Quantified Levels of Risk to Life Safety in Deemed-to-satisfy Apartment Buildings

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ABSTRACT

A range of twelve building designs contained within and deemed to satisfy the performance requirements of the Building Code of Australia have been modelled to determine their risk to life safety due to fire. The risk is measured in terms of the expected fatality rate per 1000 fires, for occupants of the apartment of fire origin (AFO) and the apartments of non-fire origin (ANFO). Three groupings of buildings have been identified from the computer modelling based on the ANFO results. Low-rise (< 4 storeys) buildings were found to have average ANFO fatality rates of ≤ 0.2 fatalities per 1000 fires. Medium-rise buildings with heights less than 25 m but with four or more storeys were found to have average fatality rates of 3.3 to 3.4 fatalities per 1000 fires. High-rise buildings with heights equal to or greater than 25 m had average fatality rates ranging from 1.7 to 2.1 fatalities per 1000 fires. These differences show the impact of different minimum fire safety systems (e.g., sprinklers in buildings ≥ 25 m in height) required by the Building Code of Australia. Interestingly there are discrete steps in these fatality rates across the range of buildings that are also present in the fire statistics. This paper reports the first computer based quantified levels of risk to life safety in apartment buildings with the minimum deemed-to-satisfy fire-safety systems.

KEYWORDS: risk modelling, fire statistics, performance-based building codes

INTRODUCTION

Regulators and designers need information on the effectiveness of fire-safety systems so that they can make rational decisions on which systems to incorporate into buildings, particularly when they have to choose between different systems or combinations of fire-safety systems, or to determine the levels of performance required of some systems. The traditional approach is to utilize the empirically developed “deemed-to-satisfy” regulatory requirements, which simply present accepted solutions. A risk-informed decision and design approach requires that the regulatory objectives be stated and quantified for evaluating the effectiveness of alternatives.

Currently there are no performance requirements in operational building safety codes that are quantified in terms of risk to life safety. A first step towards correcting this is to quantify the risk to life of deemed-to-satisfy building designs so that the communities currently accepted level of safety is identified. In a performance-based framework, it follows that these levels of safety are values that must be equalled or bettered to satisfy a set of performance requirements. This paper presents for the first time the results of

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computer modelling to quantify the risk to life safety in apartment buildings designed using the minimum deemed-to-satisfy fire-safety requirements of the Building Code of Australia [1].

For reasoned decision-making in the design process it is preferable to have quantified measures to compare different fire safety systems or their components. Ideally it would be possible to assess the effectiveness of fire safety systems and components based on their actual performance and the outcomes when fires occur in buildings [2]. However, there is very limited capability to do this because:

1. fires are quite infrequent events in buildings (relative to the number of buildings) and thus when changes are made to fire safety systems or components a substantial period of time must elapse before there are sufficient fires in relevant buildings for an accurate estimate of the corresponding change in the level of safety (this relates to property losses which can be recorded for every fire)
2. fatalities are even more infrequent (on average fatalities occur in less than seven in every thousand fires that are reported in residential buildings and in less than one in a thousand reported fires in non-residential buildings [2]) even in fires that are reported to fire brigades (which are the only fires for which significant records are available); thus to obtain estimates of the effect of changes on fatality rates many thousands of fires are required and the accumulation of them takes a very long period of time (because, initially at least, there are very few buildings with the changed fire safety system or component)
3. the fire statistics that are available do not include sufficiently detailed data on the buildings themselves or on the fire safety systems or components in the buildings (for example, in the USA NFIRS statistics [3] only the presence of sprinklers, detectors and protected construction is meant to be recorded, and even for these systems it is difficult to estimate their effectiveness in many occupancies [2])

Consequently it is necessary to estimate the effectiveness of fire safety systems and components based on models that reflect how we think fire safety systems work, but also to check the models as far as possible directly against reality. So, for example in relation to an objective such as life safety, ideally we need to consider all of the factors that might influence the rate of fatalities that would occur in fires in a building and to estimate for each factor the change in the fatality rate due to that factor. To do this a variety of modelling techniques can be used in association with fire statistics.

In this study computer modelling was conducted using CESARE-Risk [4] (also known as FIRE-Risk), a multi-scenario building fire simulator, to estimate the risk to life safety in a range of representative apartment buildings. The risk computed by CESARE-Risk is measured in terms of a fatality rate, the number of fatalities per 1000 fires, and this measure is determined for the occupant of the apartment of fire origin (AFO) and the occupants of the apartments of non-fire origin (ANFO). These two fatality rates are then combined to determine the total fatality rate of the building per 1000 fires in that building. The total fatality rates for the prescribed building designs are then compared to the NFIRS fire statistics [3].

The use of CESARE-Risk is contributing to an ongoing process of identifying and removing unnecessary, ineffective and non cost-effective safety requirements; a process of regulatory assessment and refinement.

THE CESARE-RISK MODEL

CESARE-Risk has been developed to assist in evaluating the effects of changes in fire-safety system designs on fire safety performance and the overall cost of fire in buildings. At present the model is applicable to apartment buildings, hotel and motel buildings and aged-care facilities. The work reported here focuses on apartment buildings (Class 2 buildings [1]) and only the life safety of the occupants has been assessed in this study, not the injury rate or economic loss.

The model has been presented in previous publications [4-7] and will only be briefly summarized here. It must be noted that the model has undergone substantial development since the earlier publications and will continue to be improved as new information and modelling methods are implemented. To date, the main areas of improvement have been associated with the AFO and include fire development, smoke movement and occupant behaviour. The accuracy and sensitivity of the model has been assessed to some extent by extensive sensitivity studies [4,5].

CESARE-Risk analyses the likelihood and consequences of 384 fire scenarios using a suite of sub-models ranging from fire growth to human response models. The scenarios represent different fire types, internal ventilation states and occupant states. Each of these scenarios may have a very large number of realisations due to the variability of the numerous factors that can affect the outcome. A simplified approach has been used where continuous distributions have been replaced by equivalent three-point discrete distributions [4].

CESARE-Risk has two parts that contribute to the estimate of the risk. One of these parts is referred to as the time dependent part of the model (TDP), the other as the non-time dependent part (NTD). The TDP models fire development and its consequences on a time-step basis with the size of the fire, the spread of smoke, and the effect on and response of the building fire safety system components and occupants being evaluated at each time-step. The occupant modelling includes probabilistic response and evacuation modelling, in parallel with injury, incapacity and fatality determination.

The NTD part is based around an event tree analysis and focuses on scenario likelihood and probable consequences using point estimates. The NTD part evaluates probabilistically the additional fatalities and damage caused by spread of smoke and fire beyond the room of origin including the possibility of fire spread throughout the building.

The outcomes of each part for each scenario are the expected numbers of injuries and fatalities, and the extent of damage to the building. These are then combined, weighted by the probability of each scenario, to provide an overall estimate of the expected fatalities, injuries and economic loss due to fire.

The risk of fatalities for all occupants for fires starting in an apartment on any storey ($l = 1 \ldots M$) in the building is

$$R = f \sum_{l=1}^{M} n_l \left(L_{AFO,SG} + L_{ANFO,l} \right) = f\, N\, L_{AFO} + f\, N\, \overline{L}_{ANFO} \tag{1}$$

where n_l is the number of apartments on the l^{th} storey, f is the frequency of fire-starts in an apartment (assumed to be the same whatever the storey) and the total number of apartments in the building is $N = n_l M$ for a total number of storeys in the building, M .

The ANFO fatality rates, $L_{ANFO,l}$, have been computed in this study by moving the LFO up through the building being modelled. The average ANFO fatality rate is then determined based on the computed values of $L_{ANFO,l}$. The fatality rate of the occupants of the AFO is given by $L_{AFO,SG}$, where SG denotes one of two possible types of occupant of the AFO discussed in the next section. The fatality rates computed by CESARE-Risk represent the outcomes of scenarios given a fire start in the building while Eq.1 includes the probability of a fire starting within the building ($P_i = fN$).

The sensitivities of CESARE-Risk have been extensively assessed and comparison made with fire statistics for two international reviews [4,5].

INPUTS TO CESARE-RISK MODELLING

Building Designs

The fire safety systems in the modelled apartment buildings have been chosen based on the (subjective) *minimum* deemed-to-satisfy requirements of the Building Code of Australia (BCA) [1], these requirements are deemed to satisfy the performance requirements. The minimum requirements are expected to lead to the minimum safety levels available as design options in the BCA. From a regulatory perspective the outcome of the risk modelling will be an estimate of the fatality rate that a performance-based design of a similar building must not exceed.

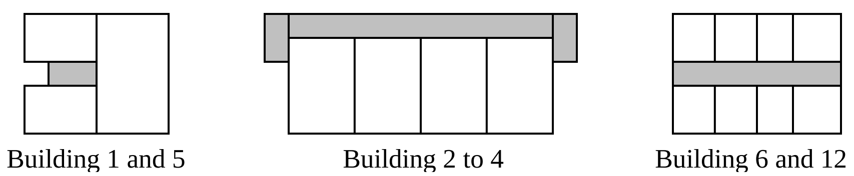

Fig. 1. Shows the buildings basic floor plans.

Basic floor plans for the twelve buildings modelled are presented in Fig. 1. In Table 1 the fire safety systems required by the BCA are presented. A physical description of the buildings is given below along with the modelled fire safety systems (this ignores exit lights, signs etc.). The physical features that have fire safety impacts are also presented as components for simplicity. The BCA requires that the construction of apartments buildings be either Type A or Type B, with an option for Type C when the apartments have direct egress to safe places (i.e., outside). The types of construction range roughly from more fire resistive construction (Type A) to less fire resistive forms of construction (Type C). Type A is typified by fire resistance levels (FRL) of 90-minutes, Type B has generally 90 to 60 minute FRL, and Type C construction is typified by FRLs of 60 to 30 minute.

Building 1 (Low-rise)

This is a two-storey block of apartments with internal stairwell connecting the levels. Apartment access is directly from a stairway landing and the stairway exits directly to the outside. All apartments are single room apartments (50 m^2) and the AFO has a room of fire origin (RFO) of 12 m^2.

Table 1. Fire safety systems and components in the modelled buildings.

Building Number	Number of Storeys	Apartments per Storey	Fire Safety System Description
1	2	3	Point Detector/Alarms in apartments, public spaces and corridors protected by linked detector/alarm system, Type B const., solid core doors[a]
2	2	4	Point Detector/Alarms in apartments only, Type B const., solid core doors[a], public balcony
3	2	4	Point Detector/Alarms in apartments only, Type C const., solid core doors[a], apartment exits direct to outside
4	2	4	Point Detector/Alarms in apartments only, Type B const., solid core doors[a], apartment exits direct to outside
5	3	3	Fire detector/alarms as in Building 1, Type A construction, solid core doors[a]
6	5	8	Fire detector/alarms as in Building 1, Type A const., fire rated apartment doors[b]
7	6	8	Fire Safety System as in Building 6, plus private apartment balconies
8	9	8	Fire Safety System as in Building 7
9	10	8	Point Detector/Alarms in apartments only, sprinklers, stairwell pressurisation, electronic fire brigade notification, Type A const., private balconies, fire rated apartment doors[b]
10	12	8	Fire Safety System as in Building 9
11	16	8	Fire Safety System as in Building 9
12	25	8	Fire Safety System as in Building 9

[a]solid core apartment doors modelled as FRL 30 minutes.
[b]fire rated apartment doors are modelled as FRL 60 minutes.

Building 2 (Low-rise)

This building is a two-storey block of apartments with an open public balcony (2 m wide) and external open stairs (2) at each end that are shielded by the bounding wall on either end of the building. The second storey apartments have access/egress via the balcony and first storey apartments access/egress is direct to the outside. All apartments are single room apartments.

Building 3 and 4 (Low-rise)

These are two-storey apartments buildings with direct access from all apartments to outside (hill side). All apartments are two bedroom apartments (85 m^2) with the AFO having a RFO of 17 m^2. Building 3 is of Type C construction and Building 4 is of Type B construction.

Building 5 (Low-rise)

Building 5 is a three-storey block of modern apartments, with the same layout and one storey higher than Building 1. The extra storey forces a requirement for Type A construction.

Building 6 to 8 (Mid-rise)

Buildings 6 to 8 vary in the number of storeys from 5 to 9 as shown in Table 1, but have the same layout as shown in Fig. 1. There is an internal corridor (length 40 m) with fire-isolated stairwells at each end. Building 7 and 8 have private balconies for each apartment and a lift shaft, while Building 6 has no balconies and no lifts.

Building 9 to 12 (High-rise)

These buildings all have the same basic floor plan as shown in Fig. 1 but have different numbers of storeys as shown in Table 1. The buildings all have private balconies for each apartment.

Modelling Particulars

The presence of private balconies means that the occupants of the apartments have the option to take refuge on the balconies during the TDP, if they can not escape or are not rescued they will contribute to the fatalities calculated in the NTD parts smoke and fire spread. Mobile occupants of the first and second storeys have the option of escaping via the windows or balconies, unless they are overcome by smoke. Buildings 2, 3 and 4 have no means of internal smoke spread and fatalities are only due to fire spread calculated in the NTD part.

Occupants Inputs

In order to simplify modelling, the occupants of the ANFOs are classified in six “occupant groups” (OG). These occupant groups are based on the Australian Bureau of Statistics census data of 1996. These data are used to give an indication of who is living in apartment buildings and the approximate ratios of household types. These groups are: a lone person under 71 years of age, a lone person over 70 years of age, two parents and a child, 2 persons (no child), a lone person who does not respond to cues (alcohol or drug affected etc.), 2 persons where one is disabled and the other is a carer.

There are two occupant groups used in modelling of fire consequences in the AFO. One group is responsive and is referred to as super group 1 (SG1). The second group is non-responsive and thus non-mobile, they are labelled as super group 2 (SG2) in the AFO.

RESULTS OF CESARE-RISK MODELLING

Fatalities in the Apartment of Fire Origin (AFO)

The occupants of the AFO are exposed to a range of 48 fires, ranging from smouldering fires to flaming and flashover fires. The scenarios to be examined are then defined by the parameters of the AFO; for example, the location of the occupants, RFO door open or closed, RFO window open or closed, detector/alarm location, fire type etc.

All of the results presented are limited to those resulting from the use of probabilities determined from US fire statistics [3], which are large data sets and cover the full range of buildings modelled here. The available Australian fire statistics do not adequately cover the full range of buildings modelled and more recent Australian fire statistics are not available.

Table 2 presents the results for the all of the AFO occupants in all of the buildings modelled. The occupant fatality rate in the AFO is insensitive to the size of the RFO in the one- and two-bedroom apartments modelled. It is also independent of where the AFO is located in the building. Table 4 shows the same results for Buildings 1 to 8 and another result for Buildings 9 to 12 because the AFO conditions are the same in those groups of buildings. There are two main impacts on the AFO fatality rate, the presence of sprinklers (in Buildings 9 to 12) and the potential for a non-responsive occupant (SG2) to be in the AFO. The non-responsive SG2 suffers high fatalities as a result of their inability to evacuate.

Table 2. AFO fatality rate results.

	Fatality rate per 1000 fires for Super Group 1	**Fatality rate per 1000 fires for Super Group 2**
Buildings 1 to 8	1.4	16.7
Buildings 9 to 12	1.3	6.1

Delving into the detail of the scenario simulation, Super Group 1 effectively evacuates in the great majority of scenarios, there are no fatalities in the scenarios where the SG1 occupants are awake (day time), irrespective of their location in the AFO. All of the SG1 fatalities occur in the fire scenarios for which they are initially asleep. Both SG1 and SG2 suffer fatalities for all of the flaming and flashover fires when they are located in the RFO. At most, SG1 fatalities are one one-hundredth of the SG2 fatalities in any single scenario. When located in the RFO, SG2 results in fatalities in all scenarios involving flaming and flashover fires irrespective of day or night conditions.

Fatalities occur in some smouldering fire scenarios for SG1 during the night and similar scenarios involving SG2 during the day and night. These smouldering fire fatalities occur in the cases when the RFO door and windows are closed. When they are in the room of non-fire origin (RNFO which is in the AFO) fatalities do not occur.

For buildings fitted with sprinklers the impact on reduced fatality rate of SG2 is significant. The impact of sprinklers on the responsive SG1 is quite minor; as discussed below.

Fatality Rate in the Apartments of Non-Fire Origin (ANFO)

The ANFO occupants are exposed to flaming and flashover fire scenarios to determine the expected fatality rate. Smouldering fires have no impact on the ANFO occupants, as would be expected. To determine the fatality rate of the occupants of the ANFO the level of fire origin (LFO) is moved up through the building. Resulting in a number of fatality rates for a given LFO, the average over these results is the average fatality rate of the ANFO occupants for that building (see Eq. 1 above). Scenario parameters include all the AFO parameters, smoke spread paths in the building (e.g., AFO door and Stair door states), responses of occupants, and fire brigade intervention.

Buildings 1 to 5

Table 3 presents the ANFO results of CESARE-Risk modelling of Buildings 1 to 5. In Table 3 it can be seen that Buildings 1 and 5 have nominally the same average building fatality rates, while CESARE-Risk estimates zero fatalities in Buildings 2, 3 and 4. The zero fatality rate is because of small fire spread probabilities and the dominance of smoke spread fatalities in CESARE-Risk.

Table 3. ANFO fatality rate in Buildings 1 to 5.

Level of Fire Origin	**Fatalities per 1000 fires**				
	Building 1	**Building 2**	**Building 3**	**Building 4**	**Building 5**
1	0.3	0.0	0.0	0.0	0.2
2	0.2	0.0	0.0	0.0	0.2
3	NA	NA	NA	NA	0.2
Average Fatality Rate per 1000 fires (std. dev.)	**0.2 (0.1)**	**0.0**	**0.0**	**0.0**	**0.2 (0.0)**

Buildings 6 to 8

The results for Buildings 6 to 8 are presented in Table 4. The fatality rates when the first two storeys are set as the LFOs of the building are quite low because of the ability of the occupants to escape through the windows or from the balconies of the 1st and 2nd storeys. Fatalities in the model are usually concentrated on the LFO and the storey above. The high fatality rate on the top floor of the building is due to a non-responsive occupant (OG5) appearing on that storey in a systematic manner. The average fatality rates for each building show only slight variation from 3.3 to 3.4 fatalities per 1000 fires.

Buildings 9 to 12

For these buildings not every storey was set as the LFO, due to the time required to run the model (about 14 hrs for one LFO of Building 12). The results of varying the LFO up through each high-rise building is that very little variation in the fatality rate is observed in the central storeys. Significant variation is seen in the first and second storey where the occupants have the option to escape via the windows or balconies, and the top storey where a non-responsive occupant systematically appears. The larger population of Building 12 is a factor in the larger average fatality rate for that building.

Summary of Scenario Simulations

This section summarizes the details of ANFO fatalities in the buildings modelled. The scenarios with the AFO door open and/or stair door open are the least likely scenarios but the number of fatalities they generate are substantial, the most likely scenarios occur with either or both of those doors closed and the outcome in this case is a greatly reduced number of TDP smoke spread fatalities. In the scenarios (AFO door open, daytime) contributing the most fatalities due to TDP smoke spread there was a consistently high number of fatalities in the corridors on the LFO (about 65 to 80 %) and in corridors on some storeys above the LFO (about 10 %) when the stair door was open. At night the great majority (>80 %) of (TDP) smoke spread fatalities occur in apartments and there is an increase in NTD smoke and fire spread fatalities because of the increased number of occupants trapped by the TDP smoke spread. The greater number of fatalities occurs at night rather than during the day.

Table 4. ANFO fatality rate of Buildings 6 to 8.

Level of Fire Origin	Fatalities per 1000 fires		
	Building 6	Building 7	Building 8
1	2.2	2.0	2.1
2	2.5	2.1	2.3
3	3.5	3.5	3.5
4	3.3	3.2	3.5
5	5.4[a]	3.3	3.5
6	NA	5.4[a]	3.5
7	NA	NA	3.3
8	NA	NA	3.3
9	NA	NA	5.4[a]
Average fatality rate per 1000 fires (std. dev)	**3.4 (1.3)**	**3.3 (1.2)**	**3.4 (0.9)**

[a]Top storey of building. NA: Not applicable, building does not have this storey.

Table 5. ANFO fatality rate in Buildings 9 to 12.

Level of Fire Origin	Fatalities per 1000 fires			
	Building 9	Building 10	Building 11	Building 12
1	0.6	0.6	0.6	0.7
2	NC	NC	0.6	0.8
3	NC	NC	1.9	2.4
5	1.9	1.9	1.9	2.4
7	1.9	1.9	1.9	2.4
9	1.8	1.9	1.9	2.4
10	2.7[a]	NC	NC	NC
12	NA	2.5[a]	1.9	2.4
14	NA	NA	1.9	NC
15	NA	NA	NC	2.3
16	NA	NA	2.5[a]	NC
18	NA	NA	NA	2.3
21	NA	NA	NA	2.3
24	NA	NA	NA	2.3
25	NA	NA	NA	2.8[a]
Average fatalities per 1000 fires (std. dev.)	**1.8 (0.8)**	**1.8 (0.7)**	**1.7 (0.6)**	**2.1 (0.7)**

[a]Top storey of the building. NC: not computed. NA: Not applicable, building does not have this storey.

As the LFO is moved up through the building the number of TDP fatalities decreases with the decrease in exposed population. The NTD part only varies significantly at the first two storeys where people trapped by smoke can escape via windows and at the top storey where a non-responsive/non-mobile occupant is trapped and not rescued, thus representing a large proportion of the estimated fatalities.

Total Fatality Rates

Figure 2 presents the AFO fatality rate with the total of the ANFO and AFO fatality rates for SG1 and SG2 set as the occupants of the AFO, respectively (see Eq. 1). The result for SG2 dominates when it is added to the ANFO result of all the buildings. The ANFO result dominates when combined with the SG1 result in Buildings 6 to 12 (mid- and high-rise buildings) but the SG1 fatality rate is the greater proportion in Buildings 1 to 5 (low-rise buildings). Fig. 2 also shows that the total fatality rate changes in discrete steps over the range of buildings. The step from Building 5 to 6 is to a degree a result of the differences in exposed building populations between the low-rise and mid-rise buildings. A difference of this nature is not as large for the population increase from Building 11 to 12. The step down from Building 8 to 9 is due to the discrete building criteria that trigger substantially different deemed-to-satisfy requirements in the Building Code of Australia; for example, the need for sprinklers in buildings greater than 25 m in *effective height*.

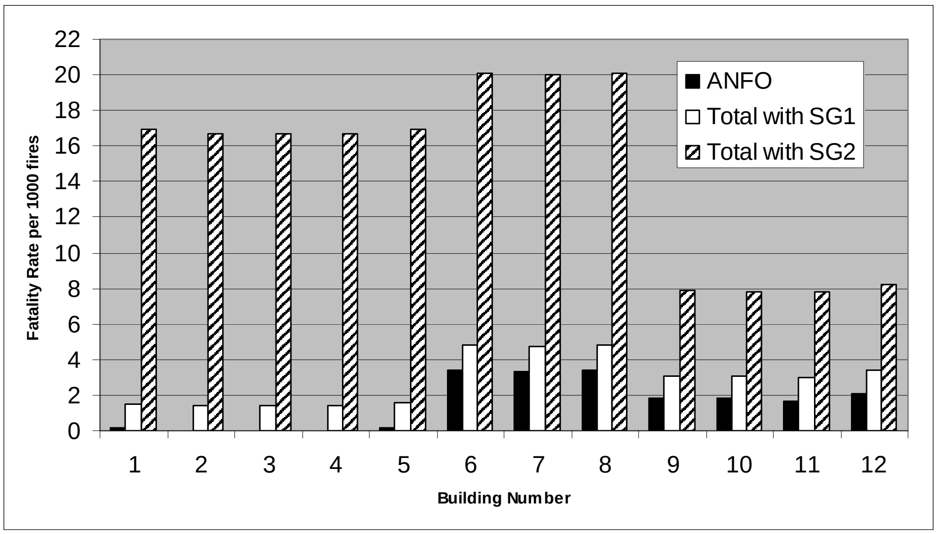

Fig. 2. ANFO and total fatality rates in the AFO using either SG1 or SG2.

FIRE STATISTICS

Fire statistics from the NFIRS database [3] presented in Table 6 indicate that there is no statistically significant difference in the fatality rate per 1000 fires for the buildings in the range 5 to 24 storeys. For comparison with the modelling it is necessary to consider the situation with respect to sprinklers and no sprinklers in the building. This is not so simple because the data in Table 6 includes buildings that are not fitted with sprinklers, buildings for which the presence of sprinklers is unknown and buildings that do have sprinkler systems; Table 7 presents these data in terms of sprinkler presence without the "unknown" data. In Table 7 shows a drop in fatality rate from buildings of 12 storeys or less without sprinklers, to building of 13 or more storeys with sprinklers.

DISCUSSION

The estimate of the total expected deaths and injuries is largely made up of the occupants of the AFO particularly in low-rise buildings that do not have the means of spreading (and containing) smoke internally. Across all the buildings the probability of the presence of a non-responsive (SG2) AFO occupant is a significant risk factor both in terms of the total risk and the risk to an individual of this type. Interestingly responsive occupants of mid-rise buildings represent only about one-third of the total risk, but almost half of the high-rise total risk. These proportions reflect findings based on fire statistics and coroner's reports [8] that most injuries and fatalities are occupants of the AFO and that the probability of injury and fatality of other occupants is much lower than for the occupants of the AFO. In the study of coroner's reports non-responsiveness was a significant factor in some age groups of males. To a large extent the AFO component reflects the 'individual' risk and the ANFO component reflects the 'societal' risk.

Table 6. NFIRS statistics for fires in apartment buildings.

Storeys	Number of Fires	Number of Fatalities	Fatality Rate/1000 fires
1 – 4	166581	1541	9.3
5 – 6	8569	63	7.4
7 – 12	9918	70	7.1
13 – 24	6766	47	6.9
25 +	1830	12	6.6

Table 7. NFIRS statistics for fires in apartment buildings with sprinkler information.

Storeys	Number of Fires		Number of Fatalities		Fatalities per 1000 fires	
	No Sp.	Yes Sp.	No Sp.	Yes Sp.	No Sp.	Yes Sp.
1 to 4	139258	3665	1335	8	9.6	2.2
5 to 6	5600	1439	46	7	8.2	4.9
7 to 12	6166	2385	55	7	8.9	2.9
13 to 24	4741	1221	39	0	8.2	0.0
25 +	602	280	8	0	13.3[a]	0.0[a]

[a]Based on relatively few fires and therefore should be used with caution.

Building code requirement for sprinklers and stairwell pressurisation in high-rise buildings leads to a significant drop in both the AFO and ANFO fatality rates as modelled by CESARE-Risk. The fire safety component contributing most to this result is the presence of sprinklers [5]. The NFIRS statistics at first glance do not show any discrete steps in fatality rate but when they are considered in terms of sprinkler presence or not, then the drop seen in the modelling results becomes apparent. The actual point at which this occurs is not clear in the statistics.

Reduction of the average fatality rate appears to be the main approach of building code requirements as opposed to fire start frequency. It appears also that the majority of building code requirements are aimed at reducing the average fatality rate for occupants of the ANFO, rather than the much higher rate for the occupants of the AFO.

CONCLUSION

This paper has presented the first results of computer modelling to quantify the levels of safety in prescribed apartment buildings. The results indicate that there are three separate building groups (low-rise, mid-rise and high-rise) characterised by the fatality rates of the occupants of the apartments of non-fire origin. Prescribed requirements for sprinklers in high-rise buildings lead to a discrete drop in the total fatality rate of the modelled buildings. This drop is also reflected in fire statistics when sprinklers presence is considered.

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