for 88% of them, 10% found it too loud, and 2% not loud enough. For people who answered the questionnaire, 68% evacuated the building, of these, 89% used the stairs while others left directly from their units at ground level. Before leaving the building, the most common actions were: 19% "find pet", 17% "gather valuables", 15% "get dressed", and 13% "have a look in the corridor". Of the 32% of people who did not evacuate, all of them had disabilities, except one who stayed with a disabled person. As many as 78% of the occupants had previously participated in the evacuation of this building during drills or false alarms. The public address messages were understood only by 15% of the people. The average age of the respondents was 46 years old.

Conclusion

The timing and movement during the evacuation of this building provide interesting information. The Time to Start to evacuate varied from 45 seconds to 5 minutes – which is consistent with assumptions presented in the literature that some time is spent in pre-evacuation actions [6].

Interestingly, the total time to reach an outside exit was about the same for most people, approximately 1 minute. This indicates that, in a mid-rise building of that size, the distance and time to reach an outside exit are of secondary concern.

Since each unit is equipped with an alarm speaker, every occupant heard the alarm. Consequently, the occupants rapidly started their evacuation and the building was almost free of occupants when the firefighters arrived – which simplified their work. However, the high number of false alarms over the last 10 years probably contributed to the low participation in the drill. False alarms have to be reduced to rebuild the faith of occupants about the meaning of the alarm.

According to the evacuation procedures planned for this building, people who needed assistance had to stay in their unit or go to their balcony and wait to be rescued. On one hand, this procedure worked very well since the people with mobility impairments did not try to leave by themselves and did not impede the evacuation of other people. On the other hand, however, people who went to their balconies couldn't hear the firefighters knocking at their doors to instruct them to move toward the other wing of the building. In theory, the firefighters could have used a master-key found in the control panel to enter each unit, but, since most people had installed additional dead-bolts on their doors, this key would have been useless. In a fire emergency, firefighters would probably knock down the doors to rescue the people, but this takes time and manpower. An alternative way to communicate with people who stay in their units has to be developed to ensure that instructions can be heard and understood by people who need assistance.

4.2 Building 2 – Montreal

Building Description

The second building studied was located in the eastern part of Montreal. The Montreal building, or Building 2, is a 6-storey building built in 1982 and containing 80 units. Figure 3 shows a typical floor plan of the "L"-shaped building. One elevator is located close to the main entrance and there are three staircases. The building has five exits leading to the outside.

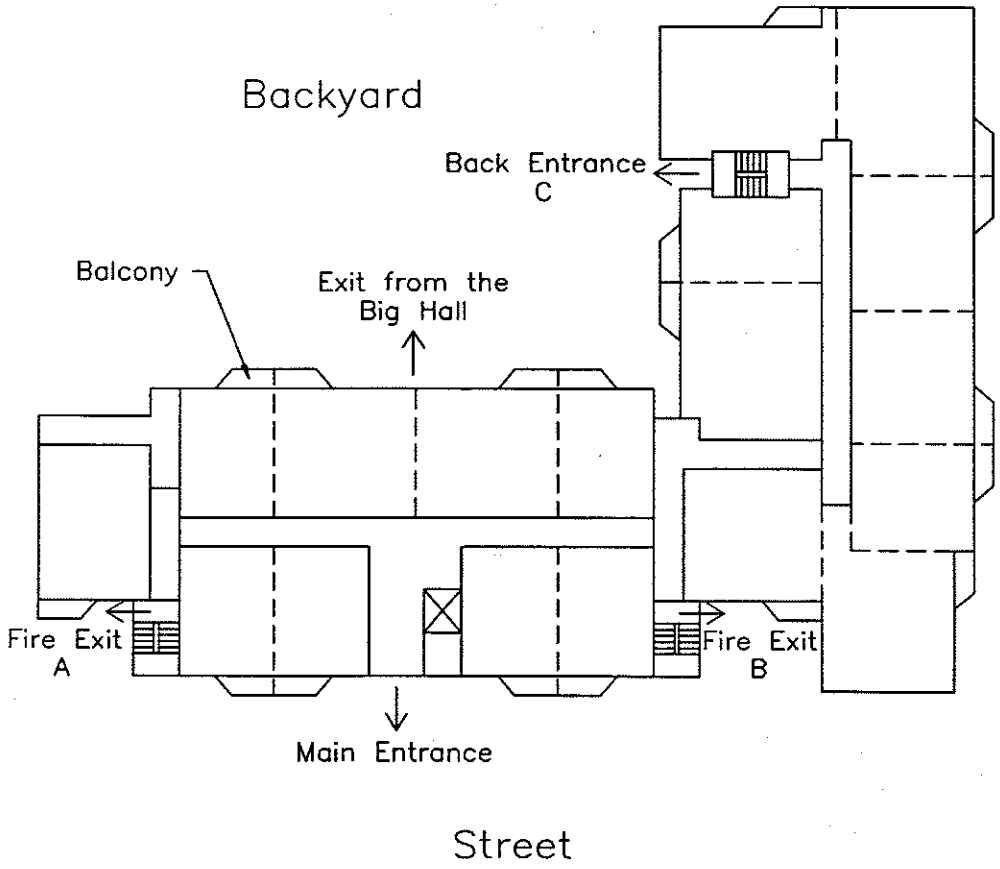

FIGURE 3: Plan of Building 2

There are no living units on the first floor of this building. The first floor contains a Big Hall for residents' meetings and social activities, an office, different rooms to store materials, and an enclosed garage. All units and areas of the building are accessible to wheelchair users.

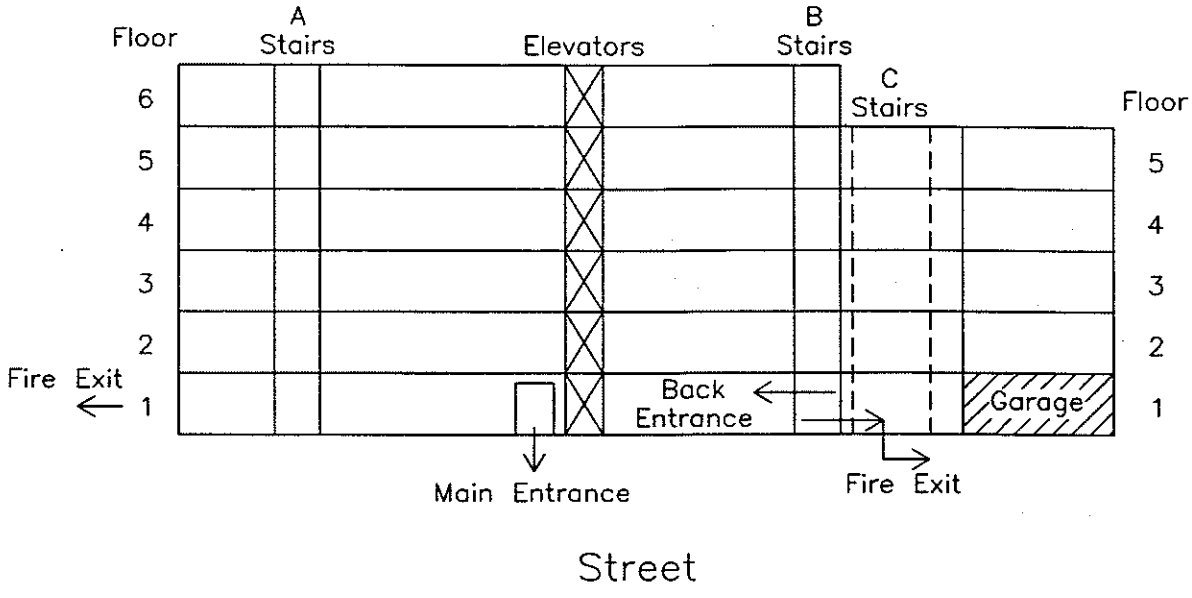

FIGURE 4: Elevation of Building 2

The building has three staircases, two exiting at the front of the building and one at the back (Figure 4). Most residents use the elevator to go in and out of the building. The back staircase and exit is also fairly well used during the summer, since the back yard has a "pétanque" court (game of balls), grass, flowers and picnic tables.

The building is equipped with a central alarm system. This means that upon activation of a manual pull station, an alert signal will sound throughout the building. The alarm bells are built-in the walls of the corridors. When the central alarm is activated, the elevator goes automatically to the first floor. There are no fire doors in this building to create compartmentation in corridors, however, each staircase is equipped with fire doors with closers. Each landing is large enough to accommodate one wheelchair, although, this space has not been planned as an area of refuge.

The fire alarm is not linked to the fire department which means that someone has to call 911, or the fire department directly, to inform the firefighters of the alarm activation. The fire alarm control panel is located in the main entrance lobby. Firefighters can find, in the control panel, the master key for the building, as well as a fire-list of people needing assistance to evacuate. Before the study, there was no fire-list. It was only after discussion with the management that a fire-list was created and placed in the control panel.

Building Occupants

At the time of the evacuation, there were 111 residents living in the building, of whom 20 presented limitations or disabilities according to management. In total, 61 occupants were elderly people, 7 were wheelchair users, 9 had other disabilities, 33 were adults and there was one child.

Most residents of this building had been living there for many years. People knew their neighbours very well, as well as most of the other building occupants. There were also closely-related people living in different apartments. For example, one man had his parents living two floors below while two sisters were living in different units on the same floor; one man had his girlfriend living one floor below, etc. This created an environment of close relationships which had an impact on the evacuation since people tended to gather before evacuating.

Procedure

All building occupants received a memo (Annex 1) at their door telling them that an evacuation would be taking place in the coming weeks. Following that note, a large number of questions in relation to the evacuation procedure were received by the building management. It was then decided to organize an evening information session with the presence of firefighters of the Montreal "Service de la prévention incendies" who are experienced in providing information to the public.

During the session, an evacuation chair was demonstrated to the residents. Two wheelchair users volunteered to be evacuated with that chair during the evacuation drill. It is important to note that the Montreal Fire Department usually proceeds with a full evacuation when there is no compartmentation in a building, such as in Building 2. In a fire, this means that all the occupants with mobility limitations would be carried to the ground level by the firefighters. For the evacuation study, it was decided to evacuate only two wheelchair users with the evacuation chair, and to ask the other mobility-impaired people to stand on their balconies.

A fire-list was put together by the management with 16 residents listed as needing assistance in case of an evacuation.

An elderly resident on the 4th floor was identified to be the one pulling the alarm-bar at a pre-determined time. This person also had to go to the office on the first floor, close to the entrance, to phone the fire department.

To record the evacuation, 11 video cameras were positioned in the staircases, corridor and outside the building. The evacuation with the evacuation chair was followed by a cameraman with a hand-held camera.

A fire scenario had been planned with the local fire department which treated this as a real fire. Once the call was received at the department, the alert was transmitted to the closest fire station, located 1 km from the building. Two trucks and eight firefighters in full gear were dispatched to the building. Due to the size of the building and the type of occupancy, further alerts were given to other fire stations. The rescue unit was called to bring the evacuation chair. The evacuation drill involved over 45 firefighters.

According to the fire scenario, the fire was located on the 4th floor, close to Staircase B. Firefighters entered the building and directed the occupants toward Staircases A or C. They asked mobility-impaired people to take refuge on their balconies. The Captain who remained near the control unit gave instructions to his crew through walkie-talkies. When the Captain judged that the evacuation was over, he gave the "all clear" signal and firefighters grouped for a debriefing session.

After the drill, the post-evacuation questionnaire (Annex 2) was distributed to all units.

Results

The information session held in the Big Hall of Building 2 was attended by over 40 residents who had numerous questions to ask about the drill and fire safety in general. The following days, the principal investigator met with 12 of the 16 people on the fire-list to talk with them about the evacuation drill.

The evacuation was carried out August 12, 1993. It was a nice warm evening (26°C). Upon activation of the alarm-bar at 19:03:52 by the occupant on the 4th floor, the fire alarm sounded, and the elevator was automatically recalled to the first floor. The "alarm-puller" took 40 seconds to reach the exit door of Staircase B, plus 1 minute to go to the office and call the fire department. The first fire truck arrived at the site at 19:10:52.

The evacuation timing is presented in Table 3. The data have been analyzed to differentiate three times: a) the Time to Start, b) the Time to Exit, and c) the Time to Move. The Time to Start the evacuation is the elapsed time between the fire alarm sounding and the moment the person left his/her unit. The Time to Exit is the elapsed time from the fire alarm sounding and the time that the person crossed one of the 5 exits. Finally, the Time to Move is the time each person took to leave the building from the starting time, to the time to reach an outside exit, without considering the distance travelled.

A total of 57 persons representing 51% of all residents living in Building 2, participated in the drill. Although this seems to be a low percentage, it represents almost all the occupants present in the building at the time of the evacuation drill. This good participation is probably due to the information session which had sensitized the residents, as well as the insistence of firefighters during the drill, who knocked at every door and asked people to leave the building.

As presented in Table 3, the Time to Start to evacuate varied from the first minute to over 21 minutes after the alarm activation. In fact, when the firefighters arrived, only 58% of the occupants had evacuated. The rest of the occupants started their evacuation once the firefighters knocked at their door and informed them that the drill was going on. The questionnaire analysis showed that 25% of the occupants did not hear the alarm until they answered the firefighters at their door. Many occupants commented that they were informed of the evacuation drill by neighbours, friends or relatives living in the building, who knocked or called them.

The Time to Exit through one of the 5 exits, is well spread during the whole evacuation; some people reached an exit after 1 minute, others after 23 minutes from the moment the alarm was activated. This long delay for some occupants to reach safety is explained by the long delay to start the evacuation. Four people left their units but never reached an exit. Two of them were mobility-impaired people who stayed on the landing of Staircase B; two others, with no apparent impairment went back to their apartment after spending some time chatting with neighbours.

The Time to Move, calculated from the time a person left a unit to the time this person reached an area of safety, varies from less then 1 minute to almost 4 minutes. The slower times to move were not due to crowding or queuing since the staircases had a very low density throughout the drill. The time to move was more dependent on the distance of travel, the speed of travel, and the time spent chatting with neighbours on the stairs or stopping at one level to inform a friend of the evacuation.

TABLE 3: Evacuation timing for Building 2

Time Intervals	Time to Start		Time to Exit		Time to Move	
	Frequency	%	Frequency	%	Frequency	%
0:00-1:00	5	9%	0	0%	20	38%
1:01-2:00	10	18%	9	18%	24	46%
2:01-3:00	8	15%	6	12%	6	12%
3:01-4:00	3	5%	2	4%	2	4%
4:01-5:00	3	5%	6	12%		
5:01-6:00	2	4%	2	4%		
6:01-7:00	1	2%	0	0%		
7:01-8:00	0	0%	3	6%		
8:01-9:00	0	0%	1	2%		
9:01-10:00	0	0%	0	0%		
10:01-11:00	2	4%	1	2%		
11:01-12:00	2	4%	0	0%		
12:01-13:00	3	5%	0	0%		
13:01-14:00	5	9%	1	2%		
14:01-15:00	0	0%	8	16%		
15:01-16:00	1	2%	0	0%		
16:01-17:00	0	0%	0	0%		
17:01-18:00	0	0%	1	2%		
18:01-19:00	0	0%	0	0%		
19:01-20:00	6	11%	0	0%		
20:01-21-00	3	5%	6	12%		
21:01-22:00	1	2%	2	4%		
22:01-23:00	0	0%	0	0%		
23:01-24:00	0	0%	3	6%		
Total	55	100%	51	100%	52	100%

Table 4 presents the movement times in intervals of 15 seconds and demonstrates the large discrepancy among evacuees for the first 5 minutes. It shows that the promptest people to start took between 16 and 30 seconds after the alarm to leave their units. The two first people to reach an exit arrived between 1:31 and 1:45 after the alarm.

The five different exits were not used equally. Although Staircase A accommodated 20% of the evacuees, only 68% of them left by the door at the bottom, while the other 42% walked the length of a corridor on the first floor to evacuate by the Main Entrance. The back entrance through the Big Hall was not used by anyone. Fire Exit B was used by 39% of the evacuees while Fire Exit C was favoured by 41%.

According to the fire-list, 16 people were in need of assistance to evacuate. From that group, 5 were not in the building at the time of the exercise. Five others evacuated with the assistance of relatives or friends. Three persons were told by the firefighters to take refuge on their balconies. One person in a wheelchair went by herself to the landing of Staircase B, and two other people in wheelchairs were evacuated by the firefighters using an evacuation chair.

TABLE 4: Movement times for the first 5 minutes

Time	Time to Start		Time to Exit		Time to Move	
Intervals	Frequency	%	Frequency	%	Frequency	%
0:00-0:15	0	0%	0	0%	0	0%
0:16-0:30	5	17%	0	0%	9	17%
0:31-0:45	0	0%	0	0%	6	12%
0:46-1:00	0	0%	0	0%	6	12%
1:01-1:15	2	7%	0	0%	9	17%
1:16-1:30	6	21%	0	0%	4	8%
1:31-1:45	2	7%	2	9%	7	13%
1:46-2:00	0	0%	7	30%	3	6%
2:01-2:15	2	7%	4	17%	2	4%
2:16-2:30	1	3%	2	9%	3	6%
2:31-2:45	4	14%	0	0%	0	0%
2:46-3:00	1	3%	0	0%	1	2%
3:01-3:15	1	3%	0	0%	1	2%
3:16-3:30	0	0%	0	0%	0	0%
3:31-3:45	1	3%	1	4%	0	0%
3:46-4:00	1	3%	1	4%	1	2%
4:01:4:15	1	3%	0	0%		
4:16-4:30	1	3%	4	17%		
4:31-4:45	0	0%	2	9%		
4:46-5:00	1	3%	0	0%		
of all	53%		45%		100%	
Total	29	100%	23	100%	52	100%

The evacuation of the two people with the evacuation chair was performed after most people in the building had evacuated. The first person to be evacuated with the chair was a women living on the 4th floor. The evacuation was performed in Staircase C and took 3:40; which comprised 60 seconds for each floor plus 40 seconds for the transfer from the wheelchair to the evacuation chair. The second person to be evacuated with the chair was a man living on the 5th floor. The evacuation was performed in Staircase A and took only 3:30; which comprised 45 seconds per floor plus 30 seconds for the transfer. This second result is surprising, since Staircase A is narrower than Staircase C. It appears that firefighters were getting better with practice.

The "all clear" was given at 19:34:53, exactly 31:01 after the sounding of the alarm bell. After the evacuation drill, some occupants returned to their apartments but most of them stayed outside to chat with the firefighters or neighbours.

The post-evacuation questionnaire was filled out by 75% of all the occupants, many of whom were in the garden at the back of the building at the time of the evacuation. For the occupants who were in the building during the evacuation drill, 75% answered that they heard the alarm and 25% said they did not. In total, 60% of the occupants judged that the alarm was not loud enough, 38% said it was correct, and 2% said it was too loud. All the respondents had left the building or reached an area of safety during the exercise. Before leaving the building, the most common actions were: 34% "have a look

in corridor", 21% "move to balcony", 11% "gather valuables", and 9% each for "get dressed" and "look through window". All the occupants found it reassuring that firefighters were present during the evacuation drill. Only 23% had previously participated in an evacuation of that building. The average age of the occupants was 68 years.

Conclusion

The Time to Start the evacuation in this building was fairly slow. Some occupants started rapidly but most occupants had to be prompted by friends or firefighters to leave the building. This delay in starting the evacuation seems essentially due to the fact that many occupants did not hear the alarm bell from inside their apartment. Occupants explained that with the television on, they did not hear the alarm, even though they have no hearing problems. It seems that the alarm was well perceived only in units adjacent to the location of the alarm bell in the corridor. Even in the corridor, the videotapes show occupants having long discussions which implies that the alarm was not loud enough to prevent conversation. Occupants mentioned that during a night-time false alarm the previous winter, only 15 people had gathered in the lobby; some occupants explained that they never heard the alarm. Unfortunately, no meter had been brought to the building to precisely measure the sound of the alarm during the evacuation drill. It appears, however, that the enclosure of the alarm bells, within the corridor walls, had an effect of reducing their audibility.

The close relationships between many occupants had an impact on the evacuation. In relation with the affiliation concept, people tended to gather before evacuating to leave as a group. This phenomenon explains the long movement time of some occupants who went to inform other people of the evacuation and waited for them to evacuate together.

4.3 Building 3 – Toronto

Building Description

Building 3, is located in North York in the metropolitan Toronto area. This building built in 1987, has 7 storeys and contains 109 units. Figure 5 shows a typical floor plan of the building. Two elevators are located on the right half of this rectangular building. A locked security door divides the building in two sections; the small East section is reserved for elderly people, and the larger West section on the left has a wide range of occupants. The purpose of this separation is to provide more privacy to the elderly. There are four exits leading to the outside.

There is only one housing unit on the first floor where the superintendent and his family live. The rest of the first floor is occupied by an activity centre for the elderly with a small chapel, a laundry room, offices for the management, and a day care centre. On the six other floors, there are 18 units on each floor.

All areas of the building, such as the laundry room and the garbage chutes, are accessible to wheelchair users. On each floor, the units having a number ending with 19 (219, 319, ...) are specially designed to accommodate wheelchair users. Each unit has a balcony.

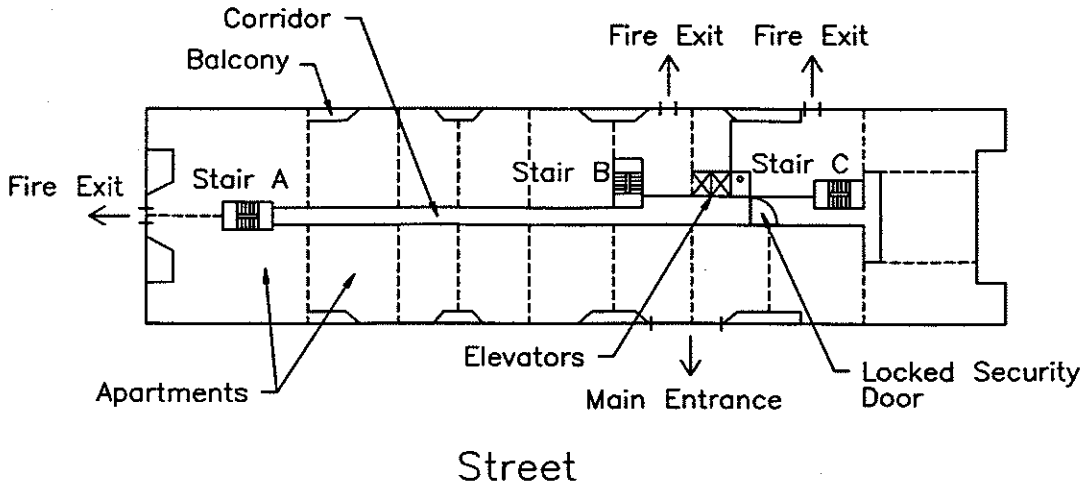

FIGURE 5: Plan of Building 3

The building has three staircases (Figure 6). Staircase A exits in the playground of the day care centre. Staircase B, close to the two elevators, exits in the front lobby; people can go out through the main entrance or go through a stock room to a back exit. Finally, Exit C, which can only be used by occupants in the elderly section, exits at the back of the building. Residents use, essentially, the elevators and the Main Entrance to go in and out of the building.

The building is equipped with a central alarm system. This means that upon activation of a manual pull station, an alert signal will sound throughout the building. The alarm bells are located in the corridors. When the central alarm is activated, the elevators have to be manually returned and locked on the first floor by the superintendent. The locked security door creates two compartments in the corridor. Each staircase is equipped with fire doors with closers.

The fire alarm is not linked to the fire department which means that someone has to call 911 or the fire department directly to inform the firefighters of the alarm activation. The fire alarm control panel is located in the main entrance lobby. Firefighters can find, in the control panel, the master key for the building as well as a fire-list, called the Gold list, of people needing assistance to evacuate.

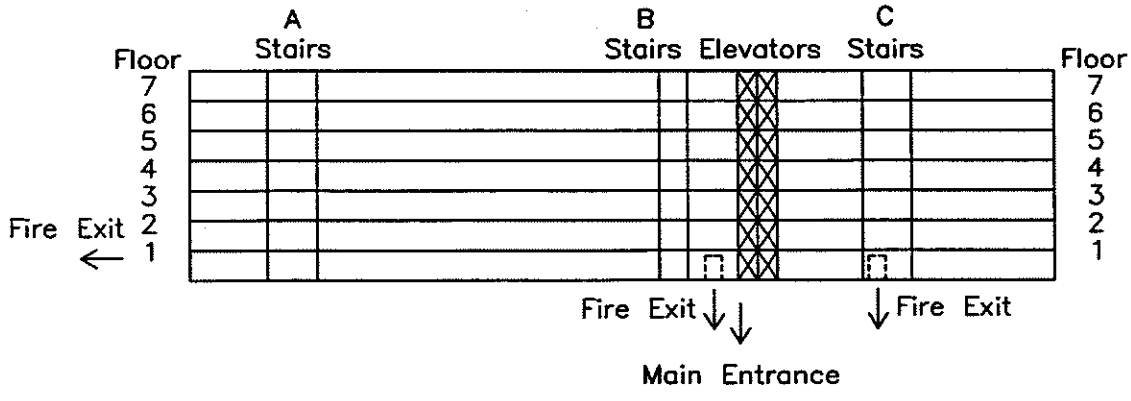

FIGURE 6: Elevation of Building 3

Building Occupants

At the time of the evacuation, there were approximately 250 residents living in the building. It was impossible for the management to give an exact number since people move in with friends or family or move out without informing anyone. There were 24 people on the fire-list identified as non-ambulatory. In total, 66 occupants were elderly people, 4 were wheelchair users, 15 had some other disability, and there were approximately 125 adults and 40 children.

Many residents were of different cultural backgrounds. There were immigrants from Somalia, India, Pakistan, Sri-Lanka, etc. Some of these residents had a limited knowledge of English.

Procedure

All building occupants received a memo (Annex 1) at their door, distributed by the superintendent, telling them that an evacuation would be taking place during the coming week.

The fire-list identified 24 residents needing assistance in case of an emergency. Normally, these occupants should have been met to inform them in more depth of the evacuation procedures and reassure them about the drill. The management of Building 3, however, refused to let the principal investigator meet with the occupants.

The substitute fire-warden living on the 4th floor was met; she would be the one pulling the alarm-bar at a pre-determined time. She also had to go to the lobby to give the signal to a fire department representative to call the fire department with his walkie-talkie.

To record the evacuation, 12 video cameras were positioned in the staircases, corridor and outside the building.

A fire scenario had been planned with the local fire department which treated this as a real fire. The call was given directly to the closest fire station 4 km from the building. Once the alert was received, two trucks and eight firefighters in full gear, were dispatched to the building. Due to the size of the building and the type of occupancy, the Toronto Metropolitan Police also dispatched six police officers to help with the evacuation. A partial evacuation is usually favoured by the North York Fire Department for mid-rise buildings.

According to the fire scenario, the fire was located on the 4th floor, close to Staircase A. Firefighters and police officers entered the building and directed the occupants toward Staircases B or C. They moved mobility-impaired people from Floors 4, 5, and 6 to the compartment across the locked security door in the elderly section. The Captain who remained near the control unit gave instructions to his crew through walkie-talkies. When the Captain judged that the evacuation was over, he gave the "all clear" signal.

After the drill, the post-evacuation questionnaire (Annex 2) was distributed to all units.

Results

The evacuation was carried out on August 24, 1993, on a warm evening (24°C). Upon activation of the alarm-bar at 19:31:21, by an occupant on the 4th floor, the fire

alarm sounded and, a few seconds later, the superintendent had locked the elevators at ground level. The "alarm puller" used Staircase A to the ground level then walked the length of the corridor to exit by the main entrance 55 seconds later. The first firefighters entered the building at 19:39:34.

There was no meeting with occupants listed on the fire-list which contributed to the confusion and fear of a few elderly disabled persons. During the drill, they did not know what to do: a person in a wheelchair was prepared to try the stairs, people from management had to go up to reassure that person.

The evacuation timing is presented in Table 5. The data have been analyzed to differentiate three times: a) the Time to Start, b) the Time to Exit, and c) the Time to Move. The Time to Start the evacuation is the elapsed time between the fire alarm sounding and the moment the person left his/her unit. The Time to Exit is the elapsed time from the fire alarm sounding and the time when the person crossed one of the four exits. Finally, the Time to Move is the time each person took to leave the building from the starting time, to the time to reach an outside exit, without considering the distance travelled.

If it is assumed that 250 people live in Building 3, 81 people, representing only 32.4% of all occupants, participated in the evacuation. This seems a low percentage but many people were probably not at home. A subjective judgment would be that half the people who were in the building at that time participated in the evacuation. In fact, most of the people in the elderly section did not leave the building and many people could be seen on their balconies throughout the drill.

As presented in Table 5, the Time to Start to evacuate, varied from less then a minute to over 24 minutes after the alarm activation. In fact, when the firefighters arrived, only 51% of the occupants had evacuated. The rest of the occupants started their evacuation once the firefighters knocked at doors, informing occupants that the drill was going on. The questionnaire analysis showed that 23% of the occupants did not hear the alarm until they answered the firefighters at their door.

The Time to Exit is well spread during the whole evacuation, some reached the exit during the first minute, others after over 25 minutes from the moment the alarm was activated. This long delay for some occupants to reach safety is explained by the long delay to start the evacuation. Many occupants left their units but never left the building.

The Time to Move from the time a person left a unit to the time to reach an area of safety varies from less then 1 minute to almost 3 minutes. The slower times to move were due to small children aged between 2 and 5 years, going down by themselves, one step at a time. These children were usually with one parent who would have a small baby in his or her arms. The parent would go down the stair behind the child to prevent other descending people from running over the child. This behaviour would slow down all the evacuees coming behind the group with the child.

Table 6 presents the movement times in intervals of 15 seconds which demonstrate the large discrepancy among evacuees for the first 5 minutes. It shows that the promptest people to start took between 16 and 30 seconds after the alarm to leave their units.

TABLE 5: Evacuation timing for Building 3

Time Interval	Time to Start		Time to Exit		Time to Move	
	Frequency	%	Frequency	%	Frequency	%
0-1:00	8	10%	1	1%	37	48%
1:01-2:00	12	16%	5	6%	26	34%
2:01-3:00	6	8%	8	10%	14	18%
3:01-4:00	5	6%	10	13%		
4:01-5:00	3	4%	6	8%		
5:01-6:00	0	0%	0	0%		
6:01-7:00	1	1%	5	6%		
7:01-8:00	5	6%	2	3%		
8:01-9:00	1	1%	1	1%		
9:01-10:00	5	6%	3	4%		
10:01-11:00	3	4%	4	5%		
11:01-12:00	2	3%	4	5%		
12:01-13:00	0	0%	2	3%		
13:01-14:00	0	0%	0	0%		
14:01-15:00	1	1%	0	0%		
15:01-16:00	2	3%	1	1%		
16:01-17:00	3	4%	0	0%		
17:01-18:00	0	0%	4	5%		
18:01-19:00	0	0%	1	1%		
19:01-20:00	9	12%	0	0%		
20:01-21:00	4	5%	2	3%		
21:01-22:00	0	0%	5	6%		
22:01-23:00	0	0%	6	8%		
23:01-24:00	5	6%	0	0%		
24:01-25:00	2	3%	5	6%		
25:01-26:00	0	0%	2	3%		
Total	77	100%	77	100%	77	100%

The "all clear" was given at 19:58:17, exactly 26:56 after the sounding of the alarm bell.

The post-evacuation questionnaire was filled out by 47 occupants representing 31% of the units. For the occupants who were in the building during the evacuation drill, 77% answered that they heard the alarm and 23% said they did not; 42% of the occupants judged that the alarm was not loud enough. Before leaving the building, the most common actions were: 23% "gather valuables", 20% "have a look in corridor", 14% "get dressed", and 12% "find children". Only 17% had previously participated in an evacuation of that building before. The average age of the respondents was 37 years.

TABLE 6: Movement times for the first 5 minutes

Time Intervals	Time to Start		Time to Exit		Time to Move	
	Frequency	%	Frequency	%	Frequency	%
0:00-0:15	0	0%	0	0%	2	3%
0:16-0:30	1	3%	1	3%	7	9%
0:31-0:45	1	3%	0	0%	17	22%
0:46-1:00	6	18%	0	0%	11	14%
1:01-1:15	0	0%	2	7%	5	6%
1:16-1:30	6	18%	0	0%	7	9%
1:31-1:45	3	9%	3	10%	10	13%
1:46-2:00	3	9%	0	0%	4	5%
2:01-2:15	0	0%	1	3%	4	5%
2:16-2:30	0	0%	5	17%	5	6%
2:31-2:45	3	9%	1	3%	5	6%
2:46-3:00	3	9%	1	3%		
3:01-3:15	0	0%	3	10%		
3:16-3:30	1	3%	3	10%		
3:31-3:45	4	12%	2	7%		
3:46-4:00	0	0%	2	7%		
4:01:4:15	3	9%	3	10%		
4:16-4:30	0	0%	0	0%		
4:31-4:45	0	0%	3	10%		
4:46-5:00	0	0%	0	0%		
of all	44%		39%		100%	
Total	34	100%	30	100%	77	100%

Conclusions

In Building 3, a number of occupants did not hear the alarm from their apartments. Once in the corridor, however, some judged that the alarm was too loud. These assessments of the alarm may seem paradoxical at first but are easily explained. On one hand, each unit tended to be soundproof which prevented occupants from hearing the alarm located in the corridor. On the other hand, in the corridors because there are only a few alarm bells, each of them has to be very loud to make them audible by unit occupants.

All the people with hearing impairments had no visual alarm link to the central alarm system to alert them to the evacuation drill. Special devices exist but it seems that the people with hearing problems did not know of these tools or did not want them. A program should be set up to make sure that everyone has access to notification by the fire alarm systems.

Occupants mentioned on the fire-list as needing assistance during an evacuation were not met before the drill. Consequently, these occupants did not react in accordance with the evacuation procedure. It is obvious that occupants cannot react according to a plan if they receive no prior information about what is expected of them. Information

should also be given to people of different cultural backgrounds to familiarize them with the alarm, the evacuation procedures, the duty of the fire department, etc.

Firefighters who knocked at doors to ask people to evacuate often had no reply, although the people were in their apartments. It seems that some people from other cultures are very fearful of figures of authority, such as police officers or firefighters. It is also possible that some people did not understand the memo sent to inform them about the drill. Finally, the fact that this building has an average of 2-3 false alarms per month can also explain that occupants tend to not bother when the alarm sounds.

The number of false alarms in Building 3, is very high. It could be expected then that occupants of this building are used to evacuating the building. Results of the questionnaire show that 2/3 of the occupants have never evacuated the building before the evacuation study. This observation confirms that occupants are reluctant to respond to an alarm when there are many false alarms in a building; they have lost faith in the reliability of the alarm to announce a genuine emergency.

The presence of families with small children tend to slow down the evacuation. Children, under the age of 5 years old, go down stairs very slowly (the steps and handrails being too high). They descended stairs, step by step, followed by their parents who blocked the way of other descending people. This observation is surprising since it was expected that people with disabilities would be the ones slowing down the flow of descending people. In fact, people with disabilities might descend slower then others, but they tend to stop at each level or stand to one side of the staircase to let other people pass them.

4.4 Building 4 – Vancouver

Building Description

The Vancouver building, or Building 4, is a 7-storey reinforced concrete building built in 1985. Figure 7 shows that Building 4 is enclosed in a larger housing project. There are two sets of rowhouses located directly on the street with a small pedestrian passage in between to access the Plaza and the building. Behind Building 4 there is a lane for neighbouring traffic.

The elevator to access the upper levels is detached from the building structure. It stops only on the 4th and 6th floors where there is a footbridge leading to the building. The building has three fire exits leading to the outside.

Figure 7 shows a floor plan of Building 4 representing only the organization of the ground floor, since every floor has a different architectural design.

Building 4 has an unusual design. Most apartments are built on two floors or many split levels. There are over 10 different apartment designs and sizes among the 75 units of the building. Thirty units have direct access to the ground floor (Figure 8). These units are built on two levels; the 1st and 2nd floors. The 4th floor, where the elevator stops, has a footbridge and an open gallery the full length of the building. From the gallery, there is access to 31. These apartments also occupy two levels, either the 3rd and 4th floors, or the 4th and 5th floors. The second elevator stop is on the 6th floor which gives access, via a footbridge and a garden open space, to corridors in the West or East wing of the building. On the 6th floor, there are a few single storey apartments where people in wheelchairs live; other units are on two levels, occupying the 6th and 7th floors.

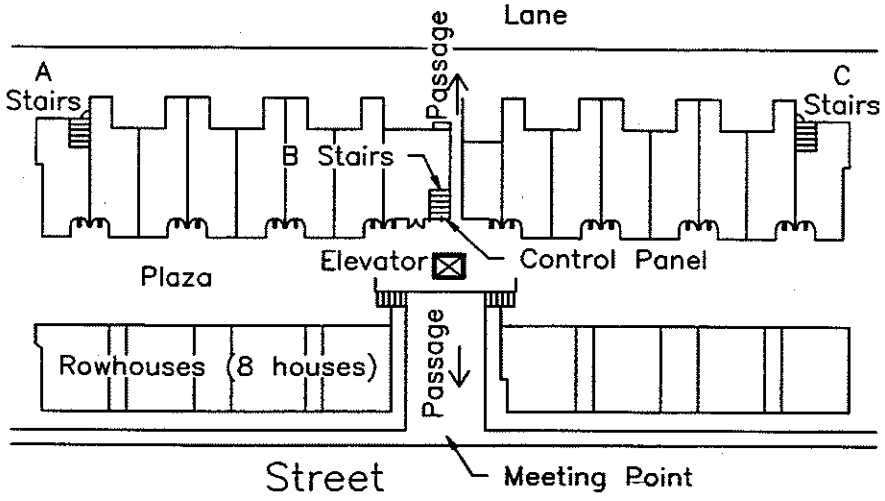

FIGURE 7: Plan of Building 4

The building has three staircases, two exiting at the back of the building on the lane, and one located in the centre, ending close to the elevator. Residents of the ground floor units have direct assess to the outside at the back and the front of the building. All the residents on the upper floors use the elevator to go in and out of the building. Staircases A, B, and C are rarely used.

The building is fully sprinklered, including the units. It is also equipped with a central alarm system. This means that upon activation of a manual pull station, an alert signal will sound throughout the building. The alarm bells are located on the 4th floor gallery, on the two stretches of corridors on the 6th floor and in the three staircases. When the central alarm is activated, the elevator has to be manually recalled to the underground level. There are no fire doors in this building to create compartmentation in the corridors on the 6th floor. Each staircase is equipped with fire doors with closers. The staircases have non-consistent designs; the width of stairs varies, the number of steps to a landing varies, the size of landings varies, etc.

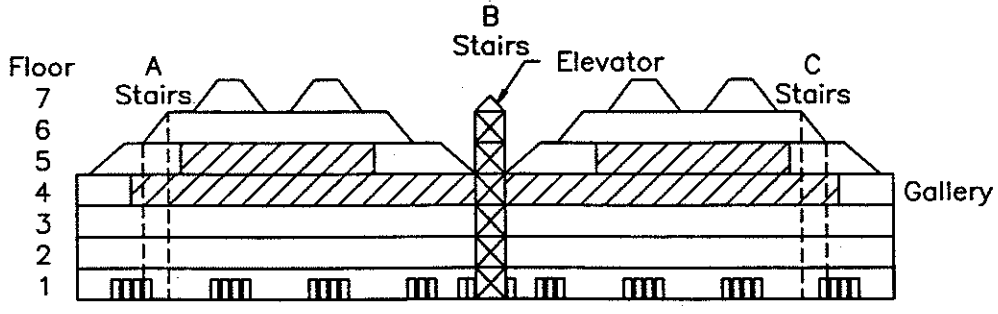

FIGURE 8: Elevation of Building 4

The fire alarm is not linked to the fire department which means that someone has to call 911 or the fire department directly to inform the firefighters of the alarm activation. The fire alarm control panel is located outside, close to Fire Exit B. Firefighters can find, in the control panel, the master key for the building. There is no fire-list for this building.

Building Occupants

At the time of the evacuation, there were 201 residents living in the building, of whom some 39 presented limitations or disabilities. In total 20 occupants were elderly people, 16 had perceptual or cognitive disabilities, 3 were wheelchair users, 103 were adults and 59 were children.

Most residents of this building had been living there for many years. People knew their neighbours well, as well as most of the other building occupants. Being a co-operative project, there are different activities where people can interact with their neighbours.

Procedure

All building occupants received a memo (Annex 1) at their door telling them that an evacuation would be taking place in the coming week. A few days before the evacuation, residents were met at a general meeting. The evacuation study was explained to the members and questions were answered by the principal investigator. Members voted unanimously to participate in the study.

A total of 24 occupants were identified by the management as needing assistance in case of an evacuation.

An occupant of the 4th floor was identified as the one pulling the alarm-bar at a pre-determined time.

To record the evacuation, 12 video cameras were positioned in the staircases, corridor and gallery of the building. Three observers were positioned outside in the Plaza area, to note the time of evacuation of occupants from the ground exits. It was impossible to locate cameras on the Plaza due to luxuriant plants.

A fire scenario had been planned with the local fire department. A fire prevention officer was on location at the beginning of the exercise. The officer alerted the Captain and his crew by walkie-talkies. Two fire trucks with firefighters in full gear were parked a block away from the building. They waited 4 minutes before driving to the building. The evacuation drill involved over 15 firefighters.

According to the fire scenario, the fire was located on the 4th floor, close to Staircase A. Firefighters entered the building and directed the occupants of the 4th floor towards Staircases B or C. They moved a wheelchair user from the 6th floor horizontally toward the East wing corridor. The Captain who remained near the control unit gave instructions to his crew through walkie-talkies. When the Captain judged that the evacuation was over, he gave the "all clear" signal.

After the drill the post-evacuation questionnaire (Annex 2) was distributed to all units.

Results

The co-operative general meeting was attended by over 40 residents who had numerous questions to ask about the drill and fire safety in general. Members voted unanimously to participate in the study. During the following days, the principal investigator met with 19 of the 24 people on the fire-list to talk with them about the evacuation drill. It was decided that three people would not participate in the evacuation drill since these people were extremely ill and weak and could not be moved without possible harm. A note was placed on their doors for the firefighters not to disturb these residents during the exercise.

The evacuation was carried out October 21, 1993. It was a cool evening (18°C). Upon activation of the alarm-bar at 19:13:21 by a family group of three people on the 4th floor, the fire alarm sounded, and the elevator was recalled by the superintendent to the basement floor. The "alarm-puller" group took 56 seconds to reach the exit door of Staircase A. The first firefighters entered Staircase B to proceed with the evacuation at 19:19:50.

The evacuation timing is presented in Table 7. The data have been analyzed to differentiate three times: a) the Time to Start, b) the Time to Exit, and c) the Time to Move. The Time to Start the evacuation is the elapsed time between the fire alarm sounding and the moment the person left his/her unit. The Time to Exit is the elapsed time from the fire alarm sounding and the time when the person crossed one of the three exits, or leave their units on the ground floor. Finally, the Time to Move is the time each person took to leave the building from the starting time, to the time to reach an outside exit, without considering the distance travelled. The time to move is not calculated for the occupants on the ground floor because the only data available is the time at which they exited their unit.

A total of 84 occupants participated in the drill. This represents 42% of all residents living in Building 4. Although this seems a low percentage, it represents a good proportion of all the occupants present in the building at the time of the evacuation drill.

As presented in Table 7, the Time to Start to evacuate varied from the first minute to over 12 minutes after the alarm activation. In fact, when the firefighters arrived, 90% of the occupants had already evacuated. The rest of the occupants started their evacuation once the firefighters knocked at their doors and informed them that the drill was going on. The questionnaire analysis showed that 17% of the occupants did not hear the alarm, especially ground floor occupants.

The Time to Exit is well spread during the whole evacuation; some reached an exit after 1 minute, others after 12 minutes from the moment the alarm was activated. This long delay for some occupants to reach safety is explained by their long delay to start the evacuation.

The Time to Move from the time a person left a unit to the time to reach an area of safety varies from less then 1 minute to almost 3 minutes. The slower times to move were not due to crowding or queuing since the staircases had a very low density throughout the drill. The time to move was more dependent on the distance of travel, the speed of travel, and the presence of children or elderly people among the evacuating group.

TABLE 7: Evacuation timing for Building 4

Time Intervals	Time to Start		Time to Exit		Time to Move	
	Frequency	%	Frequency	%	Frequency	%
0:00-1:00	17	21%	4	5%	14	38%
1:01-2:00	13	16%	15	19%	22	59%
2:01-3:00	26	33%	20	25%	1	3%
3:01-4:00	9	11%	19	24%		
4:01-5:00	4	5%	7	9%		
5:01-6:00	3	4%	4	5%		
6:01-7:00	0	0%	3	4%		
7:01-8:00	0	0%	0	0%		
8:01-9:00	0	0%	0	0%		
9:01-10:00	3	4%	3	4%		
10:01-11:00	1	1%	0	0%		
11:01-12:00	3	4%	1	1%		
12:01-13:00	1	1%	4	5%		
13:01-14:00	0	0%	0	0%		
14:01-15:00	0	0%	0	0%		
Total	80	100%	80	100%	37	100%

Table 8 presents the movement times in intervals of 15 seconds which demonstrates the large discrepancy among evacuees for the first 5 minutes. It shows that the promptest people to start took between 16 and 30 seconds after the alarm to leave their units. The two first persons to reach an exit arrived there between 31 and 45 seconds after the alarm.

The 3 different staircases were not used equally. Staircases A and C accommodated 20% of the evacuees while 60% left by Staircase B located close to the elevator. All the evacuees gathered on the Plaza or on the street which is their designated meeting point.

According to management, 24 people might have been in need of assistance to evacuate. From that group, 3 were very ill people who were not disturbed. These three people were living on the East side of the building which was the safe side according to the fire scenario. One wheelchair user was not at home, but another was moved to the East side of the building. Ten people identified has needing assistance left the building by themselves with the help of relatives or friends.

The "all clear" was given at 19:26:19, only 12:58 after the sounding of the alarm bell. After the evacuation drill, some occupants returned to their apartments but most of them stayed outside to chat with the firefighters or neighbours.

TABLE 8: Movement times for the first 5 minutes

Time Intervals	Time to Start		Time to Exit		Time to Move	
	Frequency	%	Frequency	%	Frequency	%
0:00-0:15	0	0%	0	0%	0	0%
0:16-0:30	8	12%	0	0%	0	0%
0:31-0:45	1	1%	3	5%	3	8%
0:46-1:00	8	12%	1	2%	11	30%
1:01-1:15	4	6%	5	8%	13	35%
1:16-1:30	0	0%	6	9%	6	16%
1:31-1:45	4	6%	2	3%	0	0%
1:46-2:00	5	7%	2	3%	3	8%
2:01-2:15	2	3%	7	11%	1	3%
2:16-2:30	9	13%	3	5%		
2:31-2:45	7	10%	10	15%		
2:46-3:00	8	12%	0	0%		
3:01-3:15	0	0%	2	3%		
3:16-3:30	0	0%	6	9%		
3:31-3:45	5	7%	1	2%		
3:46-4:00	4	6%	10	15%		
4:01:4:15	3	4%	1	2%		
4:16-4:30	1	1%	3	5%		
4:31-4:45	0	0%	3	5%		
4:46-5:00	0	0%	0	0%		
of all	86%		81%		100%	
Total	69	100%	65	100%	37	100%

The post-evacuation questionnaire was filled out by 64 occupants representing 75% of all the units. For the occupants who were in the building during the evacuation drill, 83% answered that they heard the alarm, while 17% said they did not. The alarm was judged too loud by 0%, while 45% found the sound correct, and 55% not loud enough. All the respondents had left the building or reached an area of safety during the exercise. Before leaving the building, the most common actions were: 30% "get dressed", 15% "gather valuables", and 13% "find children". Only 38% had previously participated in an evacuation of that building. The average age of the occupants was 39 years.

Conclusion

This evacuation drill was carried out in a very quick time. Although people in the units on the 1st and 2nd floors could not hear the fire alarm very well, the sudden activity on the Plaza made them move outside. This problem in hearing the bells is probably due to the location of the bells. The closest ones are on the gallery of the 4th floor, 2 to 3 floors above. However, in the staircases, the alarm bells were extremely loud; the videotapes showed people going down covering their ears with their hands.

The prompt evacuation of a majority of occupants made it easy for the firefighters to use the stairs, to inform the few remaining occupants and to move people with disabilities.

In Building 4, residents using a wheelchair live on the 6th floor. Because of the design of the building with two distinct corridors on the 6th floor, movement is allowed horizontally to the corridor on the other side of the building, if necessary.

The complexity of the building design made it difficult for firefighters to coordinate their search and rescue activities. On the 6th floor, for example, some doors are back doors of apartments while some are front doors. This unusual organization is confusing for firefighters.

5.0 TIMING OF THE EVACUATION FOR THE FOUR BUILDINGS

Analyses were conducted for the four buildings looking at the Time to Start, the Time to Exit, and the Time to Move. It is interesting to compare these times among the four buildings.

5.1 Statistical Analyses

A series of statistical analyses was conducted on the data. In all cases, the one-way analysis of variance was used through SPSS 6.0 for Windows. The analysis of variance, which is called ANOVA, is a method of determining whether the scores of two or more groups differ. Significant differences between groups are indicated in the ANOVA test through the p-value. A significant difference exists when the p-value is less than .05, which means there is less than 5% probability that the difference between the groups is due to chance.

Table 9 shows the mean times, in minutes and seconds, for the Time to Start, the Time to Exit, and the Time to Move, for the four buildings.

TABLE 9
Mean times among all four buildings

Building	Time to Start (min:sec)	Time to Exit (min:sec)	Time to Move (min:sec)
1	2:30	3:05	0:36
2	8:22	9:36	1:17
3	9:42	10:57	1:15
4	3:08	4:38	1:07

The ANOVA tests on the Time to Start for all four buildings showed that there were significant differences in the mean time taken to begin the actual evacuation. More specifically, there were significant differences between buildings taken two-by-two, for Buildings 1 and 2, Buildings 1 and 3, Buildings 2 and 4, and Buildings 3 and 4. However, the mean starting times were not significantly different for Buildings 1 and 4 and Buildings 2 and 3.

It appears that the occupants of both Buildings 1 and 4 began the evacuation quite quickly while the occupants of Buildings 2 and 3 were rather slow. The combined mean for the starting times was 2:49 for Buildings 1 and 4 and 9:02 for Buildings 2 and 3. See

Table 9 for the means of the individual buildings. Participant questionnaires showed that the alarm could not be heard very well from some apartments in Buildings 2 and 3. As a result, many people did not leave their apartment until they were notified of the evacuation by a knock on the door from the arriving firefighters which explains their late time to start the evacuation.

Among the four buildings, the ANOVA tests showed a significant difference between the Time to Exit. Similar to the Time to Start, there were significant differences between the mean starting times for Buildings 1 and 2, Buildings 1 and 3, Buildings 2 and 4, Buildings 3 and 4, and Buildings 1 and 4. The mean time to exit was not significantly different between Buildings 2 and 3, therefore, these two buildings were similar in the fact that they demonstrated longer evacuation times.

The Time to Move represents the time it takes for a person to reach an outside exit from the moment the person left the apartment, regardless of the distance travelled. The ANOVAs conducted show that there was a significant difference among all four buildings. The mean time for the Time to Move for occupants in Building 1 was significantly different from all other buildings. It appears that the occupants of Building 1 moved much faster once they left their apartments than the occupants of the other buildings. This is explained by the fact that a few occupants (10, including 2 wheelchair users) were standing in the building lobby when the alarm was activated. Their movement time was then reduced to the short time taken to step outside. When the lobby occupants of Building 1 were excluded from the analysis, there were no significant differences in the Time to Move among all four buildings.

Overall, the occupants of Buildings 1 and 4 started their evacuation faster than the occupants of Buildings 2 and 3. Much of this discrepancy can be attributed to the inability of people to hear the fire alarm from their apartments. Once the occupants left their apartments, the people in Buildings 2, 3, and 4 showed a similar pace for the Time to Move. For the Time to Exit, the occupants of Buildings 2 and 3 demonstrated a similar longer evacuation time than the other two buildings.

Time comparison according to gender

ANOVAs were conducted to reveal potential gender differences in the mean times for the Time to Start, the Time to Exit, and the Time to Move among buildings. Table 10 shows a summary of the results.

For all three times measured in Building 1, the mean time for females was faster than that for males. However, as the Table shows, none of the means were significantly different from any other. The opposite occurred in Building 2 where the mean times for males were faster than for females across all three times measured. Again, however, as the Table shows, the differences between the means did not reach the required level of significance.

The females were marginally faster than the males across all time levels in Building 3 but the differences in the means were not significant. Again, in Building 4, the mean times for females across all time levels were slightly faster than those of the males. The differences, however were not significant.

TABLE 10
Time comparisons for gender in the four buildings

Building	Time	Gender	Number	Mean time	p-value
1	Time to Start	Male	18	3:19	
		Female	24	1:54	p=.0941
	Time to Exit	Male	18	3:56	
		Female	24	2:26	p=.0712
	Time to Move	Male	16	0:41	
		Female	23	0:33	p=.3498
2	Time to Start	Male	18	6:34	
		Female	37	8:39	p=.3146
	Time to Exit	Male	18	7:43	
		Female	34	10:36	p=.1803
	Time to Move	Male	18	1:08	
		Female	34	1:21	p=.3374
3	Time to Start	Male	25	10:41	
		Female	52	9:13	p=.4640
	Time to Exit	Male	25	12:01	
		Female	52	10:26	p=.4350
	Time to Move	Male	25	1:20	
		Female	52	1:13	p=.5026
4	Time to Start	Male	35	3:37	
		Female	45	2:46	p=.1858
	Time to Exit	Male	16	5:15	
		Female	21	4:10	p=.3480
	Time to Move	Male	18	1:07	
		Female	22	1:06	p=.8557

Overall, the results of the ANOVAs show that gender had very little influence on the outcome of the evacuation times for all buildings. There were differences between the speeds of males and females but none of these differences was significant enough to support any conclusions that gender plays a role in the speed of the evacuations.

Time Comparison According to Age Group

ANOVAs were conducted to reveal potential age differences in the mean times for the Time to Start, the Time to Exit, and the Time to Move for the four buildings. Each building had to be studied individually due to different age distributions across buildings.

Several tests were conducted among the various age groups. Table 11 specifies the actual ages included in each group and the number of subjects. All the ages were estimated through examination of the individuals on the videotapes. As a result, the ages cannot be exact but are an estimate within the broad age ranges. The age groups were determined with specific reasoning in mind. Babies that cannot walk were kept together as their times were obtained not by their own ability but by the time of the person carrying them. Children between ages 2 and 5 were grouped together since they are able to walk but stairs are still a challenge for them. Children between 6 and 12 are usually quite energetic and they travel quickly on stairs. Teenagers were put in one group since they move at basically the same pace. The adult age range is quite large so it was split into two groups with age 40 being the midpoint. Age 65 seems to be the traditional beginning to the senior's category so the final age group was defined as 65 and over.

TABLE 11
Number of subjects across age groups

Group Number	Age Group	Building 1	Building 2	Building 3	Building 4
1	Babies (can't walk)	2	0	3	1
2	Small Children (age 2-5)	2	1	6	3
3	Children (age 6-12)	2	2	2	7
4	Teenagers (age 13-19)	1	0	2	5
5	Adults (age 20-40)	22	12	41	20
6	Older Adults (age 41-64)	8	16	10	15
7	Seniors (age 65 & over)	5	25	13	7
	Total	42	56	77	58

Analyses were performed including all age groups but excluding groups with less then 5 subjects which is an insufficient number of subjects for valid statistical analysis.

Results showed that there were no significant differences between age groups for any of the comparisons made in Building 1. For Building 2, some significant differences were observed. At the Time to Start, the mean time for older adults (age 41-65) was significantly different from that of seniors (age 65 and over) (p=.0215). **Strangely, it is the seniors who began evacuating significantly faster than the older adults.** The mean time for seniors was 6:28 whereas for older adults it was 11:38. A possible explanation for this difference is that seniors might have been more worried about the evacuations and, therefore, be in a rush to leave while older adults were more indifferent and took their time in preparing to leave. Once the participants left their apartments, the young adults (age 20-40) moved significantly faster than the seniors (p=.0223). The mean time to reach an exit was, for young adults, 0:55 and, for seniors, 1:35. This is a difference that might be expected since some seniors had to use canes and, therefore, took more care when descending stairs. For the Time to Exit there was a significant difference between the mean times of the older adults and the seniors (p=.0241). Similar to the Time to Start, the seniors were faster than the older adults for the overall Time to Exit which can be explained by the fast time seniors took to start their evacuation.

In Building 3, for age groups with enough subjects, there were no significant differences between any of the groups for the Time to Start and the Time to Exit. There was, however, a significant difference (p=.0224) between age groups 5, the young adults, and 6, the older adults, for the Time to Move. A significant difference (p=.0065) also existed between the older adults who moved significantly faster than the seniors. This difference can be explained by the physical limitations that increase with age making it more difficult to negotiate stairs.

In Building 4 there were no significant differences between age groups when comparing the Time to Move. Age, then, was not a factor in the variations of speed during the moving time of the evacuation. For the Time to Start, the mean times for age group 4 (teenagers) was significantly faster than that of age group 5 (age 20-40) (p=.0399). It is difficult to draw any definitive conclusions regarding this result except that the teenagers practically raced down the stairs. Similarly, in the Time to Exit, the teenagers were significantly faster than the adults (p=.0388).

Looking at all four buildings, **it appears that age was not a strong factor in determining the speed of the evacuation**. In some cases, as predicted, the younger people did move faster than the older individuals, but this result did not always hold true. Basically, there were very few significant time differences among the age groups. Interestingly, in two of the buildings, seniors moved faster in starting their evacuation but moved slower in the corridors and the stairs. Eventually, they reached safety in approximately the same mean time as people of the other age groups. It is unfortunate that there was not a greater number of subjects across all age ranges. The majority of the information obtained regarding people under the age of twenty could not be used because there were too few subjects for any legitimate statistical analysis to be conducted.

Time Comparisons According to Limitations

The speed at which a person can travel is determined to a large part by physical ability. The duration of an evacuation, then, can vary depending on the abilities of the building occupants. The four buildings had occupants with mixed-abilities which could hinder them and others while walking, especially down stairs. One of the purposes of this research was to examine evacuation times for individuals with limitations. This was an attempt to determine whether significant differences existed in evacuation times between those with limitations and those without.

Through examination of the videotapes, the occupants were placed in either a "limitation" or "no limitation" group based on their general behaviour during the evacuation. The categories in the "limitation" group were: wheelchair user, carrying baby, slow walker, and walked with a cane. There was also one visually-impaired individual and one person with M.S. For those who were in wheelchairs, walking with a cane, visually-impaired, or having M.S., the limitations were quite obvious. However, some other occupants may have had limitations not easily observable on the videotapes that could have passed unnoticed. Furthermore, if occupants were not registered on the fire-list and did not mention on the questionnaire their limitation, they were counted as subjects with no limitations.

It was assessed that those carrying children were limited in their speed on the stairs because of the extra care they had to take. There were also some occupants who had no outward signs of limitations; usually elderly people, who were included in the "limitation" group because of their age. It should be noted that people in wheelchairs were not included in the following analysis because most of them remained in their apartments until firefighters moved them to an area of safety.

ANOVAs were conducted for all four buildings comparing the times of those with limitations to those without limitations. The results from Buildings 1 and 4 are not valid, however, because of the insufficient number of people with limitations who actually evacuated the building. When comparing such a small number of people to a much larger group without limitations, it become very difficult to reach any conclusions. As a result, analyses were concentrated on Buildings 2 and 3. The differences between the occupants' times for these two buildings for all three times studied were insignificant so these subjects were combined. All participants with limitations from Buildings 2 and 3 were allocated to one group and those without limitations were put in another group. ANOVAs were conducted comparing these two groups at all three times.

TABLE 12
Time comparisons - Limitations vs. No Limitation

Time Level	Limitations	No Limitation	p-value
Time to Start (mean)	10:34	8:49	p=.3314
Time to Exit (mean)	12:06	10:05	p=.2872
Time to Move (mean)	1:37	1:12	*p=.0167

* denotes significant difference in mean times between those with limitation and those without.

The mean times and p-values in Table 12 show for the Time to Start and overall Time to Exit, that the occupants with limitations were slower than those without limitations. These differences, however, are not significant. This result can be explained for the Time to Start because people with limitations can usually move rapidly in familiar places, such as an apartment. A significant difference, however, does exist between the two groups in the Time to Move. Once people have exited their apartments, finding the staircase and negotiating the stairs seemed to pose a problem for those with limitations and, as a result, they moved significantly slower than the others.

Overall, whether the occupants have some limitations or not does not have a great impact on the evacuation timing. People with limitations are generally slower than others when evacuating but this difference is only significant during the actual moving time outside the apartments. **The overall evacuation time, however, is not significantly affected by the presence of people with limitations.**

5.2 Speed of Occupants on Stairs

The use of video cameras provided invaluable information on the movement of occupants on stairs. The mean time to descend one flight of stairs (from floor to floor) was determined for the occupants of all four buildings. Not all occupants were able to be used in these calculations since some exited from the main floor and, therefore, never used the stairs. Others were not included in this analysis because they stopped repeatedly in the staircases to chat with neighbours.

TABLE 13
Speed of occupants on stairs

Building	Mean Time to Descend One Floor (sec)	Speed (meters/second)
1	16.1	0.47 m/s
2	16.4	*0.44 m/s
3	16.6	0.41 m/s
4	9.6	**

* estimated dimension of stairs
** unable to determine stairs dimension

Table 13 shows the mean times to descend one floor, as well as the converted speed in metres per second. It is important to remember that the stairs were never crowded during the evacuation. However, Stair B in Building 3 was used by 75% of the evacuees which caused it to become lightly crowded at the bottom with one person for every two steps. The average speed shown for Building 2 (0.44 m/s) is based on an estimated measurement of the stairs. It was impossible to obtain a speed for Building 4 because of the non-uniform architectural organization of the staircases and the impossibility even to estimate the distance to travel down one floor in that building. As explained in Section 4.4, Building 4 had three staircases of complex design, which varied in stair width, number of steps between landings, shape, size, and number of landings.

ANOVA calculations show that Building 4 is significantly different from all other buildings. The occupants in that building were much faster with a mean time of 9.6 seconds to travel what can be approximated as one floor. It is difficult to determine reasons for this discrepancy in times compared to the other buildings. Architectural differences could cause part of the variation; for example, lesser floor height would make a shorter distance to travel and, therefore, a faster time. However, as mentioned earlier, due to the heterogeneous nature of the staircases, a true dimension of the stairs could not be obtained. Another explanation for the quick-travelling occupants in Building 4 could be that there were fewer people in age groups 6 and 7 (older adults and seniors), than in the other buildings. It is possible, then, that the small number of older people in Building 4 caused a decrease in the general mean time to descend one floor.

Overall, occupants of three of the four buildings studied showed a comparable mean speed on the stairs. Among all occupants, they travelled between .41 m/s and .47 m/s on non-crowded stairs. This speed, although slow when compared to pedestrian speed on stairs in public facilities [7], is comparable to other research on evacuation drills on crowded stairs in office buildings [6]. The slow speed on stairs in this study is probably due to the heterogeneous occupant composition in the residential buildings studied as well as the lack of training in evacuating these buildings.

Speed Comparison according to Gender

As was seen in previous analyses, ANOVAs were conducted on gender, this time for mean times to descend one floor. As Table 14 shows, there were no significant differences between males and females in any of the four buildings. In fact, the times were actually very similar. As was demonstrated earlier, gender does not play a role in the differences in speed while evacuating a building.

TABLE 14: Time comparisons according to gender for descending one flight of stairs

Building	Gender	Number	Mean time sec	Speed m/s	p-value
1	Male	12	16.3	.47	p=.9010
	Female	9	16.0	.48	
2	Male	18	16.6	.43	p=.9519
	Female	30	16.4	.44	
3	Male	22	15.8	.43	p=.4576
	Female	43	17.0	.40	
4	Male	18	9.3	*	p=.6458
	Female	22	9.8	*	

* Value not available

Speed Comparison According to Age

ANOVAs were conducted to study the impact of age on the speed on stairs. Table 15 shows the distribution of occupants over the seven age groups for all four buildings. In some cases, there were no subjects in a certain age group and the lack of time and speed in the table is represented by a dash.

TABLE 15: Speed on stair for all age groups

Building	Age Group	Number	Mean Time sec	Speed m/s
1	1	2	19.0	.40
	2	0	-	-
	3	1	20.0	.38
	4	1	7.0	1.08
	5	14	15.1	.50
	6	2	22.0	.34
	7	1	18.0	.42
2	1	0	-	-
	2	1	6.0	1.20
	3	2	4.0	1.79
	4	0	-	-
	5	11	12.8	.56
	6	13	13.0	.55
	7	21	22.5	.32
3	1	3	14.0	.49
	2	5	20.5	.33
	3	2	14.5	.47
	4	1	8.0	.85
	5	36	14.5	.47
	6	8	19.1	.35
	7	10	22.3	.30
4	1	1	7.7	*
	2	2	8.6	*
	3	5	7.9	*
	4	5	6.9	*
	5	19	9.6	*
	6	5	12.3	*
	7	3	13.4	*

* no dimension obtained for stairs

Various comparisons between age groups were made and the ANOVA tests were conducted on groups having more than five subjects. For Building 1, because many of the occupants did not use any stairs when evacuating, no real comparisons could be made. In Buildings 2 and 3, Group 7 (seniors) was significantly slower than the younger groups. This is a common trend as many of the elderly people had to use canes or the support of the handrail when descending the stairs.

Building 3 was the only one with a substantial number of small children aged 2-5 from Age Group 2. These children were significantly slower on the stairs than the adults of Age Group 5. Their speed on the stairs was very similar to those in Age Groups 6 and 7. Most likely this is because children at that age can walk but still have difficulty with stairs, sometimes descending one step at a time, holding the handrail at a height over their shoulders which slows their movement on the stairs. As was seen before, those over 65 travel significantly slower than the younger people during the evacuation, although seniors did not impede the evacuation of faster occupants who could overtake them on the uncrowded staircase. Contrary to the seniors, small children aged 2 to 5, who were accompanied by a parent, tended to use the full width of the staircase preventing other descending occupants to overtake them.

Carrying Children

There were only five occupants among all buildings who evacuated down the stairs while carrying a child. There were two in Building 1 and three in Building 3, as shown in Table 16.

TABLE 16
Mean times for subjects carrying children in stairs

Building	Mean time/floor sec	Speed m/s
Building 1	20.	.38
Overall Mean = 16.1	18.	.42
Building 3	12.	.57
Overall Mean = 16.6	17.	.40
	12.	.57

Although the speed of people carrying children is comparable to the general average speed, it was observed that these people had to take extra caution while going down the stairs. They were usually carrying the baby on one hip and holding the handrail with their free hand. The absence of crowding permitted the use of lateral space as needed which probably contributed to their fast speed of movement. In a more crowded staircase, the occupants carrying a child would probably have a slower speed and could impede the evacuation due to their posture and the extra care they have to take while moving down the stairs.

Group Behaviour During Evacuation

Through analysis of the videotapes, it became apparent that people travel in groups during evacuations. These groups are mainly pairs or groups of three. The composition of these groups is broken down and displayed in Table 17.

TABLE 17: Composition of groups

Building	2 Adults	2 Seniors	Adult/Child	3 Adults	3 Children	3 Mixed	4 +
1	4	1	2	2			1
2		4		3	1		
3	6	2	5	2		2	4
4	4		1	1		2	3

The most prevalent type of group was that of the couple. Out of the 50 groups who evacuated in all four buildings, 29 of those were couples. Families with small children (5 and under) would typically evacuate in a close group with a parent usually carrying one of the children or holding the child by one hand. As Table 17 shows, children rarely travelled without a parent. The family groups tended to split up as the children increased in age. Children, 6 and older, still travelled with the family but were usually four or five steps ahead and were in much more of a hurry to get to the bottom.

Although some seniors evacuated individually, they usually travelled in groups of two or three. Often, they would exit their apartment and gather together to discuss the fire drill and then proceed to leave the building in a group.

Table 18 compares the number of occupants who evacuated individually with those who evacuated in groups. In all buildings, except Building 2, more people travelled in groups than alone. For all buildings combined, the majority (62%) evacuated in groups of 2 or more.

TABLE 18: Distribution of evacuees alone and in groups

Building	Alone	in a Group
1	18	26
2	36	20
3	22	55
4	7	33
Total	83	134
%	38%	62%

These group formations very likely delayed the speed of movement of evacuees because members of a group tended to assume the speed of the slowest person. In most cases, the slowest person was a young child or an elderly person. Older people in groups also tended to stop to converse rather than maintain the same speed during the evacuation.

Direction of Movement

In all four buildings studied, the occupants had a choice of at least two staircases when evacuating. The different sets of stairs were not used equally as means of egress. It is generally believed that people will use the closest stairs to evacuate, however, more progressive concepts, such as "the affiliation concept", predict that people will move toward areas with which they are most familiar [4]. Areas around the elevators, and stairs leading to main exits, are seen as familiar. In apartment buildings, stairs that do not lead to main exits are rarely used. Therefore, people may use stairs that are less convenient in proximity to their apartment, simply because they automatically go to areas with which they are familiar. Table 19 shows the percentage of occupants using each staircase in the different buildings. Refer to floor plans in Section 4.0 for the exact location of staircases.

TABLE 19: Direction of movement

Building	Stair A	Stair B	Stair C
1	32%	68%	N/A
2	20%	39%	41%
3	25%	75%	0%
4	20%	60%	20%

The occupants of Building 1 had a choice of two sets of stairs located at extreme ends of the building. As the Table shows, the majority of the people used Stair B. The explanation was mentioned previously, the arriving firefighters directed the occupants toward Stair B. Therefore, much of the movement occurred on the side of Stair B.

In Building 2, the distribution of the occupants during the evacuation was more uniform. In this case, there were three possible sets of stairs to use in this "L"-shaped building. However, Stair B, located in the centre of the building, and Stair C, leading out to a garden and play area, were favoured.

In Building 3, Stair B was mainly used because it is located at the centre of the building near the elevators which is the familiar direction of movement to leave the building. Some evacuated through Stair A, which is located at an extreme end of the building. Stair C, located in the limited access wing where only elderly people lived, was not used at all. Many of the elderly were immobile and did not evacuate. Those who did evacuate moved toward the elevators to see what was happening and then proceeded to use the central staircase – Stair B. People refrained from using Stair C as well because it led to the back of the building next to the garbage container.

The rectangular Building 4 has three sets of stairs. Stair A and Stair C are on extreme ends of the building and Stair B is in the middle, close to the elevator. The results in Table 19 show that a similar small number of people used the stairs at the extreme ends while the majority used the stairs in the middle. Stair B is central to the apartments and is located close to the elevator

To evacuate, most occupants of the four buildings used either the most central staircase located in their familiar path of travel or a staircase that lead to a familiar area.

6.0 GENERAL CONCLUSIONS

The results of this study show that the inability of people to hear the fire alarm from their apartments is a major factor in delaying the evacuation of a building. In two of the buildings studied, some occupants could not hear the fire alarm from their apartments. Consequently, these occupants started their evacuation only when the arriving firefighters knocked at their doors, providing a mean time to start the evacuation of 9:02 for these two buildings. Overall, it took about 25 minutes to totally evacuate these two buildings. This evacuation time is much too long because it would have impeded the work of firefighters if there had been a real fire and, by that time, the presence of smoke in the corridors and staircases could have become a serious threat to evacuees.

In the two other buildings, where the alarm was audible to most occupants, the mean time to start the evacuation was 2:49. This time is probably a good representation of the time normally used by occupants to prepare to evacuate their apartment. Questionnaires showed that this time delay was used to get dressed, gather valuables, find children or find pets. Most of the mobile occupants had already evacuated when firefighters arrived which made their work more easy.

These first results show that it is essential to develop strategies to shorten the time to start the evacuation in a way to reduce the total evacuation time of all occupants. Most of all, building management should make sure that every occupant can hear the fire alarm from every location in the building. One way to make sure that the alarm is audible is to have alarm bells in each apartment. This strategy is better than trying to increase the sound of alarm bells in corridors and stairs because their sound is usually at the limit of audible comfort. Making alarm bells louder could impair hearing for people who have to

pass close to the bell. A too-loud alarm is also counter-productive because occupants cannot discuss a plan of action and exchange information about the situation which is essential in a real fire emergency. As shown in this study in Building 1, the addition of alarm bells set at a lower sound level in each apartment appears to be the appropriate strategy to ensure that every occupant is aware of the situation.

This study also shows that more information and training is necessary to make people understand that immediate response is important for their safety and for the safety of others. Education should be provided on what action is expected from occupants when the fire alarm sounds. Occupants who have some limitation should receive specific information on what action they are expected to take when the alarm sounds. The local fire department can be a great help in providing accurate information on fire safety and emergency procedures.

Results of the statistical analyses showed that gender had very little influence on the outcome of the evacuation procedure for all buildings. There were differences between the speeds of males and females but none of these differences were significant enough to support any conclusions that gender plays a role in the speed of an evacuation.

Looking at all four buildings, age was also not a strong factor in determining the speed of the evacuation. In some cases, the younger people did move faster than the older individuals, but this result did not always hold true. Basically, there were very few significant time differences among the age groups. Interestingly, in two of the buildings, seniors moved faster in starting their evacuation but moved slower in the corridors and the stairs. Eventually, they reached safety in approximately the same mean time as people from the other age groups. Consequently, having a proportion of 20 to 45% of mobile seniors in regular residential mid-rise buildings does not change the overall evacuation time and procedure for all occupants.

Altogether, whether the occupants had some limitation or not, did not have a great impact on the evacuation timing. People with limitations who evacuated were generally slower than others but this difference was only significant during the actual moving time outside the apartments. The overall evacuation time, however, was not significantly affected by the presence of people with limitations because most occupants with serious mobility limitations stayed in their apartments waiting to be rescued by arriving firefighters. Once firefighters moved these occupants to a safe area, most of the other occupants had generally started their evacuation or were already outside. Occupants with mobility limitations had received specific information a few days before the exercise on the evacuation procedures and actions expected from them. Usually these occupants had never received any specific instructions on evacuation procedures and were reassured with the information received and the outcome of the exercise.

Occupants in three of the four buildings studied showed a comparable mean speed on the stairs. Among all occupants, they travelled between .41 m/s and .47 m/s on non-crowded stairs which is a slow speed but comparable to some other studies in crowded office buildings. The heterogeneous occupants' composition can explain the slow speed on stairs as well as the lack of training in evacuating their building. It was demonstrated that gender did not play a role in the differences in speed while evacuating a building. Two groups of occupants travel slower on stairs then other occupants; those over 65 and children between the age of 2 and 5. These occupants did not generally slow other evacuees because there were no crowds on the stairs and it was easy for faster occupants to take overtake slower ones.

Most occupants tended to evacuate in groups. In three of the buildings studied, there were more people exiting in groups, than individually. The majority of these groups were couples. Children, for the most part, evacuated in a group which included an adult. When travelling in groups, all members tended to move at the pace of the slowest member of the group.

Finally, occupants tended to use either the most central staircase located in their familiar path of travel to exit the building, or a staircase that led to a familiar area, such as the main entrance. The proximity of a staircase to the apartment played a limited role in the choice of a staircase to evacuate.

7.0 RECOMMENDATIONS

1 **It is imperative to make sure that every occupant in a residential building can hear the fire alarm from every area of the building**. An evaluation of the audibility of the fire alarm system should be made once the building is occupied. This assessment should be made with the residents of the building. An easy way to assess if everyone can hear the fire alarm is to perform an evacuation drill. After the drill, a short questionnaire can ask occupants if they heard the alarm or the building manager can go to every door and ask the occupants if they heard the alarm.

2 **To improve the audibility of the fire alarm, the number of fire alarm bells should be increased rather then increasing the sound of existing alarm bells**. In most buildings, the sound of each alarm-bell is loud enough. In fact, increasing the sound of each alarm-bell would not be a viable solution because the resulting sound levels would be too high for people directly exposed to it and could cause hearing impairment for evacuees. A too loud alarm would also prevent exchange of information between people, which is often essential. To improve the audibility of the fire alarm, the best way is to increase the number of alarm-bells, ideally locating an alarm-bell in each apartment. Researchers Sultan & Halliwell [8] at NRCC have developed guidelines for proper location of alarm bells in apartment buildings.

3 **The number of false alarm should be limited**. False alarms tend to reduce occupants' participation in evacuations since the occupants consider the alarm as an unreliable source of information to indicate an emergency situation. It is important to reduce the number of false alarms to rebuild faith of occupants about the meaning of the alarm.

4 **In buildings where a public announcement system is installed, it should be used to give evacuation instructions to the occupants**. It is, however, necessary to test the system to make sure that everyone can hear and understand the content of the messages from all areas of the building.

5 **Occupants with hearing disabilities should have a compensatory alarm system linked to the central fire alarm**. It is essential that occupants with hearing disabilities be provided with an acceptable "alarm system" to make them aware of an emergency situation at the same time as other occupants.

6 **Occupants with limitations should personally be met to discuss the evacuation procedure**. People with limitations are often very worried by the idea of an emergency and have very little knowledge of what would be expected of them. A specific procedure should be planned by the building management and be explained to the occupants. The local fire department can help in providing specific instructions according to their own procedures.

7 **Specific training should be undertaken with occupants of non-Canadian cultural background**. Problems arose during evacuations because some occupants did not understand the meaning of the fire alarm. Some were also frightened by the firefighters and refused to vacate their apartments. It is necessary to provide an information session for these residents in their own language, if necessary.

8 **Building occupants should be aware of the planned evacuation procedures for their buildings**. The evacuation procedures should be posted in the elevator lobby, the staircases and other specific areas, such as the laundry room or the underground garage. It would be worthwhile to provide a copy of the evacuation procedures to every resident when they sign their lease, for example.

9 **Building occupants should practice the planned evacuation procedures**. Once a year, it would be useful to perform an evacuation drill to make sure that occupants recognize the sound of the fire alarm, experience different means of egress and apply any specific procedures for their building.

8.0 REFERENCES

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ANNEX 1
Memo distributed to occupants

EVACUATION DRILL

***** An evacuation drill will be carried out in the coming weeks *****

The _____ building has been selected to be part of a research project on evacuation procedures. The National Research Council of Canada, in collaboration with the Canadian Mortgage and Housing Corporation, and the _____ Fire Department will be studying the evacuation drill.

For the research project, the evacuation drill will be filmed with video cameras located in different corridors and staircases. All the video-films will be keep confidential and will be viewed only by Ms. Guylène Proulx the principal investigator, and her research team from NRCC.

After the evacuation drill you will be asked whether you are willing to fill a short questionnaire on your experience during the drill. Your name and address will be kept confidential. You are free to refuse to fill out this questionnaire.

We know that an evacuation drill is disruptive but we need to carry this out for your safety and that of others. Drills and training are the best way to know how to deal with an emergency situation. It is why it is important for everyone to participate.

If you have any questions on this research project, please call the principal investigator:

Dr. Guylène Proulx
National Fire Laboratory
National Research Council of Canada
Ottawa, Ontario
K1A 0R6

Tel.: (613) 993-9634

Exercice d'évacuation

*** Un exercice d'évacuation en cas d'incendie
aura lieu dans les prochaines semaines***

Votre bâtiment situé au _____ a été sélectionné pour faire partie d'un projet de recherche concernant les procédures d'évacuation en cas d'incendie. Le Conseil national de recherche du Canada, ainsi que la Société canadienne d'hypothèque et de logements et le Services d'incendie de la ville de _____ vont étudier cet exercice d'évacuation.

Dans le but de réaliser cette étude des cameras vidéo vont filmer l'évacuation. Ces cameras vont être positionnées dans certains corridors et cages d'escaliers. Tous les films vidéo seront tenus confidentiels et seront utilisés uniquement par Mme Guylène Proulx et son équipe de chercheurs.

Après l'exercice d'évacuation on vous demandera de remplir un questionnaire concernant l'exercice. Vos noms et adresse ne seront pas mentionnés. Notez que vous pouvez refuser de remplir le questionnaire sans fournir d'explication.

Nous savons que les exercices d'évacuation crées des inconvénients mais rappelez vous qu'il s'agit de votre propre sécurité et celle des autres. Participer à des exercices permet de mieux connaître les procédures d'évacuation et permet de mieux réagir en cas d'urgence. C'est pourquoi il est important de participer.

Si vous avez des questions concernant ce projet de recherche n'hésitez pas à communiquer avec: Dr. Guylène Proulx
Laboratoire national d'incendie
Conseil national de recherche
Ottawa, Ontario
K1A 0R6

Tél.: (613) 993-9634

ANNEX 2
Questionnaire post-evacuation

While using the staircase to evacuate did you have any problems such as;

- ☐ opening the door
- ☐ entering the staircase
- ☐ going down the steps
- ☐ finding the handrail
- ☐ other _____

7. Did you need assistance to evacuate the building? ☐ Yes ☐ No

8. Have you taken part in an evacuation in this building before? ☐ Yes ☐ No

   If Yes, how many times,_____ when was the last time,_____

9. When you started to evacuate the building did you think it was;

   - ☐ a real fire
   - ☐ an evacuation drill
   - ☐ a false alarm

10. Do you always leave the building when you hear an alarm? ☐ Yes ☐ No

11. Do you suffer from any limitations that could prevent you from evacuating a building? ☐ Yes ☐ No

    If Yes, explain the kind of limitation you have: _____
    _____
    _____
    _____

12. Your age _____ Sex: ☐ F ☐ M

Thank you for your help.

Dr. Guylène Proulx, Researcher,
National Fire Laboratory
National Research Council of Canada
Ottawa, Ontario
K1A 0R6

Phone: (613) 993-9634

Résidents du _____
Questionnaire sur l'exercice d'évacuation

1. Avez-vous participé à l'exercice d'évacuation de votre immeuble ce soir?
   ☐ Oui ☐ Non, si la réponse est non, ne pas remplir ce questionnaire.

2. Avez-vous entendu l'alarme d'incendie? ☐ Oui ☐ Non

3. Si oui, à votre avis, l'alarme d'incendie était; ☐ trop forte
   ☐ suffisamment forte
   ☐ pas assez forte

4. Où étiez-vous lorsque l'alarme s'est mise à sonner?
   ☐ Dans votre appartement;
   - ☐ dans la cuisine
   - ☐ dans le salon
   - ☐ dans la chambre, ☐ endormi?
   - ☐ dans la salle de bain

   ☐ A l'extérieur de votre appartement;
   - ☐ sur le balcon
   - ☐ dans le corridor
   - ☐ dans l'ascenseur
   - ☐ au sous-sol
   - ☐ dans le hall d'entrée

   Sur quel étage?_____

5. Qu'est-ce que vous avez fait comme première, deuxième et troisième action après avoir entendu l'alarme? Écrivez 1, 2, 3 dans les carrés;

   - ☐ chercher les enfants
   - ☐ chercher un parent
   - ☐ chercher un chat, un chien, etc.
   - ☐ s'habiller
   - ☐ diriger les autres
   - ☐ téléphoner pour avoir de l'information
   - ☐ demander aux autres quoi faire
   - ☐ regarder dans le corridor ce qui se passe
   - ☐ chercher sacoche, porte-monnaie, etc.
   - ☐ regarder par la fenêtre
   - ☐ aller sur le balcon
   - ☐ attendre de l'aide
   - ☐ rien
   - ☐ quitter le bâtiment
   - ☐ autres _____

6. Pour quitter le bâtiment avez-vous pris; ☐ l'ascenseur ☐ les escaliers

   Si vous avez utilisé les escaliers, est-ce que c'est un escalier que vous utilisez; ☐ très souvent ☐ rarement
   ☐ à l'occasion ☐ c'était la première fois que j'utilisais cet escalier

En utilisant les escaliers avez-vous rencontré des problèmes du genre;

- ☐ difficulté à ouvrir la porte
- ☐ difficulté à entrer dans la cage d'escalier
- ☐ difficulté à descendre les marches
- ☐ difficulté à trouver la rampe (main-courante)
- ☐ autres choses _____

7. Avez-vous eu besoin d'aide pour évacuer le bâtiment? ☐ Oui ☐ Non

8. Aviez-vous déjà participé à des exercices d'évacuation dans ce bâtiment avant ce soir? ☐ Oui ☐ Non

   Si, Oui combien de fois,_____ la date de la dernière fois,_____

9. Quand vous avez commencé à évacuer le bâtiment avez vous pensé qu'il s'agissait;
   - ☐ d'un vrai feu
   - ☐ d'un exercice d'évacuation
   - ☐ d'une fausse alarme

10. Est-ce que vous quittez toujours le bâtiment quand vous entendez l'alarme? ☐ Oui ☐ Non

11. Est-ce que vous avez des limitations physiques qui pourraient vous empêcher d'évacuer un bâtiment? ☐ Oui ☐ Non

    Si Oui, expliquer le genre de limitations que vous avez:_____

    _____

    _____

    _____

    _____

12. Votre âge _____ Sexe: ☐ F ☐ M

Merci de votre collaboration.

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