Means of escape from a fire is one of the most important aspects of a building design. This applies whether it’s a new building or an old one undergoing alteration, change of use, extension of life or subdivision. In an old building, the Building Act 2004 cites means of escape as one of the first aspects to be addressed. The Building Act also enables the New Zealand Fire Service, to which a building design has been submitted, to provide the relevant building consent authority with a memorandum that sets out advice on provisions for means of escape from fire.

All modern international building codes give high importance to means of escape, as does the New Zealand Building Code and compliance documents.

Inadequate means of escape can be deadly
Most fatalities in fires occur because occupants cannot escape before they are affected, whether by smoke inhalation or direct contact with the fire. This is most marked for fires in places with a lot of people, such as shopping centres, malls and nightclubs. For example, Dublin disco (1981), Bradford Stadium (1985) and Paraguay supermarket (2004).

Several of these high-profile fires highlighted egress problems and changes to building codes resulted in a number of cases. Reports on these incidents regularly state that means of escape were inadequate, with some of the main contributing factors being:

- overcrowding
- locked or blocked exits (mostly for security)
- inappropriate features (final exit doors opening inwards)
- poor exit definition (lack of signage and instruction from staff/fire wardens)
- inadequate warnings (no alarms)
- inadequate active fire protection (no sprinkler systems)
- occupant inattentiveness (unappreciative of the speed of fire growth or part of the ‘show’).

In house fires, human factors such as alcohol, drug use and age play a significant part in impeding escape.

These factors are mostly addressed by the New Zealand Building Code Clause C Fire Safety, Compliance Document C/AS1 Part 3, which gives requirements for:

- number of exits
- conditions when single means of escape are permitted
- path lengths and widths
- features of escape routes
- lighting and signs.

The Fire safety and evacuation of buildings regulations 2006 provide for alarms and fire wardens. Together these form a prescriptive Acceptable Solution to devising means of escape, but an Alternative Solution is possible based on the concepts of ASET and RSET.

ASET and RSET
Available Safe Egress Time (ASET) is the time for the fire to grow to such an extent as to prevent safe escape. Required Safe Egress Time (RSET) is how long occupants will take to leave a building safely. The two can be summarised as follows:

- ASET: driven by fire development – determined by fire model
- RSET: driven by human behaviour – determined by evacuation model.

To determine ASET, computer fire models such as FAST, BRANZFIRE and Fire Dynamics Simulator (FDS) are commonly used to give information on temperatures, smoke levels and tenability – the ability of people to survive under the simulated fire conditions.

At its simplest level, RSET is modelled on people’s speed of movement and passage through openings. There is a large field of historical data based on commuter pedestrian traffic flows, but this may not be representative of building evacuation. Evacuation time may vary with the pre-movement behaviours and decision making by occupants, and this must be included in RSET.

Computer-based evacuation models
There are many complex computer-based evacuation models. EVACNET4, EGRESS, SIMULEX, EXIT89, and BuildingEXODUS are some of those commonly available. Each model has a different approach.

EVACNET4 is a flow-based model. The egress of evacuees is determined almost entirely on the basis of a building’s physical constraints. No provision is made for motion rules that apply to social interaction or group processes.

EGRESS uses the concept of ‘cellular automata’ which gives individuals a space around them and models the node density in individual floor ‘cells’. Occupants are modelled as ‘individuals’ on a grid.

SIMULEX is an agent-based model that ‘individualises’ the movement of groups. That is, it fixes a certain set of attributes to each person, so that their walking speed is assessed independently of the average
density of a group in a defined area. The model allows each person to decide upon his or her walking speed. SIMULEX includes several factors such as physical motions and gestures (body swaying and twisting), the proximity of other occupants, the shape of the building structure, and the influence of gender and age (parameters defined for persons 12–55 years old). These factors are said to have social significance but are not based on concepts or information about social relations, culture, or group integration. Instead, the program assumes the presence of a rational person able to assess the optimal escape route, avoid physical obstruction and overtake other occupants who impede their movement.

EXIT89 is similar in concept but uses different processes.

BuildingEXODUS provides the most complete set of social psychological attributes and characteristics for each occupant. This set includes age, name, gender, breathing rate, running speed and dead/alive. The model simulates the egress of large numbers of persons from an enclosure. It also accounts for the eventual cessation or delay of movement due to extreme heat or effect of toxic gases. Within BuildingEXODUS, an occupant’s knowledge of the structure is not necessarily fixed. They can use the signage system to help them find a route out of an unfamiliar building and can communicate with each other and pass on exit location information.

Post-fire investigation

These evacuation models have been used to gain an understanding of what happened in fires. SIMULEX was used to evaluate people movement in the 2003 Rhode Island disco fire in which 100 people died. A feature of this fire was that most occupants made for the main exit whilst other exits were not used. Other contributing factors were the speed of fire growth and delays in evacuation because people thought the fire was part of the show. Another SIMULEX output shows various stages of movement within the building.

BuildingEXODUS was used to model the evacuation process in the 1998 Gothenburg nightclub fire where there were 63 fatalities. The building was approved for 150 occupants, but there were estimated to be 400 present at the time. Part of the output is shown in Figure 1.

Behaviour is key

The outputs from evacuation models, whilst showing complex graphics and using computer algorithms, must be treated with care. An analysis of EXIT89 and SIMULEX simulations of a high-rise hotel building evacuation, in which the same design elements were used, found significant differences in egress times.

EXIT89’s evacuation times were 25–40% lower than those of SIMULEX for the design scenarios. These differences between the models were attributed to differences in unimpeded speeds, movement algorithms, methods of simulating slow occupants, density in the stairs, and stair configuration inputs. EXIT89 also produced maximum evacuation times 30–40% lower than those of SIMULEX. These results show that more work needs to be done to validate evacuation models.

There are many methods of ensuring the physical characteristics of a building meet the escape requirements, from the prescriptive requirement of the appropriate building code to a fire engineering design. But in the end it’s the behaviour of people during fire that counts. Good escape procedures and preparedness plans are therefore crucial. This applies to all buildings, simple or complex, large or small, including your own home.