EVACUATING VULNERABLE AND DEPENDENT PEOPLE FROM BUILDINGS IN AN EMERGENCY

David Crowder and David Charters

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EXECUTIVE SUMMARY

This guide has been written for those involved in developing plans and strategies for evacuating premises containing large proportions of people with mobility impairments:

- fire safety managers
- facilities managers
- nursing staff, particularly staff responsible for the day-to-day care of those with mobility impairments
- architects and designers
- fire safety engineers
- approval authorities.

It is intended to provide some understanding of:

- The role of fire safety management, and its interaction with the role of front-line staff.
- The role of fire protection systems in buildings and the role of appropriately trained staff, and the importance of striking a balance between fire protection levels and staffing levels:
  - fire detection and alarm systems and their effect on pre-movement time, reducing the Required Safe Egress Time
  - suppression systems controlling fires, increasing the Available Safe Egress Time
  - passive fire protection systems containing fires, increasing the Available Safe Egress Time.
- The amount of time available for evacuating people, and how this is determined by the level of fire protection provided throughout a building. The greater the level of protection designed into a building, the greater the time will be available for evacuation to be completed, and the smaller the number of staff that will be required to assist in that evacuation.
- The different strategies that are available for protecting building occupants, particularly those with mobility impairments, from fire.
- The potential difference in the levels of a person's ability to carry out horizontal or vertical movement.
- Points to consider in evacuating people with mobility impairments.
- Techniques available for evacuation.
- The importance of training in maximising the effectiveness of staff helping to evacuate people with mobility impairments.
- Ensuring that care can continue to be provided to individuals, where necessary, after an evacuation has been completed.

Appendices have been provided to give more information on the behaviour of fire, as well as on some of the findings of the data analysis carried out during the drafting of this guide.

The research presented in this guide was undertaken before the investigation into the Rosepark care home fire was published, but much of the information it contains should help to prevent future similar fire events.

1 INTRODUCTION

There is no simple way to know how long it will take a person with mobility impairments, or a highly dependent person, to evacuate or be evacuated from a building before conditions become untenable because of fire. For example, in the attack on the World Trade Center in 2001, over 1000 surviving occupants had a limitation that affected their ability to evacuate, including recent surgery or injury, obesity, heart condition, asthma, advanced age and pregnancy. An investigation into the evacuation indicates that evacuation flow rates were approximately half those normally observed in fire drills[1].

Recent fires, such as those at the Rosepark care home (where 14 people died)[2] and at Warrington District General Hospital (three staff were injured while evacuating patients) illustrate how society's most vulnerable people are at risk from fire.

In addition, many of the 400 or so attendees at a series of seven fire safety seminars run by BRE indicated that 'if they had a magic wand, the fire safety problem they would like to solve' would be the need for a better understanding of evacuation of mobility-impaired people. Delegates' responses included the following:

'Realistic evacuation times/travel distances for residential care premises.'

'Evacuation time/staff ratio in respect of residential care premises. We include figures for staffing levels and bed complement in compartments. We will probably have to step back from this in future – I'm not aware of any research re dependency of patient/staff and travel distances.'

'Patient evacuation training – how far, how long, health and safety issues, legal issues, physical – should actual patients be involved?'

'The effectiveness of signage in a fire.'

A research programme was therefore commissioned by BRE Trust to consider the means of evacuating people who are elderly or ill, or children, from buildings – residential care, healthcare and domestic premises.

This guide has been written as the outcome of that research. It aims to provide support for designers, owners and managers of buildings so that they can formulate efficient strategies for the effective evacuation of people with mobility impairments.

Qualitative guidance is given to illustrate the points to consider when developing an evacuation strategy that will be as inclusive as practicably possible.

Formulae and data are also provided in order to quantify the relationship that exists between the size and nature of a population that may need evacuating, the resources that are available to effect that evacuation and the level of fire protection afforded by the building requiring evacuation.

This guidance is supplementary to that provided by HTM 05-03: Part K[3] as well as the Fire Safety Risk Assessment Guides, and in particular:

- *Fire safety risk assessment: healthcare premises*[4]
- *Fire safety risk assessment: residential care premises*[5]
- *Fire safety risk assessment supplementary guide: means of escape for disabled people*[6].

It is intended for application to buildings that have been designed and constructed according to the Building Regulations[7]. As well as buildings designed to satisfy the recommendations of Approved Document B[8] or HTM 05-02[9], it may be equally suitable for fire-engineered buildings.

This guide has been prepared particularly for those responsible for buildings in which large numbers of people with mobility impairments are expected to be present. It gives an overview of the nature of existing fire strategies in healthcare premises, particularly with respect to evacuation.

It is intended to provide information for management as well as front-line staff, since it is successful communication between these two groups that will maximise the effectiveness of evacuation strategies.

The research carried out for the production of this guide involved BRE Global gathering information from evacuation drills and real evacuations. Two evacuation drills were organised with the direct involvement of BRE Global, and information (video and questionnaires) was submitted on a further six exercises and two real incidents over the course of a three-year period. The data from these evacuations and evacuation drills cannot be included in this guide for reasons of data protection.

The research presented in this guide was undertaken before the investigation into the Rosepark care home fire was published, but much of the information it contains should help to prevent future similar fire events.

2 ROLES

2.1 FIRE SAFETY MANAGEMENT

The fire safety manager or management team is responsible for coordinating the various aspects of a fire evacuation strategy so that they work together efficiently and effectively. This is especially true when the occupants' dependency and the design features of a building require those in the building to be aware of the necessary actions in the event of a fire, and possibly be involved in ensuring that those actions are taken.

When organising an evacuation that includes people with mobility impairments, effective fire safety management should ensure that sufficient people with relevant training are available to take control of the situation. They will be aware of the most effective methods for evacuating people, and of the most efficient order in which to carry out the evacuation. People managing evacuations may wish to take measures such as separating evacuators into two groups, one dealing with the preparation of mobility-impaired people, the other dealing with getting those people out. The decisions that need to be taken will vary from one situation to another, but an effective fire safety manager will be familiar with the needs of the occupants of the building for which they are responsible, and will therefore have sufficient information with which to make these decisions.

Fire safety managers are responsible for organising the training of staff on the evacuation of people with mobility impairments. Training should include understanding the systems installed in the premises, and instruction on suitable techniques and strategies for carrying out evacuations. Research shows that drills are essential if staff are to evacuate those occupants of a building who cannot evacuate themselves, efficiently, quickly and safely. Drills can be carried out safely if prior consideration is given to manual handling and infection control.

A successful fire safety plan, capable of satisfying the requirements of the Fire Safety Order[10], will need to include an evacuation plan that ensures the safety of those at risk from fire. This will be most effectively achieved through consultation with all the people involved in undertaking the evacuation.

2.2 ROLE OF FRONT-LINE STAFF

Staff responsible for the day-to-day care of people with mobility impairments are most likely to be physically involved in assisting an evacuation, should it be required. However, they will also be able to provide useful information on which techniques are likely to succeed in achieving successful evacuation. They will be most familiar with evacuees' requirements, and therefore will be able to evaluate how best to evacuate them from the building, and how much time and help will be needed.

In the case of people with mental impairments, children or elderly people, it is those staff who interact with them on a regular basis that will know how to achieve an efficient evacuation without causing undue distress to individuals. Keeping evacuees calm can be crucial to avoiding losing time due to evacuees resisting help or becoming lost in the building.

Patients in acute healthcare premises may be attached to one or several pieces of equipment as part of their treatment or life support. Front-line staff should be consulted on whether a person can be disconnected from any of this equipment, and for how long. Plans for ensuring continuity of care are vital, particularly for patients on life support.

Acute care staff will already have plans and techniques in place for moving patients during normal circumstances, and in the event of power cuts, equipment failures or medical emergencies. Fire safety is not necessarily a primary concern for such staff, but using the skills and knowledge that they already possess can expedite training significantly. This will be discussed later in Section 7: Training.

3 AVAILABLE SAFE EGRESS TIME AND REQUIRED SAFE EGRESS TIME

The time that passes between the ignition of a fire and the onset of life-threatening conditions is the maximum time that occupants have to move to a place of safety. This is often referred to as the Available Safe Egress Time (ASET).

The total time needed for evacuation is termed the Required Safe Egress Time (RSET). This is often compared with the ASET to determine whether or not a particular fire scenario poses an unacceptable hazard.

Detection and alarm systems play a vital role in maximising the amount of time available for an evacuation. A detection system (automatic or observation by occupants) that provides early warning will maximise how much of the ASET people can use to make their way out of the building. Automatic systems that generate unwanted fire signals and false alarms may lead to staff and other building occupants doubting the validity of alarms, and thus increase the 'recognition time' shown in Figure 1. This would be particularly significant where occupants are dependent on staff for their evacuation.

Features can be introduced into a building to prevent or control the spread of fire and smoke. Fire-resisting construction plays a key role in progressive horizontal

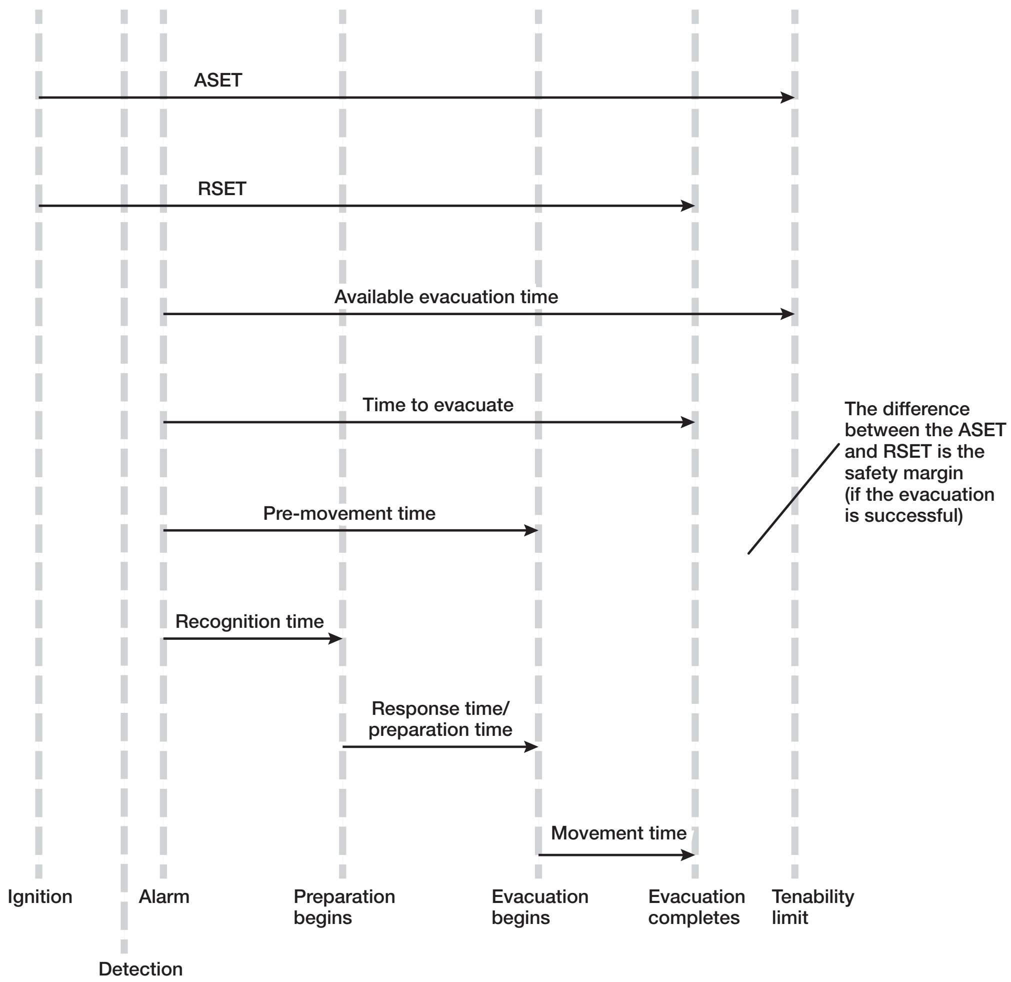

Figure 1: Example non-scaled timeline showing time required to evacuate against the time needed for a fire to proceed from ignition to creating untenable conditions

evacuation (discussed later) by providing successive lines of defence, buying time until the fire and rescue services arrive to deal with the fire.

The mechanisms through which a real fire grows are highly sensitive to the characteristics of the space within which it is growing. Some additional information on fire behaviour has been provided in Appendix A for readers unfamiliar with this. The multitude of factors that affect a fire's growth mean that no two fires will ever be identical, and the severity of their effects will also differ. Conversely, standard fires, which are used to assign fire resistance periods, are designed to be entirely repeatable. There is a common misconception that a standard fire and a real fire relate directly to one another.

Fire resistance periods are determined during testing using standard fires or heating conditions defined by a specific time–temperature curve. It is highly unlikely that a real fire will bear much similarity to such a standard fire. Fire resistance periods are nominal, for the purpose of classification, and provide a means of comparing different products against a standard benchmark. A product that provides 30 minutes' fire protection cannot be assumed to last for exactly 30 minutes during a real fire: if it is more severe than the standard fire, then the period of fire resistance achieved is likely to be less than 30 minutes. Conversely, if the fire is less severe than the standard fire, then the period of fire resistance achieved is likely to exceed 30 minutes.

The size of a fire may be controlled by using manual first-aid firefighting and sometimes automatic suppression systems (if installed), or by minimising the amount of fuel available in a building, or by improving the ignition resistance and flame spread properties of materials. Smoke control measures may be in the form of barriers and screens to contain the smoke in reservoirs, or exhaust systems to remove the smoke, or pressurisation systems to prevent smoke entering sections of the building. These methods are collectively known as smoke control systems.

Some buildings incorporate sprinkler systems and/or smoke control systems. These are likely to have a major impact on the ASET for the overall building, and must be considered when developing evacuation strategies.

Premises dealing with large numbers of mobility-impaired people are also more likely to present particular hazards with respect to fire, such as compressed oxygen cylinders. These are often present in both healthcare and residential care premises, and if directly involved in a fire will significantly increase its severity.

Figure 1 shows how a fire and the corresponding successful evacuation might unfold. The time available for evacuation is dependent on all the factors discussed above. These factors can to a large extent be controlled by those responsible for fire safety.

The provision of people suitably trained in first-aid firefighting helps to minimise the probability of any one fire being allowed to develop to the stage where it presents a significant life safety hazard to a building's occupants. This reduces the number of incidents that escalate to a stage that initiates the evacuation procedures, since these in themselves can pose a health and safety risk to patients as well as to staff, such as injuries during the movement process, or heart attacks from stress.

4 EVACUATION OF PATIENTS

Data were collected from evacuation exercises and fire incidents for the production of this guide. These data indicated that there are two distinct phases involved in the evacuation of a person with mobility impairments: pre-movement (which includes alarm perception/response and preparation for movement), and movement. Pre-movement time is considered further in Section 6. Movement must be further broken down to consider the potential difference in ability that a person may have with respect to vertical and horizontal evacuation. Figure 2 shows how these two aspects fit into the overall process of evacuating mobility-impaired people from a fire.

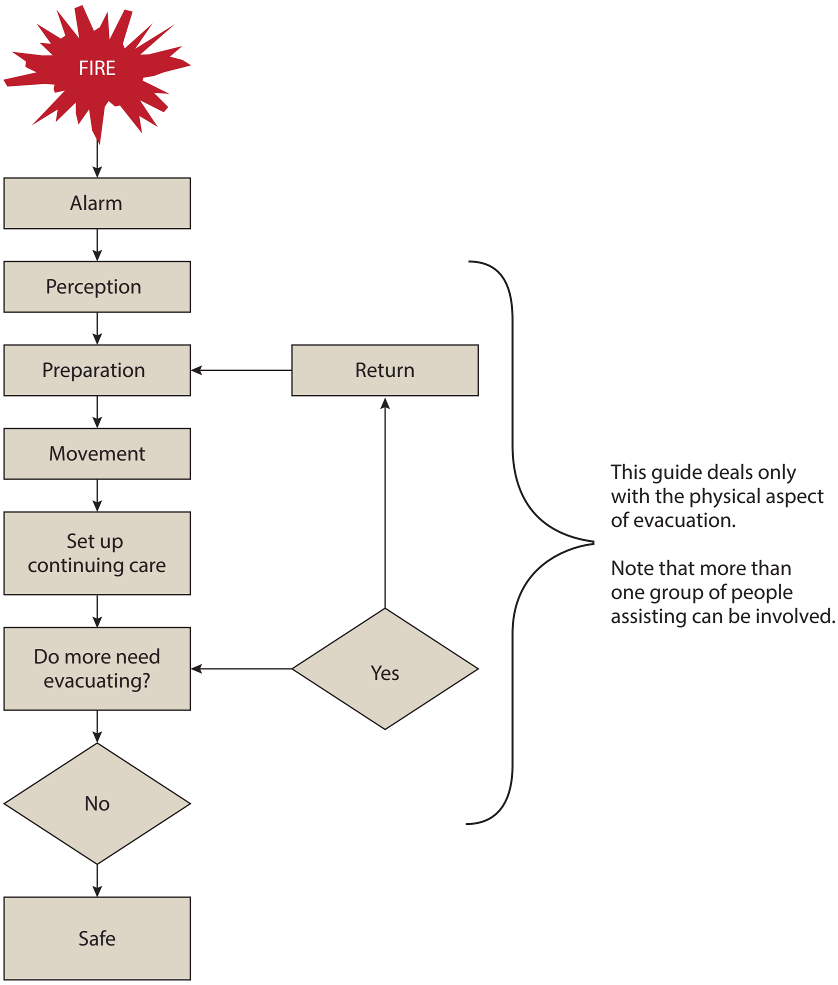

Figure 2: The critical processes and decisions involved when staff are evacuating people with mobility impairments

5 EVACUATION STRATEGIES

In premises serving large numbers of people with mobility impairments, and particularly in patient access areas in healthcare premises, the immediate and total evacuation of the building in the event of fire may not be possible or desirable. People with restricted mobility, people who use wheelchairs and the bedbound cannot negotiate escape routes, particularly stairways, unaided. Patients who are dependent on electrical or mechanical equipment for their survival cannot always be disconnected and moved rapidly without serious consequences. Patients under medication, although they may be classed as having normal mobility, may require staff assistance.

The three main strategies in use for keeping people safe during fire can be described as:

- simultaneous evacuation
- progressive horizontal evacuation
- defend in place.

5.1 SIMULTANEOUS EVACUATION

Simultaneous evacuation, as currently encountered in most buildings, relies on individuals making their own way to a place of safety immediately upon activation of the alarm. This strategy is suitable for people who are not expected to need assistance.

5.2 PROGRESSIVE HORIZONTAL EVACUATION

The principle of progressive horizontal evacuation is that occupants are moved from an area affected by fire, through a fire-resisting barrier to an adjoining area on the same level designed to protect them from the immediate dangers of fire and smoke – a temporary refuge. They may remain there until the fire is dealt with, or await further evacuation to another, similar adjoining area, or down the nearest stairway. This procedure should give sufficient time for non-ambulant and partially ambulant patients to be evacuated down stairways to a place of safety, should it become necessary to evacuate an entire storey.

Progressive horizontal evacuation strategies require that, wherever possible, fires are extinguished using first-aid firefighting, or that they are contained. There should be sufficient containment of the fire so that patients can be evacuated progressively further from the fire on the same level. This is particularly important when considering progressive horizontal evacuation, in view of the increased risk that fire poses to those who will find evacuation difficult.

Progressive horizontal evacuation is, despite its name, not limited to horizontal movement. Should all available horizontal egress routes become unavailable, it may become necessary to evacuate further to another floor. This is more difficult for those with certain mobility impairments, though, and poses greater risks of incurring strain or injury.

Thus the three main stages of progressive horizontal evacuation are:

- Stage 1 – horizontal evacuation from the subcompartment where the fire originates to an adjoining subcompartment or compartment.
- Stage 2 – horizontal evacuation from the entire compartment where the fire originates to an adjoining compartment on the same floor.
- Stage 3 – vertical evacuation to a lower floor remote from the floor of origin of the fire (at least two floors below), or to the outside. Further information on vertical evacuation is given in Appendix C.

There are three fire conditions when evacuation is necessary or should be considered:

- Extreme emergency – where there is an immediate threat to safety from fire or smoke.
- Emergency – no immediate threat, but fire or smoke are likely to spread from an adjoining area.
- Precautionary – no immediate threat to life or safety, but there is a fire on an adjoining floor or in an adjacent building.

In extreme emergency situations, the sequence of evacuation might be:

- those in immediate danger
- ambulant patients
- the remaining patients who are not ambulant.

Additional information on evacuation strategies can be found in HTM 05-03: Part K[3] and the Fire Safety Risk Assessment Guides[4, 5].

5.3 DEFEND-IN-PLACE STRATEGY

Like progressive horizontal evacuation, a defend-in-place strategy requires that, wherever possible, fires are extinguished using first-aid firefighting, or that they are contained.

A defend-in-place strategy requires that the perimeter of the area being defended must be able to withstand fire for a significant period of time. This strategy is most commonly encountered in operating theatres, and seeks to avoid any kind of movement on the part of the patient. If correctly executed, this strategy should avoid the need for movement in all but the most extreme scenarios. Fire protection schemes for enabling defend-in-place strategies will have cost implications, but these will be mitigated by the reduction of impact on business continuity, particularly if smoke can be extracted or contained within the immediate fire area.

The defend-in-place strategy is not of primary concern in this document, as such a strategy does not seek to achieve any kind of patient evacuation.

6 POINTS TO CONSIDER WHEN EVACUATING MOBILITY-IMPAIRED PEOPLE

The evacuation of people with mobility impairments from fire is highly dependent on both the nature and the severity of individuals' impairments. Impairments will not always affect a person's locomotive ability directly, but they may have an impact on that person's ability to respond to an alarm, regardless of the form that alarm may take.

Pre-movement time (see Section 4) can be broken down into recognition time and response time. If a person cannot perceive an alarm, they will be entirely reliant on information from others in order to become aware of the need to evacuate. In crowded areas this may become apparent from the movement of others, but in sparsely populated areas such a person would have to rely on others to perceive the alarm and be aware of the need to convey that information in the appropriate form.

Conversely, a person may be entirely aware that an alarm has been raised, but be unable to get into a state or position in which they can evacuate the area. In addition, and given the range of healthcare treatments and procedures that are available, a person may be connected to one or a number of pieces of equipment or machinery. This again may not affect the person's overall mobility directly, but may prevent travel until someone with suitable knowledge or tools can disconnect them from that item, or prepare them to be moved.

A person's ability to travel for the purpose of evacuation is determined not only by their locomotive ability, but also by other physical and mental abilities. Locomotive impairments will generally affect the speed at which a person can walk, or will necessitate the use of walking aids or frequent rest periods. Other forms of impairment may result in a person finding obstacles such as doors difficult to negotiate, or may present way-finding difficulties.

Table 1 lists points to consider in relation to specific forms of impairment being suffered by individuals, adapted from the Office of Population Censuses and Surveys (OPCS) surveys of disability in Great Britain[11]. Additional information on helping people with special needs can be found in section 1.15 of the Fire Safety Risk Assessment Guides[4–6].

Table 1: **Points to consider for various forms of impairment that may be encountered**
NB: This is not an exhaustive list

Nature of impairment	Points to consider
Locomotive	• Staff availability for providing support • Accessible exit routes • Person blocking route/slowing down others
Reaching and stretching	• Door handles • Handrails • Fire exit door push bars
Dexterity	• Door handles • Handrails
Strength	• Door handles • Fire exit door push bars • Self-closing doors
Personal care	• Getting up
Seeing	• Way-finding
Hearing	• Alarm perception • Receiving instructions
Communication	• Alarm understanding • Receiving instructions
Behaviour	• Restraining during evacuation • Segregation during evacuation
Intellectual functioning	• Following instructions • Way-finding • Alarm understanding
Consciousness	• Falls

Those suffering from long-term mobility impairment will generally be familiar with the nature of their limitation, and may have developed strategies for facilitating activities that their impairment affects. Conversely, those suffering from acute injury or illness are unlikely to have had sufficient time to develop strategies for carrying out tasks.

In situations involving multiple people with mobility impairments, it is important to consider the availability of resources that will be needed to achieve their safe evacuation. The time restriction that a growing fire in a ward or other building space places on the evacuation makes it particularly important to plan how these resources will be implemented.

When deciding the measures that will be used to evacuate a given individual or group of individuals presenting mobility impairments, the nature of the impairment must be considered before choosing a suitable aid. Impairments fall into one of two broad categories: those that affect the person's ability to recognise that evacuation is necessary, and those that affect their ability to effect independent evacuation from a building.

7 TRAINING

7.1 GENERAL

Training of staff is critically important when preparing an evacuation strategy involving a significant proportion of mobility-impaired people. Evacuation trials have highlighted the significant decrease in the efficiency of the evacuation procedure when those carrying out the evacuation are unfamiliar with the task at hand.

Lack of familiarity with the task at hand has been shown to lead to:

- the use of incorrect handling and lifting procedures
- excessive numbers of people being required to assist
- time being lost because people are unsure about their next action.

It is also important to stress that staff responsible for the day-to-day care of people with mobility impairments will be most familiar with their requirements, and how their training can address these requirements. They should therefore be involved throughout the development of evacuation strategies, especially where staff and time requirements are being estimated.

If acute healthcare staff are presented with the possibility of a fire occurring, the results can be mixed, depending on the perceived plausibility of such an event, and on the impact that it would have. A highly effective way to identify whether it would be possible to move patients and continue their care elsewhere is to consult staff on the approach they would take if particular facilities or pieces of equipment were taken out of action. Fires requiring evacuations are a relatively low-probability event in healthcare premises, largely because of the high concentrations of staff throughout the building able to identify and get to fires early on to carry out first-aid firefighting. However, if staff are presented with a range of scenarios that might require them to move a patient quickly in order to continue their care, the importance of successful evacuation techniques, regardless of reason, becomes apparent. This approach to evacuation training will therefore have the added benefit of providing resilience against other disasters, such as flooding.

Particular issues regarding the importance of training were identified through analysis of evacuations and evacuation trials during the research carried out for the production of this guide. These issues are dealt with in Appendix B.

7.2 BACK CARE

The Manual Handling Operations Regulations (MHORs) 1992 (updated 1998 and 2004)[12] state in Regulation 4(1) that employers should ensure that employees avoid hazardous handling so far as is reasonably practicable, assess any hazardous handling that cannot be avoided and reduce the risk of injury so far as is reasonably practicable. Regulation 5 states that these provisions do not preclude well-intentioned improvisation in an emergency, for example during efforts to rescue a casualty or fight a fire.

It is therefore widely accepted that, during an actual fire, any reasonable approach may be adopted in order to move a patient to a place of safety. There is, however, currently no accepted approach for training involving techniques that are not approved methods of safer moving and handling.

Fire safety managers should consult with, and obtain agreement from, staff before instructing them on any training methods. If managers feel that a non-approved lifting method may become essential during an emergency, then they should carry out a risk assessment, and put measures in place to minimise the risk of back injury as far as possible. It may be necessary simply to try the motion of a technique without lifting any load, in order to keep that risk to a minimum.

Particular consideration should be given to the potential for evacuating bariatric patients, for example by placing them on floors with level egress routes and/or locating them in different fire compartments (or fire-resisting bedrooms) of the hospital, depending on their medical condition. There should be an evacuation plan, and equipment to evacuate them. When undertaking fire risk assessments, complex patients' needs should be considered in consultation with staff. If an organisation accepts these complex patients, they have a duty to provide all aspects of care, balanced with a duty to not discriminate against them because of their exceptional medical circumstances.

7.3 INFECTION CONTROL

Like back care, infection control will become a secondary consideration when a fire poses an immediate threat to life. However, during the normal operation of healthcare premises, and evacuation drills and exercises, infection control is a major consideration. There are concerns that, because some evacuation aids are integrated into the set of tools used to cater for patients on a regular basis, they may present an additional breeding ground for infectious bacteria. The possibility of increased risk of bacterial transfer needs to be considered when selecting evacuation aids. Front-line healthcare staff should be able to assess the possible increased risk of infection from the introduction of an evacuation aid.

8 EVACUATION AIDS AND TECHNIQUES

A wide range of techniques and aids are available for carrying out evacuations. Each has its own set of benefits, and its potential drawbacks. A selection is provided in Table 2 for consideration when putting together an evacuation plan. A brief explanation has been provided for evacuation aids that may not be familiar to the reader. Appendix D contains more information on the effect that different types and extents of dependency have on time to prepare, move horizontally and move vertically. There is also information provided on how these data can be combined with the number of staff present to give an estimate of the time to evacuate. Appendix D also includes consideration of fatigue, which can quickly reduce the speed of movement of staff during an evacuation.

Table 2: **Evacuation aids and techniques**
NB: This is not an exhaustive list

Technique	Advantages	Disadvantages
Assisted walking	• Allows vertical evacuation • No equipment required	• Dependent on patient capabilities • Can be staff and time intensive
Bed evacuation	• Minimal manual handling required • Evacuation can proceed without interrupting life support	• Not compatible with vertical evacuation • Large corridor width required • Space required at destination
Mattress evacuation	• Allows vertical evacuation	• Heavy lifting or dragging needed for use, especially down stairs • Can require many staff • Patient must be secured to mattress • Danger of injury to patient • Danger of injury to staff • Requires as much corridor width as bed
Ski sheets (sliding sheets with handles fixed to undersides of mattresses)	• Always ready to use, once fitted to mattresses • Allow vertical evacuation • Simple to use • No storage requirement (fitted to mattresses) • Fastening straps included in design • Less effort required than with mattress evacuation	• Infection risk • Danger of injury to patient

Table 2: **Evacuation aids and techniques**
NB: This is not an exhaustive list

Ski pads (sliding padded sheets kept near escape routes)	• Storage does not require significant amount of space • Allow vertical evacuation • Can fit through narrower gaps than beds or mattresses • Fastening straps included in design • Less effort required to move than with mattress or ski sheet evacuation	• Heavy lifting needed to transfer patient onto pad • Danger of injury to patient
Wheelchair	• Can be self-operated • Relatively little effort required by assisting staff	• Not easily compatible with vertical evacuation • Patient may need transferring from bed
Evacuation chairs (chairs on skis/wheels/tracks underneath for moving up and down stairs)	• Allow vertical evacuation • Can be stored in stairwell • Storage does not require significant amount of space • Can provide highly controlled vertical evacuation • Little effort required from operator	• Can only be used on straight stairways • Specific training required • Patient may need transferring from bed
Stretcher evacuation	• Allows vertical evacuation • Life-support equipment can be included on stretcher	• Heavy lifting • Large numbers of people required to help
Crutches	• Allow vertical evacuation • Patient can move independently	• Patient must be capable of use
Cot evacuation (babies)	• No lifting required • Evacuation can proceed without interrupting life support	• Not compatible with vertical evacuation • Space required at destination
BabEvac Cots (padded cots designed for evacuating special-care babies, carried by nursing staff)	• Some designs allow for integration of life support • Allow vertical evacuation	• Specific training required
Lifts (manual handling)	• May allow for vertical evacuation	• Heavy lifting • Can be staff and time intensive • Many lifting techniques not approved as safe
Lifts (elevators)	• Allow vertical evacuation • Allow evacuation of wheelchairs and life-support equipment with beds	• May become stuck if lift mechanisms affected by the fire

9 ENSURING CONTINUITY OF CARE

Continuity of care is of paramount importance when considering the evacuation of acute care patients. Plans should be in place to enable hospital staff to continue to provide life support during the movement of patients from one area to another; they should also be able to provide short- to medium-term treatment and monitoring facilities until permanent alternative facilities can be arranged. If particularly high-risk patients may have to be moved, consideration should be given to making medical records available from a secondary location so that treatment information can be accessed. This is particularly important if there is a possibility that these patients will have to be moved from their building of origin.

Where patients require supplies such as oxygen, or power for equipment, an alternative location providing these or a portable emergency supply should be considered. If this cannot be arranged, then it may be necessary to consider a defend-in-place strategy around the location of these.

APPENDIX A: NATURE OF FIRE

This appendix has been provided to give people using this guide with little or no previous fire experience a basic understanding of fires in buildings.

Fire is a self-sustaining chemical reaction. It is typically characterised by the release of heat and light, perceived as flame. In order to start and grow, a fire needs a supply of fuel, oxygen and heat.

These three requirements are sometimes referred to as the **fire triangle**. Most buildings have a plentiful supply of combustible contents, and oxygen is present in the air all around us. In healthcare premises oxygen is often also present in pressurised cylinders or piped systems, which present their own particular hazards.

Fortunately, however, sources of heat sufficient to cause ignition are usually kept well away from any combustible materials. Consequently, fires – from the viewpoint of individual premises – are fairly rare events. Once a fire has started, though, the heat that the combustion of the fuel releases can become sufficient for the fire to sustain itself and grow larger. If the fire gets larger, it produces more heat, resulting in further fire growth.

Most energy from a typical fire is taken away as convected heat, rising up in the smoke plume. The rest of the energy is radiated as heat and light from the flames. The smoke that the fire produces flows away, upwards and outwards, and is diluted by the air that is entrained in the smoke as it rises. The high temperature of the smoke usually means that a hot smoke layer will be formed immediately below the ceiling.

The fire will not keep growing indefinitely; eventually it will run out of fuel, or oxygen, or both. The first way it can run out of fuel is after the item first ignited has been consumed. Whether or not the fire can spread beyond this first item depends on how near neighbouring combustible items are to it, and on the size the fire has reached on the first item. An important mechanism for heat transfer is radiation from the hot smoke layer beneath the ceiling. This may be sufficiently intense to cause near-simultaneous ignition of all fuel surfaces within the compartment – a process termed **flashover**. The heat-release rate then increases very rapidly.

A compartment fire in which all the fuel in the room is burning may arise from flashover, or from the slower spread of fire from item to item until all are involved. The size of such a fire will ultimately be restricted by the availability of oxygen. The initial amount of air within a closed compartment will be sufficient only for the combustion of a small quantity of fuel, and a fire in a closed compartment will go out through lack of air. Openings in the compartment walls (such as doors and windows) can allow the smoke to flow out and fresh air to flow in, at a rate that depends on the size of those openings. If the oxygen supply is sufficiently restricted, the fire will reduce in size or eventually go out. The combustion will be less efficient, producing lower yields of the end products of combustion (mainly carbon dioxide and water) and more smoke and intermediate products (such as carbon monoxide). In extreme cases, the temperature in the fire compartment may be sufficient for significant vaporisation of the fuel, but without enough oxygen for the combustion. If the oxygen supply is suddenly increased (eg a door opens or a window breaks), the fuel vapours may burn very rapidly when the inflow of air mixes with them, a phenomenon termed **backdraught**.

The fire may be controlled or extinguished by various suppression measures, which either remove the heat or cut off the oxygen supply, or both. Alternatively it will go out when it finally runs out of fuel.

In building fires, smoke will usually move from the location immediately surrounding the fire to other parts of the building, creating a threat to the occupants. Several processes are responsible for the movement of smoke. They include the effects of:

- buoyancy of hot smoke or fire gases
- turbulent mixing and entrainment (dilution)
- ventilation systems in the building, and consequent air movement
- wind.

These processes will lead to the development of hazardous conditions throughout more and more of the building, forcing the occupants to evacuate further and further away.

APPENDIX B: EVACUATION DATA

B1 INDIVIDUAL EVACUATIONS

Evacuations and evacuation trials were studied in detail during the research leading up to the drafting of this guide. From these the values were obtained for the patient categories in Appendix D. In addition to these values, there were several key findings:

- Training is one of the most important factors governing how well evacuations will proceed. The level of training that staff receive will determine how they react to a fire, and particularly how efficient they are at moving people.
- Medical staff will go to extraordinary lengths to ensure their patients' safety. One real incident involving a fire in a hospital's air-conditioning unit led to surgeons temporarily closing up a patient in order to move them to another theatre and continue the procedure. Such responses should not be relied on when setting up evacuation strategies, but they go some way to explaining the relatively low fire casualty rate in healthcare premises.
- Evacuation trials are very useful for highlighting weaknesses in evacuation strategies, and areas where staff may need additional training.
- Evacuation trials should not be used to estimate how long an evacuation might take in a real fire. Concerns exist regarding:
  - the lack of urgency in trials, affecting the speed at which staff act
  - staff reacting unrealistically quickly to an alarm during a drill, compared with how they would react in real life
  - evacuees in drills being too easy to deal with, as they are unlikely to resist the evacuation, or get lost
  - drills not involving any mock-up equipment needing disconnection, or transporting with patients.

B2 EVACUATION DATA

The London Fire Brigade (LFB) provided data on fires in buildings serving large numbers of mobility-impaired people that they had investigated between January 1996 and March 2007. Analysis of these data has been completed, but the findings are limited by the dataset available.

The most significant factor in the time to evacuate is the dependency/mobility of the people evacuating. This may explain why no clear correlation was found between the total time required to evacuate premises and the building population (Figure B1), or the number of storeys, or the number of staircases per storey. This indicates that the building design itself is not necessarily the deciding factor for time required to evacuate.

Most evacuations involve less than 50 people and take less than five minutes to complete. Some evacuations involve a larger number of people (up to 250) and also take less than five minutes to complete (outpatient clinics might fall into this category). A small number of evacuations involve less than 50 people and can take up to 30 minutes to complete. These might be typical of highly vulnerable and dependent operating theatres and intensive therapy units. Figures B2–B4 support this as they show that, across most property types, the evacuation flow rate increases as the premises' population increases. An indication of staffing levels in each of the premises would be a useful means of confirming the importance of evacuee/staff ratios in maintaining prompt evacuations regardless of total population.

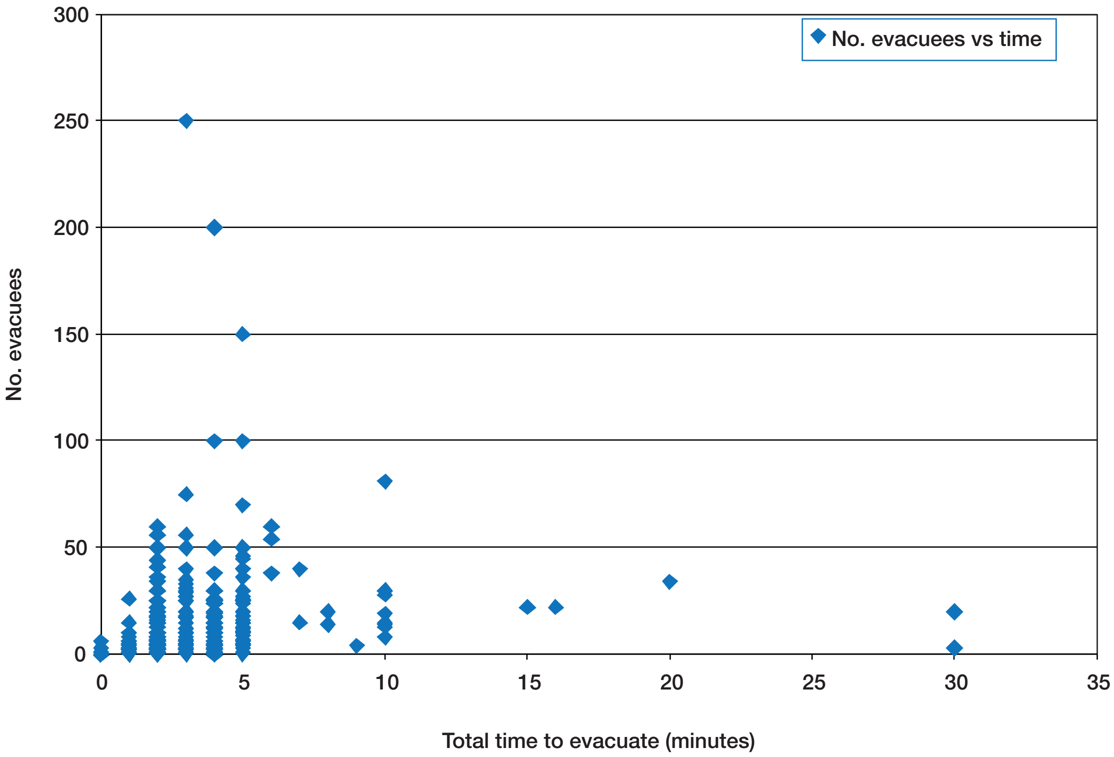

Figure B1: Number of evacuees in hospital premises, plotted against time required to evacuate them, during incidents encountered by LFB from 1996 to 2007

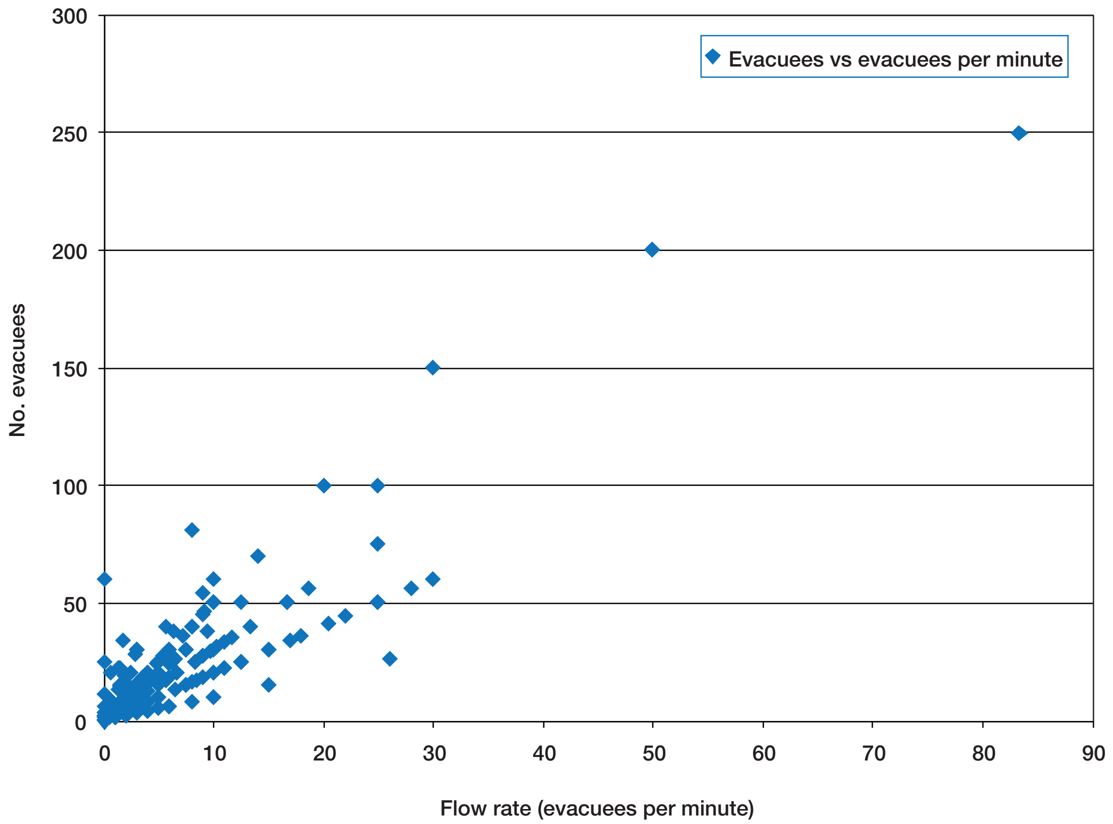

Figure B2: Evacuees vs flow rate. Number of evacuees in healthcare premises, plotted against flow rate out of building to evacuate them, during incidents encountered by LFB from 1996 to 2007

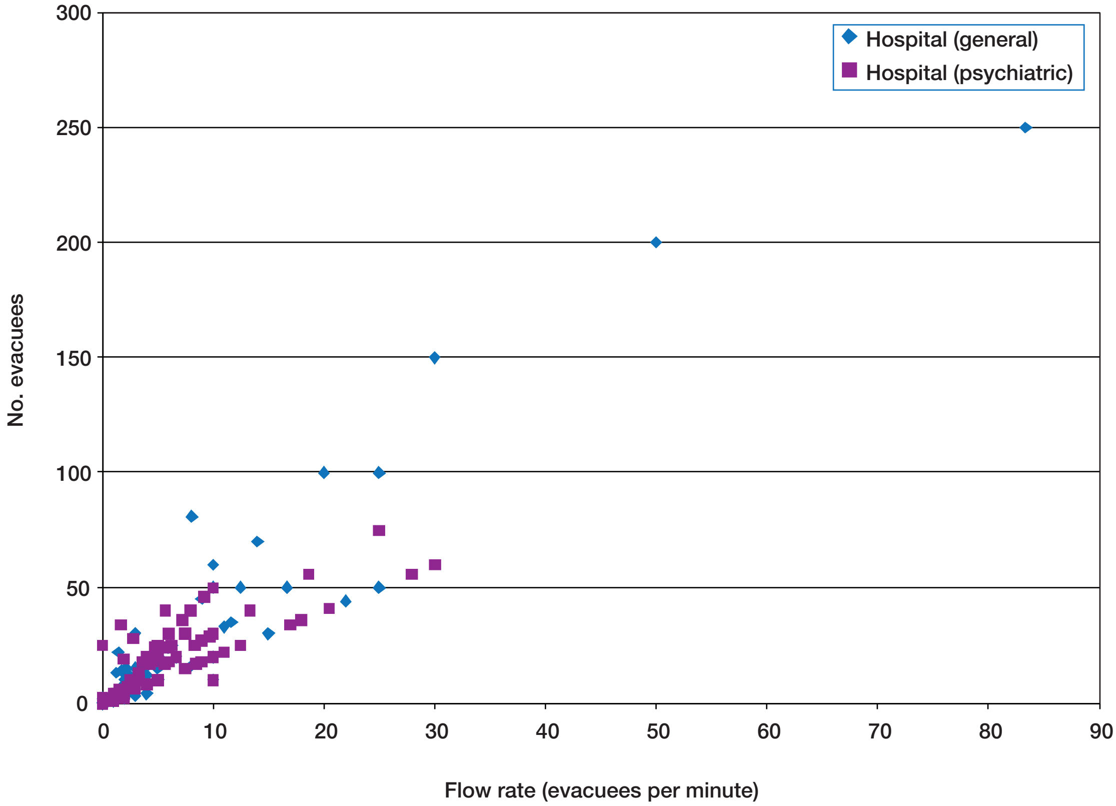

Figure B3: Evacuees vs flow rate by property type. Number of evacuees in hospital premises, plotted against flow rate out of building to evacuate them, during incidents encountered by LFB from 1996 to 2007

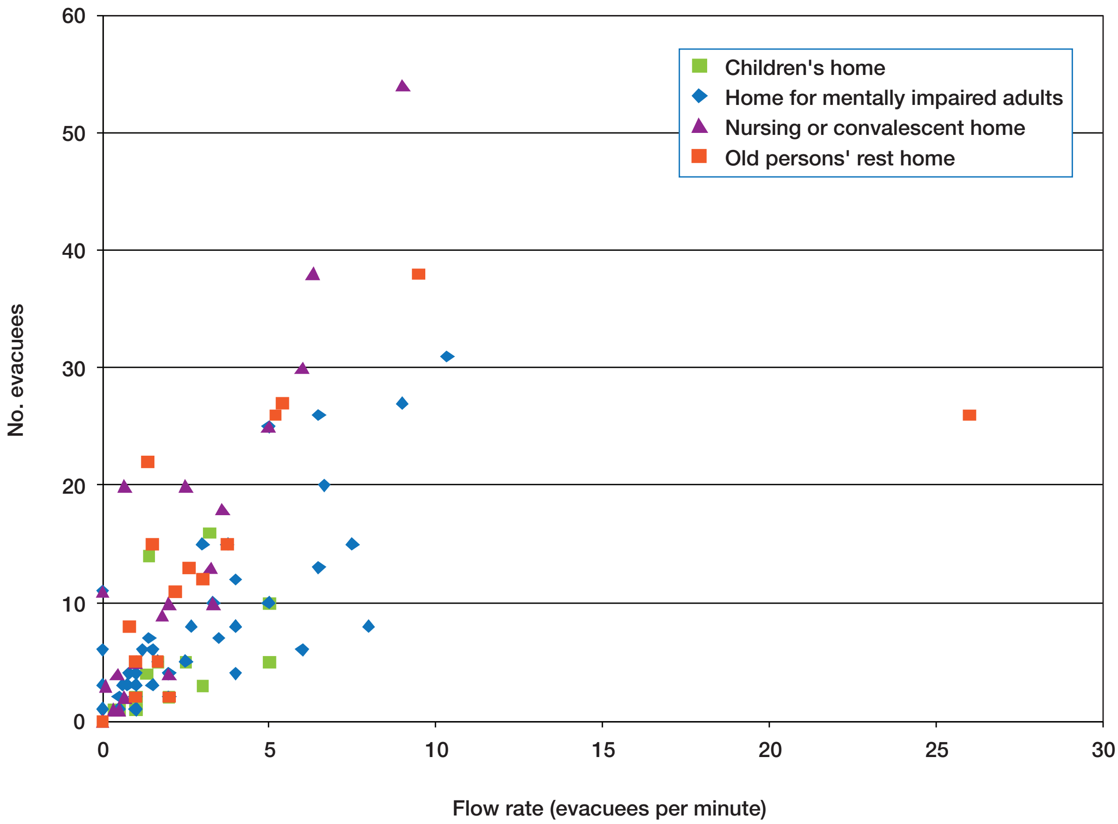

Figure B4: Evacuees vs flow rate by property type. Number of evacuees in other care premises, plotted against flow rate out of building to evacuate them, during incidents encountered by LFB from 1996 to 2007

APPENDIX C: VERTICAL EVACUATION

C1 INTRODUCTION

This appendix summarises a research study undertaken by Janette Midda at Loughborough University[13]. The study's findings are only indicative, and further experimentation would be required to substantiate them.

The method for this data collection used a set scenario, and documents the time taken to place a dummy, 'Resuscitation Annie', securely in both the ski pad and the ski sheet. This scenario was undertaken five times to observe the carers' rate of tiring from sustained activity. In a real fire evacuation the same staff would be required to continue evacuation until all patients were safe, or until the building was declared unsafe by the fire brigade.

The ski sheet was placed under the mattress, as is the norm in most hospitals. The ski pad was brought to the patient.

Digital photographs were taken at varying intervals to highlight the postures that carers would need to adopt to place the dummy in either piece of equipment to evacuate. From these photographs the Rapid Entire Body Assessment Scores (REBA) were assessed, to highlight any unsafe manual handling issues due to biomechanical overload.

Using a push/pull meter and working to Health and Safety Executive guidance on force limits, the forces required to pull the ski pad and ski sheet on the flat and down stairs only one level were assessed. This particular assessment was not timed.

C2 PILOT TESTS

The scenario used Resuscitation Annie as a post-operative surgical patient who had one intravenous line and a urinary catheter in situ. This patient was deemed to be compliant, and able to understand instructions.

1. Fire alarm activated.
2. Approach patient and explain evacuation is required.
3. Secure the intravenous line and catheter bag.
4. Slide or lift dummy onto ski pad with or without the sheet.
5. Secure dummy in place using the straps.
6. Drag ski pad and dummy to the door.

Pilot tests to date used this scenario with five attempts to place a ski pad, and on a separate occasion a ski sheet, with timings recorded.

During these tests, digital photographs of potentially harmful postures were captured, and subsequently analysed to assess which steps appeared risky or harmful to staff.

C3 RESULTS

The results are listed according to the equipment used, with ski pad results tabulated first, followed by ski sheet results:

- The time to explain to the patient (dummy), secure them to the equipment and move them to the door of the clinical skills room. The team did not attempt vertical evacuation.
- The forces required to pull the equipment; 'gentle pull' indicates controlled usage and 'forced pull' indicates an energetic, very quick pull. These results include measurements on the flat and during vertical evacuation.
- REBA scores when moving/lifting the dummy from the bed.

The data in Table C1 (ski pad) and Table C2 (ski sheet) show the gradually increasing time taken by the same two members of staff to evacuate the dummy from the bed to the door of the clinical skills room.

***Table C1:* The increase in seconds with increased attempts: ski pad**

Attempt	Time (seconds)
1	52
2	57
3	65
4	72
5	85

***Table C2:* The increase in seconds with increased attempts: ski sheet**

Attempt	Time (seconds)
1	53
2	58
3	68
4	75
5	89

Table C3 lists the recommended forces required to push or pull, according to the Manual Handling Operations Regulations 1992 (updated 2004)[12]. Tables C4–C7 show the data obtained from the trials carried out using Resuscitation Annie.

***Table C3:* L23 (Manual Handling Operations Regulations)**

Recommended limits for push/pull	Initial pull (kg)	Sustained pull (kg)
Male	20	10
Female	15	7

***Table C4:* Results from push/pull forces using the ski pad on the flat**

Measurement	Initial pull (kg)	Sustained pull (kg)
Gentle pull	13–15	7
Forced pull	23	N/A

***Table C5:* Results from push/pull forces using the ski pad down stairs**

Measurement	Initial pull (kg)	Sustained pull (kg)
Gentle pull	16	2
Forced pull	22	N/A

***Table C6:* Results from push/pull forces using the ski sheet on the flat**

Measurement	Initial pull (kg)	Sustained pull (kg)
Gentle pull	17	9
Forced pull	18	14

***Table C7:* Results from push/pull forces using the ski sheet down stairs**

Measurement	Initial pull (kg)	Sustained pull (kg)
Gentle pull	12	Gravity
Forced pull	N/A	N/A

The ski sheet with mattress was found to be much heavier than the ski pad, and therefore more difficult to pull on the level. The ski sheet has a more slippery surface, making vertical evacuation in some parts hazardous. A further trial was carried out to examine the push/pull forces required to move an actual person. Data from this trial are shown in Table C8.

***Table C8:* Results for ski pad on the flat with patient weighing 84 kg**

Measurement	Initial pull (kg)	Sustained pull (kg)
Gentle pull	33	33
Forced pull	N/A	N/A

APPENDIX D: CALCULATION OF EVACUATION TIME

D1 INTRODUCTION

Appendix D provides information that can be used to estimate the time taken to evacuate people who are dependent, such as patients. There is much variation in people's abilities to evacuate, and in the extent of assistance that they will need. Therefore any evacuation times calculated using the data and equations in this appendix should be considered only an overall estimate, and an adequate safety margin (Figure 1) should be incorporated in any evacuation time assessment.

The values in Table D1 are taken from the evacuations and evacuation trials carried out in support of the drafting of this guide. Times given are averaged, and have been rounded to the nearest 10 seconds. This is because any further refinement of the time will be lost in the variability of evacuation time. In addition, as the degree of mobility impairment increases, so does the variability in the time or speed and assistance that may be required to move such a person. Times for individuals falling into categories where time, speed and staff required have been listed as 'specialist judgement' can therefore be estimated only by those familiar with the individual in question. It is difficult to predict the challenges that may be encountered during an evacuation, especially those presented by bottlenecks due to the layout of a building, or by particularly slow-moving individuals slowing down those behind them. The values given here are therefore intended to give only an indication of the time, speed and staff required. They may be used to compare one level of impairment with another, but should be considered to provide only an order-of-magnitude indication of the time that may be required to complete an evacuation.

The categories given in Tables D1–D3 are adapted from the OPCS surveys of disability in Great Britain[11].

Table D1: **Preparation**

Category	Description	Associated time (seconds)	Staff required
P1	No help/notification needed	~ 60	0
P2	Deaf (awake)/minimal assistance needed	~ 70	1
P3	Deaf (asleep)/assistance needed	> 100	1
P4	Must be disconnected from one piece of equipment/machinery	Specialist judgement	1
P5	Must be moved to evacuation aid; one helping	100–120	1
P6	Must be moved to evacuation aid; two helping	80–100	2
P7	Connected to two or more pieces of machinery; at least one cannot be disconnected	Specialist judgement	Specialist judgement
P8	Unconscious	Specialist judgement	Specialist judgement
P9	On life-support machinery	Specialist judgement	Specialist judgement
P10	On assisted ventilation	Specialist judgement	Specialist judgement

Table D2: Horizontal movement

Category	Description	Associated speed (m/s)	Staff required
H1	Can walk/use wheelchair/walking aid unassisted, requiring only occasional rests	0.3–0.4	0
H2	Can walk/use wheelchair/walking aid unassisted, requiring frequent rests	0.1–0.2	0
H3	Cannot negotiate obstacles (such as doors) without help	Depends on premises	1
H4	One person required to assist	0.2–0.3	1
H5	Two people required to assist	0.2–0.3	2
H6	Must be transported	0.2–0.4	2+
H7	Must be transported lying down	0.2–0.4	1+
H8	Must be transported lying down with at least one associated piece of equipment/machinery	Specialist judgement	2+
H9	Five or more people required to move or transport with connected equipment	Specialist judgement	5+
H10	Cannot be disconnected from life-support apparatus for more than 60 seconds	Specialist judgement	Specialist judgement

Table D3: Vertical movement

NB: No account of evacuation using lifts has been included

Category	Description	Associated speed (m/s)	Staff required
V1	Can negotiate stairs unassisted, requiring only occasional rests	0.2–0.4	0
V2	Can negotiate stairs unassisted, requiring frequent rests	0.05–0.2	0
V3	Cannot negotiate stairs facing direction of travel	0.1–0.4	0
V4	Assistance required	0.2–0.3	1+
V5	Must be transported	0.1–0.4	1+
V6	Must be transported lying down	0.1–0.4	2
V7	Three people required to move or transport connected equipment	0.1–0.3	3
V8	Four people required to move or transport connected equipment	0.05–0.3	4
V9	Five or more people required to move or transport connected equipment	0.05–0.3	5+
V10	Cannot be disconnected from life-support apparatus for more than 60 seconds	Specialist judgement	Specialist judgement

D2 CALCULATING INDICATIVE EVACUATION TIMES

In general terms, an evacuation plan should facilitate the completion of the evacuation of patients before conditions become hazardous on the room, sub-compartment and/or compartment of fire origin. The time for evacuation, t_{evac}, is based on the time from when the alarm is raised to when the occupants have been evacuated:

$$t_{evac} = t_{pre} + t_{trav}$$

where:

t_{evac} = the evacuation time
t_{pre} = the pre-movement time for the people in an enclosure (including the preparation of the patient(s))
t_{trav} = the travel time of the enclosure's occupants to a place of relative safety within the building(s) or safety outside the building(s)

This document provides information on the pre-movement and movement times for patients and highly dependent people. Information to calculate the Available Safe Egress Time (ASET) and the time to detect and raise the alarm can be found in the Published Documents (PD) that support BS 7974:2001[14].

Staff time to evacuate a patient

The staff time required to prepare and move a patient, and to return ready to prepare the next patient, can be calculated as follows:

$$t_{staff}(p) = \underbrace{\left(t_{pre}\,.\,n_{pre}\right)}_{\text{Preparation of patient}} + \underbrace{d_h.\,n_h\left(\frac{1}{v_h}+\frac{1}{v_r}\right)}_{\text{Horizontal movement}} + \underbrace{d_v.\,n_v\left(\frac{1}{v_v}+\frac{1}{v_r}\right)}_{\text{Vertical movement (if needed)}}$$

where:

t_{staff}(p) = the staff time required to get a patient to safety
t_{pre} = the time required for pre-movement (including preparation of the patient(s))
n_{pre} = the number of staff required fore pre-movement (including preparation of the patient(s))
d_h = the horizontal travel distance (m)
n_h = the number of staff required for horizontal movement
v_h = the horizontal movement speed (m/s)
d_v = the vertical travel distance (m)
n_v = the number of staff required for vertical movement
v_v = the vertical staff velocity

Some patients will require little or no preparation, so in these cases the preparation time can be neglected. Equally, some evacuation routes will be purely horizontal (particularly when a progressive horizontal evacuation philosophy is adopted), so in these cases the vertical term can be neglected.

Total staff time available during the evacuation time

The preparation and movement of patients to a place of relative safety should be completed in a reasonable time after a fire is detected and the alarm has been raised[15]. This period is often known as the evacuation time. The staff time available during the evacuation time can be calculated based on the amount of time that is deemed acceptable for evacuation to occur, the number of staff available in the immediate area, and the size and time at which subsequent groups of staff assisting with evacuation will arrive from adjacent areas:

$$t_{staff}(evac) = [n_0.\,t_1] + [(n_0+n_1)\ (t_2-t_1)] + [(n_0+n_1+n_2).\,(t_3-t_2)] + \left[\left(\sum_{i=0}^{i=N} n_i\right).\,(t_{evac}-t_{evac-1})\right]$$

where:

t_{staff}(evac) = the staff time available for patient preparation and travel before the end of the evacuation time is reached
n_0 = the number of staff available when the evacuation alarm is raised
t_i = the time at which staff group *i* arrives to help
n_i = the number of staff in staff group *i*
n_{x-1} = the number of staff in the last group to arrive before time *x*
N = the number of staff groups that arrive before the end of the evacuation time
t_{evac-1} = the time of the arrival of the last group before the end of the evacuation time

Total staff time available during the evacuation time when fatigue is taken into account

Data on fatigue have been collected for staff pushing beds and using ski pads and ski sheets (Figure D1). Based on these data, an adjustment of the total staff time available during evacuation can be made to take into account the effect of fatigue.

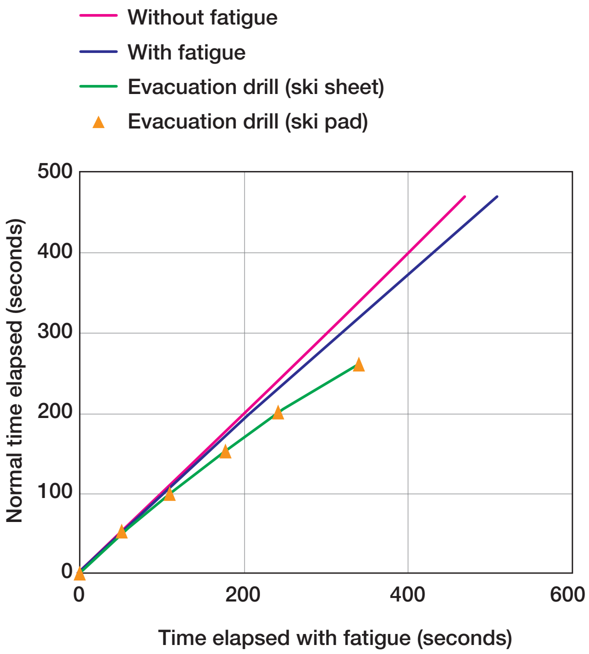

Figure D1: The effect of fatigue on movement time during evacuation

The rate at which staff fatigue depends on the type of evacuation that is being undertaken. Therefore, the effective total staff time available (in seconds) during evacuation once fatigue is taken into account can be approximated by:

$$t_{staff}(evac_{fatigue}) = 2.n_{av} \left\{ \frac{t_{staff}(evac)}{2.n_{av}} - \left[k.\left(\frac{t_{staff}(evac)}{200.n_{av}} \right)^2 \right] \right\}$$

where k is a coefficient of fatigue where:

$k =$ 0 for all activities that can be performed almost indefinitely

$k =$ 1.8 for activities requiring lighter exertion, such as moving wheeled beds

$k =$ 10.0 for evacuation of patients using ski pads

$k =$ 10.5 for evacuation of patients using ski sheets

The average number of staff available for evacuation is expressed as n_{av}:

$$n_{av} = \frac{\left(n_0 + \sum_{i=0}^{i=N} n_i\right)}{2}$$

The sum of all the staff time required for each patient should be less than the total staff time available during the evacuation time once fatigue has been taken into account:

$$\sum t_{staff}(p_1, p_2, \dots p_n) < t_{staff}(evac_{fatigue})$$

where:

$p_n =$ the last patient being evacuated.

These formulae make it absolutely clear that the limiting factors in the evacuation of dependent people from buildings are the degree of their dependency and the availability of trained staff to assist them. They also show that fatigue can become a major challenge during extended or extensive evacuations.

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