Evacuation Data from a Hospital Outpatient Drill The Case Study of North Shore Hospital

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Abstract – Assessing the fire safety of buildings is fundamental to reduce the impact of this threat on their occupants. Such an assessment can be done by combining existing models and existing knowledge on how occupants behave during fires. Although many studies have been carried out for several types of built environment, only few of those investigate healthcare facilities and hospitals.
In this study, we present a new behavioural data-set for hospital evacuations. The data was collected from the North Shore Hospital in Auckland (NZ) during an unannounced drill carried out in May 2017. This drill was recorded using CCTV and those videos are analysed to generate new evacuation model inputs for hospital scenarios. We collected pre-movement times, exit choices and total evacuation times for each evacuee. Moreover, we estimated pre-movement time distributions for both staff members and patients. Finally, we qualitatively investigated the evacuee actions of patients and staff members to study their interaction during the drill. The results show that participants were often independent from staff actions with a majority able to make their own decision.

Keywords: Hospital Evacuation, Human Behaviour, Pre-evacuation, Unannounced Evacuation Drill.

1. Introduction

Many egress models have been developed in the recent decades and they are used worldwide to assess the fire safety of buildings. To date, egress model users need to specify input values such as pre-evacuation times, evacuee speeds and evacuee actions, to define an evacuation scenario depending on the occupancy of the building. This is done by selecting those values from existing databases, when available, (see for instance [1-3]) or by making reasonable assumptions. Evacuation data is therefore needed to model and simulate occupants' behaviour [4, 5] as well as to validate existing and new evacuation models [6, 7].

Many drills have been carried out in a wide range of building types, such as schools, apartments, stores and cinemas to collect egress data (reader can refer to [1] for a comprehensive list of those drills). However, only few studies investigated healthcare facilities and hospitals. Moreover, existing studies, carried out in healthcare environments, have been mainly conducted to evaluate the movement data such as evacuee walking speeds in horizontal planes [8-9] and in stairways [9-12]. Only two studies [13, 14] have been carried out to quantify the pre-movement times and evacuees' behaviours in case of an emergency happens in such buildings. For example, the study by Gwynne *et al*. [13] performed at a Londoner hospital outpatients' facility which showed that in a hospital the onus is really on staff members. In fact, it was found that the patients observed and studied the staff members actions and made decisions based on their perception. One of the social behaviours that was observed in this study is that patients only evacuated once a figure of authority had instructed them to do so. Later, Folk *et al*. [14] conducted an announced fire drill at a retirement home in Canada. They attempted to develop a baseline for the behaviour and actions of elderly people during pre-movement and travel phases of the engineering evacuation timeline model [1]. They observed through this study that some residents exhibited information seeking behaviours, either exiting their rooms or opening their room doors to observe the situation. It was also shown that the residents were dependent on staff members. Even the residents who were fully ambulant did not evacuate until a staff member went to their room, prompted them to leave, and walked with them to the fire doors.

The goal of this paper is to expand existing data on hospital evacuation by analysing evacuee behaviours during an unannounced evacuation drill recorded using the closed-circuit television (CCTV) videos. The drill was carried out in one of hospital outpatients' areas of the North Shore Hospital in New Zealand (see Fig. 1 and 2) and it involved 55 evacuees. Two participants had disabilities: a wheelchair user and a patient with a walking stick. A behavioural analysis was performed to study evacuees' decision-making and behaviours. Moreover, different quantitative measurements were also made by analysing those videos such as pre-movement times, exit choices and total evacuation times. Finally, we propose new pre-evacuation distributions and compare them with the existing data provided in [13].

Fig. 1 – CCTV shot showing evacuees in the corridor and main waiting room

Fig. 2 – CCTV shot showing evacuees targeting the main exit

2. Experimental Methods

The drill was part of the routine evacuation drills conducted twice a year at the hospital according to NZ regulations [15]. This drill was unannounced and involved both staff members and patients. There were two classes of staff members: the staff who had a procedural role and the staff who had not. Staff members with a procedural role swept each of the rooms, forcing the occupants to leave the building and informed them of the path they should follow. It should be noted that the patients were in majority capable of evacuating the building without any help from the staff. Only about 4% of patients with disabilities were involved into the drill. In general, patients took part into the drill in the same manner as other participants excepting those who needed for assistance. Upon the completion of the drill, video images were analysed, frame by frame, using a video software (i.e. using Avidemux) and results were transcribed onto a spreadsheet file (i.e. using Excel).

Approval was obtained from Waitemata District Health Board (WDHB) committee to analyse the CCTV recordings of an evacuation drill held in May 2017. The drill was carried out in the outpatients' area of the hospital. This area extends over three floors and is currently used for a variety of purposes. However, only the ground floor is accessible to the patients. The upper floors include offices, stores, kitchens and teaching rooms allocated to the University of Auckland and for administrative purposes. Fig. 3 shows the configuration of the ground floor. This floor houses mostly clinic rooms, staff offices and waiting areas and has three exit points: the main exit (Exit A in Fig. 3) and the emergency exits (Exits B and C in Fig. 3), while the upper floors have two emergency exits (the staircases in Fig. 3).

Eight CCTV cameras were used to collect data relating to the starting position of evacuees, their actions, their pre-evacuation times, their exit choices and their total evacuation times. These cameras are permanently located throughout the building at each final exit, waiting rooms and corridors (see Fig. 3 for their locations) and are normally used for security issues. Given the permanent positions of those cameras with a majority not located within rooms (excepting the one located in the main waiting room), the pre-movement time of evacuee is defined as the time from the beginning of the alarm signal to the time the person left the applicable room. This approach is consistent with previous studies such as [16], [17], [18] and [19].

Fig. 3: building configuration, CCTV cameras and exits locations

3. Results

3.1. Pre-movement time

For the analysis of pre-movement time, a subset of total population (i.e. 55 evacuees) could not be investigated because their initial positions were not covered by the surveillance system as those cameras are located only on the ground floor. In total 30 pre-evacuation times were measured from the drill: 14 staff members and 16 patients. The pre-movement times of the observed population are categorised according to the different areas: main waiting room, sub-waiting room, pathology area, lift lobby area and corridor area as reported in Table 1.

Table 1: Pre-evacuation times in seconds for the staff members and the patients

	Staff		**Patients**		**All**	
Area	**Mean (St Dev)**	**Range (Sample size)**	**Mean (St Dev)**	**Range (Sample size)**	**Mean (St Dev)**	**Range (Sample size)**
Main Waiting Room	63.6 (29.0)	25.0 - 95.0 (5)	36.1 (10.2)	22.0 – 52.0 (9)	45.9 (22.6)	22.0 - 95.0 (14)
Sub-Waiting Room	12.0*	12.0 – 12.0 (1)	33.0*	33.0 - 33.0 (1)	22.5 (14.8)	12.0 – 33.0 (2)
Pathology	34.0 (24.0)	17.0 - 51.0 (2)	57.5 (7.8)	52.0 - 63.0 (2)	45.8 (19.9)	17.0 - 63.0 (4)
Lift Lobby	12.0*	12.0 – 12.0 (1)	NA	NA	12.0*	12.0 – 12.0 (1)
Corridor	49.8 (21.3)	33.0 - 87.0 (5)	17.5 (11.3)	7.0 - 33.0 (4)	35.4 (23.8)	7.0 - 87.0 (9)
All	47.1 (27.7)	12.0 - 95.0 (14)	33.9 (15.3)	7.0 - 63.0 (16)	40.1 (22.6)	7.0 - 95.0 (30)

*Using the formula $\sqrt{\sum \frac{(x-\bar{x})^2}{(n-1)}}$ for the standard deviation of a sample, it is not possible to obtain a numerical value for only one participant
NA means no patient was in this area

There were seven patients in the "main waiting room" when the alarm signal was sounded. The video recordings showed that those patients started to seek information by looking around and at the staff members. However, none of them evacuated prior to being instructed to do so. These observations are consistent with the studies [13] and [14]. Two other patients evacuated from adjacent clinic rooms without necessarily being dependent upon the staff actions. The average patient pre-evacuation time observed was 36.1 seconds, while the average staff pre-evacuation time observed was 63.6 seconds. At the beginning of the drill, there was only a staff member in the main waiting area. Despite their presence, no instruction was given to the patients present there to evacuate before seeing other people leaving the building. From the video footage, it was apparent that the average staff pre-evacuation time was increased by the late evacuation of two fire wardens who swept the areas of the building to encourage individuals to evacuate. Also, due to the presence of a few vulnerable people, some staff members showed an assisting behaviour (e.g., helping an elderly to rise or assisting a wheelchair user to leave the building) which increased the average staff pre-evacuation time.

Two occupants were initially in the "sub-waiting room": one patient and one staff member. The staff member was in an adjacent clinic room to this area. S/He started the evacuation after 12 seconds, whereas the patient started the evacuation after being instructed to do so by a fire warden who appeared into the area after 20 seconds. Hence, the average patient pre-evacuation time observed was 33 seconds while the average staff pre-evacuation time observed was 12 seconds.

There were four participants in the "pathology area": two staff members and two patients. The average staff pre-evacuation time was 34 seconds while the average patient pre-evacuation time was 57.5 seconds. After 57 seconds, a fire warden appeared in the area but he did not saw the patient who was not in her/his field of view. Hence, the presence of the fire warden in this area had no impact on reducing the pre-movement time of the patient.

Only one staff member was in the "lift lobby area". S/He took 12 seconds to start the evacuation.

There were 5 staff members and 4 patients in the "corridor area". The staff members were seen to act after 2 seconds (e.g., searching for their warden vest). However, the first one started to evacuate only after 33 seconds when being sure that no patient is still in the area. The mean staff pre-evacuation time observed was 49.8 seconds, while the mean patient pre-evacuation time was 17.5 seconds. The mean staff pre-evacuation time was increased by the late evacuation of some staff members who did not have a procedural role. Some of them waited in the corridor and started to move only after being instructed to do so by a colleague. Other staff members stayed at their room (e.g. clinical room or office) until they have been notified by another staff member. Another staff member who had a procedural role (i.e., a fire warden), started to evacuate only after 95 seconds.

3.2. Exits usage

Table 2 reports the exits used by staff members and patients during the drill as well as their initial positions and the closest exits to their initial positions. The reader can refer to Fig. 3 to locate each of the positions. It can be seen from Table 2 that all evacuees (i.e. 30 occupants) inside the ground floor evacuated through the main entrance (i.e. Exit A), the same door which they walked in, even those who were close to the emergency exits (18% of the participants), while all participants who were inside the first floor (i.e. 25 occupants) evacuated through the staff entrance (i.e. Exit B). The exit routes were therefore the normal routes for the evacuees. It seems that occupants were guided by familiarity. To be more efficient, staff members should familiarise themselves with the use of alternative exits.

Table 2: Exits usage

Initial Positions	Closest exits	Staff	Exits Used	Patient	Exits Used
ADMIN	Exit A	2	Exit A	1	Exit A
VAccWC	Exit A	-	-	1	Exit A
MW	Exit A	1	Exit A	7	Exit A
NS020	Exit A	2	Exit A	-	-
SW058	Exit B	-	-	2	Exit A
SW032	Exit C	-	-	1	Exit A
R016	Exit B	1	Exit A	-	-
CR023	Exit C	1	Exit A	-	-
CR044	Exit C	1	Exit A	-	-
CR048	Exit A	1	Exit A	-	-
CR050	Exit B	2	Exit A	-	-
CR056	Exit B	1	Exit A	1	Exit A
CR060	Exit B	1	Exit A	1	Exit A
CR064	Exit B	1	Exit A	2	Exit A
1stLevel	Exit B or C	25	Exit B	-	-

3.3. Evacuation curve and exits flow rate

Fig. 4 shows the relation between the number of evacuees and arrival time for all the occupants, including the fire wardens who were last to leave the building. The reader should be aware that the arrival time is the sum of the pre-movement time and travel time. This means, that it doesn't include the detection and warning times of the engineering evacuation timeline model. As seen in Fig. 4, the first person reached an exit after 11 seconds. It should be also noted that the arrival time was increased by the late arrival of two fire wardens who were checking that everyone is out of the building and this can be seen from the long tail of the curve in Fig. 4. After 2 min 13 seconds, all the occupants were evacuated. In addition, it should be noted that about 75% of occupants left the building between 37 seconds and 1 min 23 seconds.

This data can also be broken down according to the arrival time for exit A (i.e. main exit) and exit B (i.e. emergency exit) because the flow rate of each exit was different. Exit C was not used by occupants. Thus, the flow rate is equal to zero and it is not reported in Fig. 5. According to Fig. 5, a general trend was that participants who were initially in the ground floor left the building earlier compared to those initially located in the first floor. This might be the result of lower pre-movement time values or lower travel distances. Unfortunately, these assumptions cannot be verified as it was not possible to collect data on the pre-evacuation quantities of the first-floor occupants neither their starting positions. To garner a greater understanding of factors influencing the evacuation time of this subset of occupants and to investigate their pre-evacuation activities, cameras in the first floor are desirable.

Another observation is that most participants (about 87%) who took exit A were evacuating in "one large group", between 37 seconds and 1 min 15 seconds. For those who were initially in the first floor, it can be identified that at least three groups of people evacuating together at different time intervals (see the red marks in Fig. 5) were formed. The first group evacuated between 52 and 54 seconds. The second one evacuated between 68 and 83 seconds. The last group evacuated between 102 and 107 seconds.

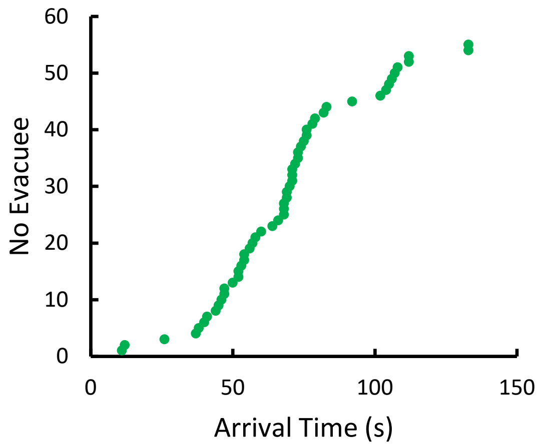


Fig. 4: Evacuation curve. The arrival time (x-axis) starts from the fire alarm.

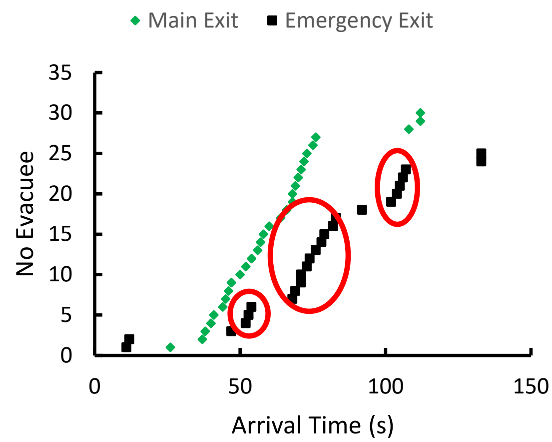
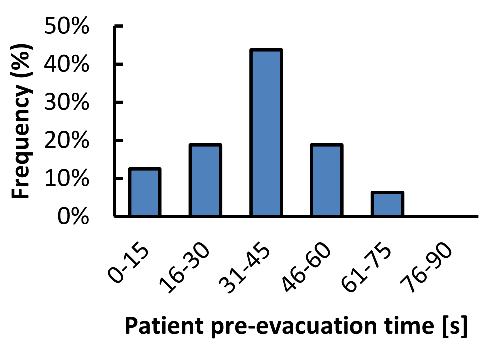


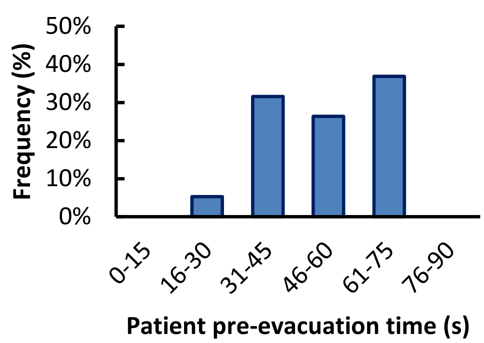
Fig. 5: Arrival time for the exits used during the drill. The red marks identify three groups of people evacuating together.

3.4. Comparison of collected pre-evacuation data with previous studies

Fig. 6 and Fig. 7 show patients and staff members pre-evacuation times distributions retrieved from the present study and from a previous study by Gwynne *et al.* [13] using a class limit of 15 seconds. According to Fig. 6a, it is apparent that very long pre-evacuation times were rare. In fact, most patients responded between 0 and 60 seconds. In the study by Gwynne *et al.* [13] (see Fig. 6b), most patients responded between 30 and 75 seconds. It was concluded from [13] that this reflected the time for the staff to instruct patients to evacuate and for patients to collect their personal goods, more than the time it took them to process the alarm signal information or to perform other pre-evacuation behaviours. The difference in patient pre-evacuation times distribution may be explained this way: in the current study not all the patients were dependent upon staff actions; some of them evacuating with no prior prompting; whereas, in the study by Gwynne *et al.* [13], the patients' movement was fully dependent upon staff members action. The data presented in the current study gives a better understanding on how patients behave in a hospital outpatients' area as most of them acted following their own decisions.

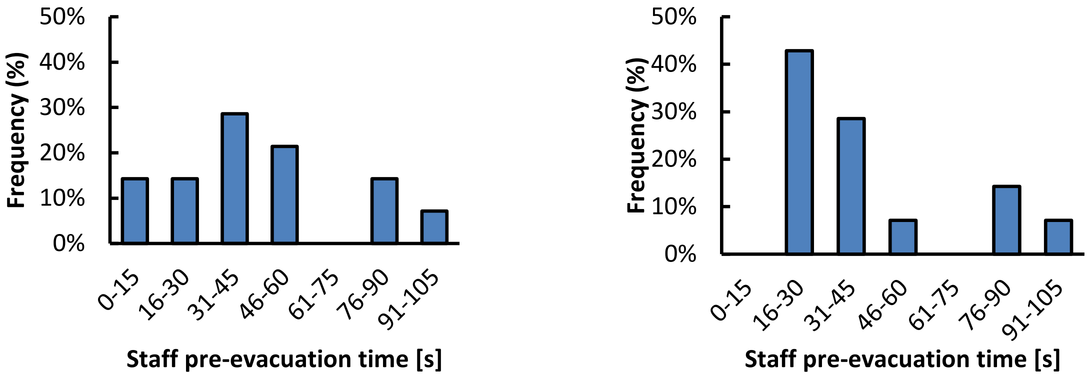


a- Current study



b- Previous study by Gwynne *et al.* [13]

Fig. 6: Frequency distribution of patient pre-evacuation times



a- Current study b- Previous study by Gwynne *et al.* [13]

Fig. 7: Frequency distribution of staff pre-evacuation times

4. Conclusion

This study presented new evacuation data of 55 occupants evacuating one of the North Shore Hospital outpatients' areas (Auckland, NZ) based on the recordings of an *unannounced* fire drill. This drill involved a heterogeneous population consisting of staff members and patients. Pre-movement times of a subset of the population were obtained as well as the exits choice, the drill evacuation curve and exits flow rate. From the collected data, new pre-movement time distributions for patients and staff were estimated and compared with the data provided in [13]. These new distributions are useful to feed evacuation models to simulate hospital evacuations. However, the model users should be aware of the context of this data and its limitations. The data was collected to be used for hospital evacuation simulations and specifically for outpatients' area evacuation simulations.

The pre-movement time calculations showed differences in patient pre-evacuation time distributions between the current study and the previous one by Gwynne *et al.* [13]. Indeed, the patients in the current study were less dependent upon staff members action.

We recommend that staff members should familiarise themselves with the alternative emergency exits (i.e. exits B and C). In fact, all the participants, including staff members, made their exit choice based on their habits with the building. The routine usage of the doors to get in the building was one of the reasons leading to these observations. However, the staff having a procedural role, reacted and acted efficiently. They were the last to evacuate the building and often made prompt decisions asking people to move as quick as possible and showing the routes to follow for getting out. In addition, when help was needed, the assistance of at least one staff member was essential.

The drill was completed reasonably fast (i.e. 2 min and 13 seconds). However, the occupants who were inside the ground floor evacuated faster than those who were inside the first floor. This may be explained by three different reasons: 1) The travels distances of occupants of the first floor were greater than those of the ground floor; 2) walking speeds were lower than those of the occupants of the ground floor; 3) their pre-movement time was greater than the one of the occupants of the ground floor. Unfortunately, these hypotheses cannot be verified due to the absence of cameras in the first floor. Cameras in this floor and inside rooms are desirable to garner a greater understanding of factors influencing the evacuation time of occupants and to investigate their pre-evacuation activities.

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