Guidance on designing for crowds – an integrated approach
Guidance on designing for crowds – an integrated approach
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CIRIA

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Key messages

1. Designing for crowds requires an integrated approach, which means designing for operation and not just for compliance with codes.

2. This requires input from operators (or technical representatives of the operator if they are not yet appointed), and other key stakeholders (disability groups, user representation groups etc).

3. It also means taking into consideration areas around a venue (including transport systems) and considering the issues in a wide whole-life context.

4. All decisions should be people centric.
About this guide

This guidance contains details of what is considered good practice and has been developed to assist designers to enhance user experience and minimise the risk of crowd incidents and accidents within their design. This guidance is applicable for sports stadia, music venues, arenas, theatres, railway stations, shopping malls, religious venues and any other environment where crowds are expected, including places where crowds gather, such as at Hogmanay or for public events such as the return of a victorious team, a state funeral or a royal wedding.
Who should read this guide?

- developers and end-users (clients)
- project managers
- specifiers
- architects
- engineers
- operators
- facilities managers
- regulatory authorities and licensing bodies – including safety and planning officers
- promoters.
Introduction

There are ever more buildings, spaces and events that are intended to attract crowds or help their movement. This naturally focuses attention on the design and management of those buildings, spaces and events to ensure that the crowds are safe and comfortable.

There is a range of regulation or guidance relating to user comfort and crowd safety. Much of it is designed with specific types of venue or building in mind, reflecting the safety aspects and user expectations of the particular environment. For example, the crowd movement and safety issues in metros are different from those in green field music events. Some of the reference documents for different environments are included in the reference material later in this guide.

This advice builds on the environment-specific guidance and regulation to describe common challenges and approaches to ensuring crowd experience and safety are addressed in the design process. Some of the benefits of doing so are listed overleaf.
Benefits of a design that effectively integrates operational issues

- better visitor comfort and enjoyment or reduced journey time, resulting in more repeat business
- increased revenues (people who are happier or more comfortable often stay longer and spend more)
- improved revenue protection
- smooth operation, fewer control costs
- saving on design fixes and operational work-arounds
- right first time design, reducing whole-life operating costs
- comfort of operational staff
- reduction of accidents and incidents
- reduction of insurance costs and claims
- enhanced corporate reputation and shareholder value
- protection of brand image.
Lessons learned

There are many examples of accidents resulting in serious injuries or loss of life in all types of environments where crowds are present. These include rock concerts, football matches, religious gatherings and even shopping centres.

This guidance takes into consideration some of the lessons learned from these accidents and describes processes that should be implemented during the development process to *design out* as much risk as possible.
Beyond compliance – an holistic approach

There are many published standards applicable to different types of environment. These range from published design standards such as Building Regulations to operational guidance such as the Event safety guide (HSE, 1999). Currently, however, the design of the environment and the operational planning for that environment, for many projects, is unrelated.

Figure 1 shows the independence of standards with the only linkage being that they are both applicable to the environment that accommodates crowds.

There are many examples where environments can be compliant with published design standards, but a lack of effective integration means they perform poorly operationally.
An example of this is the entrance staircase of an international exhibition centre where the stair widths, risers, handrails etc, are all designed and installed to the relevant design standards. However, because of the context of use (exhibitors arrive by taxi at the main entrance and carry exhibition materials up the stairs), there have been many serious fall accidents that resulted in the staircase being closed. The reason for this type of failure is due to the venue having its own distinctive location, layout, operational constraints, systems, environment, usage patterns etc, and these factors have not been taken sufficiently into account during the design phases for the venue.
This guidance aims to plug the gap and move towards a more integrated design approach that fully considers operational needs as well as the more prescriptive design standards during the design phase.

Figure 2 shows the co-existence and interdependencies of these standards. There are many issues that need to be considered when designing in terms of crowd behaviour. The table overleaf gives examples of operational issues that are related to design detail.
Operational issue | Design ramification | Comment
--- | --- | ---
Slip, trips and falls | Floor surfaces, stairs, obstructions | The contextual use of floor surfaces is often ignored when specifying them. Overcrowding or crowd crushes may be caused by one person slipping or tripping over.
Route choice and wayfinding | Signage – specification and positioning | The signage and wayfinding strategies need to be fully integrated with the operational plan in all of its four operating conditions (see Operational states, page 17). Vital signage can often be obscured by crowds themselves.
Weather/climate | External facilities such as canopies | Risk that people crowd under covers (e.g., at an outdoor event or a stadium). This may also affect train loading patterns and platform usage as people slow down or stop before going out into rain.
Security | Gates and barriers, CCTV, radio systems | Improvements in security can impede flows so a balance has to be reached.
Non-fire evacuations | Communication and alarm systems | Terrorism, or other non-fire evacuation, requires a different set of procedures, communications, and training etc. that have implications for general building or event layout and facilities.
Disabled users | Gradients, circulation widths, companion seating | The needs of disabled users should be taken into consideration, remembering that most disabled users are not stereotypical wheelchair users. Improving access for people with disabilities usually helps circulation of all users when properly designed and managed. A detailed access statement or disability strategy should be developed very early in the design stage of a venue or building and should involve consultation with a wide range of people with disabilities and representative groups.
Luggage | Space provision, signing, gating | The presence of luggage in transport systems, for example, can have a major affect on the space required as well as the performance of the design – especially in terms of ingress and egress. Designers must take into account users’ changing needs and behaviours. It should also be noted that speed of movement may also be affected by luggage carried. There may also be a security requirement of search and storage.
Retailing | Space take, effects on circulation routes | The positioning of retail and advertising can have significant detrimental effects on operational management and even safety. Retail activities can help fund developments and events but they must be planned to take account of circulation needs and crowd management.
Queuing | Space requirement, effects on circulation routes | Places where people queue or wait can often be influenced by positioning of information boards, lines of sight or other layout features. So understanding likely behaviours and designing optimum layouts requires operational input. This is a specialist area that needs to be carefully planned for. Standards for queue sizes, service durations and queuing times should be set or determined to inform the design.
Ticketing | Nature and number of ticketing service points | How the ticketing and entry system works can have significant effects on crowds and their behaviour. Layout should be designed with the operational entry system in mind. Pinch points such as ticketing and security checking needs to be understood and planned for. Service standards for ticketing (number of tickets sold, rate of service) should be defined and operational requirements included in design. Consideration should be given to unfamiliar users especially where new electronic systems are being implemented.
Vibrations | Behaviour of the crowd can affect the structural integrity of a building. Crowd behaviour can be predicted under certain circumstances | Examples include rock and pop music venues which need to be designed with likely crowd behaviour such as jumping and stamping in mind. What would the effect on the structure be if the crowd were to stamp at a frequency of 120 bpm? (Typical speed for many rock and pop songs).

Table 1 | Detail issues to consider in integrated design
Figure 3 shows a socio-technical system model that can be used to describe a total system, whether it be a railway station, concert venue, sports stadium etc. With reference to this model, designers traditionally concentrate on the environment (e.g., building) and technology elements of the model. The operators tend to be involved with the process and people elements. It is important from the outset to consider this model as one integrated whole. This is achieved by a system integration process.

**Technology**
- lifts, escalators, PA, CCTV, alarms, signage, telephones, radio, information systems, mimics, control panels...

**Process**
- crowd management/control, marshalling, monitoring, security, evacuation, incident handling, safety, emergencies, communication, signalling, working reference manual, training...

**People**
- behaviour (individual, group and organisation), anthropometrics, volume, gender, age, speed, impairments, language, culture, role (e.g., parent), mental workload, human reliability...

**Environment**
- building, space, heating, lighting, humidity, air quality, surfaces, reverberation, obstructions, floor surfaces, steps, ramps, water, power, ventilation, layout...

**System integration**

*Figure 3  System integration diagram*
For a design to work well, all the elements of the total system must integrate effectively. For example, there is no point in having a high technical specification for a PA system if it is installed in an environment with a high reverberation characteristic without acoustics being considered – the result is likely to be an unintelligible sound system.
Achieving operational integration during design

Operational Integration means the integration of operational systems design into the physical design of a venue and its environs, including transport systems.

So how do we integrate operational needs into the design?

It is important to understand what will be happening within the environment that is being designed. While this might sound obvious it is not always as easy as it may seem. For example, if a football stadium is being designed, does the design take into consideration all of its other possible uses? Perhaps it will occasionally be used as a large music venue, a conference centre or for hosting different types of sport?

These different uses are likely to attract a different profile of crowd – for example, a venue in Glasgow that normally hosts football may be used for a Christmas entertainment for families. If there were to be an evacuation, what would happen? Where would children be sheltered from the cold and how would this be organised?
Operational concept

It is recommended that the client generates an operational concept (or strategy) document that details all the envisaged uses. This document is, however, more than a standard brief. It should contain details of how the client envisages the operational management of the environment, including the people, processes and technology. This will enable the design team to have a greater understanding of the operation and develop the design accordingly.

We suggest that the operational concept should contain:

- the different types of event or operating mode
- the required layout for different events
- the operational accommodation requirements for different events
- the staffing and security requirements for different events
- the defined operating conditions and how the environment is managed in each
- numbers and profiles of crowds
- crowd movement targets and standards (e.g., rate of arrivals and queue standards will drive entrance infrastructure)
- key visitor experience standards
- policy on inclusive design and accommodating the needs of disabled persons
- identified operational stakeholders
- job roles and responsibilities
- operational equipment.
**Operational states**

It is suggested that four operational states (or **conditions**) are taken into consideration. These are:

1. **NORMAL** – planned normal operation with full staffing, expected crowd numbers, normal ingress/egress flows, service running to plan etc.
2. **ABNORMAL** – operational but with planned disruption, eg areas closed for planned maintenance, special events and gatherings, peak holiday times etc.
3. **DEGRADED** – operational but with unplanned disruption, eg service failure, staff shortages, hooliganism, illness.
4. **EMERGENCY** – incident or accident that results in emergency procedures being invoked, eg evacuation after fire, bomb, collapse, as well as invacuation (ie movement to internal shelter/place of safety) in the case of an external threat.

It is important to ensure that the behaviour of users and operational staff are considered during the design, and assumptions such as “equal egress” (in which each exit is assumed to have the same degree of usage) are adequately challenged to ensure that the as-built delivers the design requirement.

It is tempting to consider only **normal** and **emergency** but the **abnormal** and **degraded** conditions are quite distinct.
Operators need to be able to recognise the current status so that they can respond to the changes as they occur and try to avoid an abnormal or degraded situation deteriorating into an emergency situation. Tools are available that are designed to provide real-time decision support for operators.

An example is the crowd density measurement tool developed by the Rail Safety and Standards Board (RSSB). This tool requires real-time monitoring of crowds, so has implications for the positioning and monitoring of CCTV. Operators may be able to predict changes in condition from events unfolding elsewhere. The operational plan may include details or a specification for systems that provide information to the operators (eg local and remote CCTV).

The operational concept should describe the conditions and define how operations will be affected. This, in turn, is likely to generate requirements for the environment and technology. In the previous example where evacuation could result in users being mustered in a cold outdoor location, the operational risk mitigation plan may include provision of space blankets. So the implication for design is the storage for these and access to the storage.

Figure 4 Crowd management chart – see Crowd management at stations, a good practice guide by the Rail Safety and Standards Board
An integration plan

Using the information contained within the operational concept, a plan for integration needs to be made. This plan should contain details of how the identified stakeholders will be engaged to understand their operational needs. This will normally be through meetings, workshops and presentations. To enable the optimum design, an understanding will need to be established of how the environment will be operated and what processes (actual, not documented) will be used and by whom. From this it is then possible to ascertain the design requirements for the environment and the technology to be installed.

Operational engagement

It is critically important to engage both operational managers and front line staff to enable an understanding of how the environment operates and which design features are required. This can sometimes be difficult when the ultimate users are not yet in place, but this can be overcome to some extent by visiting other similar operational environments to understand what is working well and what is not. This is a good way for the design team to learn positives and negatives from other projects.
Stakeholders

It is important to engage all stakeholders actively in the design from the start of the planning process. This obviously includes the client but should also be extended to other applicable stakeholders such as:

- emergency services (police, fire service, ambulance)
- users, including client and staff representatives, user groups (including people with disabilities and impaired mobility), national groups (such as the National Association of Disabled Supporters – NADS) and local groups
- licensing authorities and regulatory bodies
- local authorities
- promoters
- operators
- maintainers
- security
- transport providers
- neighbours, including businesses.

The design team needs to identify stakeholders’ experience, views, ideas, requirements – and design to meet them in an integrated manner.

There may be other stakeholders that are not listed here. A full list of stakeholders should be established with the client early in the design phase. A strategy for their engagement should be developed as part of the design process, initially for two-way communication and, as design develops, for consultation on what is proposed.
Who should perform the integration work?

The integration process is very important for the outcome of the design, so should be taken seriously and become an integral part of the project master plan. To enable effective integration it is advisable to assign a specific role both in the client organisation and in the design organisation. This person will be responsible for ensuring that the integration is achieved within the project plan.

These roles can be filled by members of the client and design team, but it may be beneficial to appoint an independent specialist consultant to advise on the process or even undertake these roles.
Crowd safety

It is important to understand that the health and safety risks associated with movement or gatherings of large numbers of people, or even a small densely packed crowd, can be significant even though the probability of a hazard occurring is low. Designing for crowd environments should include a formal risk assessment. The risk assessment process must include the operator or its representative.

There are many examples of serious accidents resulting in serious injuries or loss of life in all types of environments where crowds are present. These include:

- Roskilde (rock concert) in 2000 where there were nine fatalities and 26 people injured
- Hillsborough (football) in 1989 where there were 96 fatalities
- Mecca (religious gathering) in 1990 where there were 1426 fatalities
- Ikea (shopping), Saudi Arabia in 2004 where there were three fatalities.

Crowding or crowd behaviour can also exacerbate other incidents leading to greater loss of life (eg crowd crush during evacuation due to fire).

Because of these and other incidents much design guidance, (most notably relating to fire safety) The green guide and metro design planning guides, place considerable emphasis on managing the safety of crowds.
This guidance takes into consideration some of the lessons learned from these accidents and describes processes that should be implemented during the development process to design out as much risk as possible.

1 Determine the safe capacity of the place
   a Has the capacity of the place been determined?
   b What crowd density in the crowd entry, exit and circulation systems does this imply?

2 Control the number of users and visitors
   a Is the number of visitors or users each year increasing? (For example what is the trend in year-on-year attendance).
   b Can the number of visitors to, or users of, the place be controlled? Eg is the event non-ticketed?
   c Is it possible for the place to become overcrowded?
   d What happens if people stay longer than expected?

3 Is it safe when things don’t work?
   a What happens if the transport system suffers perturbation?
   b What happens if one of the exits is not available?
Know your crowd

Different types of crowds can behave in very different ways. Even for the same type of event there can be significant variations in the profile of the crowd. For example, a crowd attending the first night of a rock music event may behave differently from a crowd attending the second night. So it is important that the profile of the crowd is known for the management of that crowd to be planned accordingly.

To this end it is vital that the design of the environment is suitable for all the different profiles of crowds expected and is able to accommodate the operational needs of the stakeholders.

Normal peak flows of people will vary. For work travel, there is often a high morning peak but a less intense evening peak. For sporting or entertainment events, the arrival peak is generally much less intense than the leaving peak.
Pedestrian or crowd flow modelling

Crowd modelling is the process by which the specification of the crowd movement system can be defined and used to inform or test the design and operation of any venue, facility or event, for example circulation paths, concourses, stairs and escalators, emergency exits and entry gates.

The requirements for developing a crowd model include, but are not limited to:

1. A demand forecast that includes forecasts for the number of people expected, their arrival and departure profiles, and the number of people circulating at the place (and their objectives or movement patterns).
2. The layout of the crowd flow system – often a CAD drawing.
3. Crowd flow rates or densities to be used. The required width of a crowd flow corridor will be a function of the crowd demand and the crowd flow rate. The flow rates and densities may be determined by the operators’ standards (e.g., metro such as London Underground), by guidance (e.g., the Green Guide) or other standards.
4. Service rates for processes in the environment. These might be the rate of ticket checking or the capacity of escalators or lifts.
5. Assessing the time required for emergency evacuation.
6. Consideration of encumbering factors such as rubbish.
7. Cross flows including access to disabled facilities and areas.
It is good practice to test the proposed design or operation of the system by creating a spreadsheet model of the crowd circulation system. Sometimes this may be supplemented by creating a computer simulation in which individual people move through a virtual environment to show how the space is used and how the different elements of the place relate.

Computer simulations can be powerful tools to test and visualise the assumptions and performance of the intended design, and to communicate this to stakeholders.

However, it is important to remember that spreadsheet models, and particularly computer simulations, are just models and may not reflect the actual outcome (just as a financial spreadsheet model does not necessarily reflect the actual outcome of a business).

All the rules of modelling apply – the quality of the output depends on the quality and reliability of the inputs and the quality of the model (often a function of the modeller!). Standard accepted rules for flow-rates, sometimes built into software, may be incorrect due to the make-up of the crowd or the presence of roll-along luggage.

People's ease of movement and personal space is influenced by the level of crowding. This affects their visitor experience and, at higher crowd densities, their safety.
Sensitivity testing, operational scenarios and contingency planning

People do not always behave as expected, and crowds do not always behave as expected in the forecast. More or fewer people turn up, or arrive later, or spend longer at an event than expected. So it is important to identify the visitor experience and safety consequences, or the actual outcome being different from the forecast.

Sensitivity testing involves testing the various inputs to the forecast and seeing how they affect the outcome. Scenario testing might involve a change, or set of consistent changes, in the operating environment (e.g., delays to the train service).

It is advisable to use operational scenarios to test the performance of the design and to inform any special features that may be required. A set of sensitivities and scenarios should be developed as part of the operational concept by the client and these can then be used by the integrator to help user involvement by performing desktop exercises and verification.
Terrorism threat

Unfortunately crowded buildings, spaces and events can provide targets for terrorists. Advice on protecting these places, and making them secure by design, is available from the National Counter Terrorism Security Office (NaCTSO) and local police forces through their architectural liaison officers. More specific design advice is also available from security consultants and other expert authorities.

Government has a strategy of four principal strands: prevent, pursue, protect and prepare, and has set up programmes and plans to give these effect. The work of NaCTSO is primarily concerned with the protect and prepare strands of this strategy.

The protect strand is concerned with reducing the vulnerability of the UK and its overseas interests to a terrorist attack. Consideration of crowded places is part of this strand and focuses on enhancing the protective security advice available to those who own or operate venues or places that may be more vulnerable to attack. The whole community has a part to play in devising and implementing measures that are dynamic, flexible, agile and adaptive.

In support of the crowded places work, NaCTSO has recently developed and published guides for sporting stadia, arenas, shopping centres and bars, pubs and clubs. Counter terrorism security advisers liaise with such sites to help deliver the guidance. Early inclusion of such measures at the design and pre planning stage are often cost neutral and highly desirable.
Design integration guidelines

- do undertake pedestrian modelling early in the design development and re-visit the model regularly as the design progresses
- do use pedestrian modelling to scenario test various degraded and emergency operating conditions
- do start the operational integration as early as possible in the design process (the later you start the less effect on outcome is achievable)
- don’t pay lip service to operational engagement
- do look at the larger area – remember when people leave your building/environment they need to go somewhere – your design can have a knock-on effect further down the line
- do ensure that all stakeholders are engaged in the process – missing just one could result in a vital flaw in the design
- do visit similar, existing environments and speak with operational staff to understand what works well and what does not – this information can be effectively used to develop your design
- don’t assume that compliance with design standards alone will ensure that your design will work for crowds, as these standards cannot always fully take into account the operational context of the specific environment.
Other tips for designers

- do ensure that specified floor surfaces have the correct slip resistance characteristics for the application. See CIRIA C652 Safer surfaces to walk on – reducing the risk of slipping (Carpenter et al, 2006)
- don’t rely on flooring manufacturers’ slip resistance specifications alone to determine suitability
- do ensure that obstacles such as fixed street furniture, and moveable obstacles such as café tables and chairs, are taken into consideration in the pedestrian modelling and that clear routes are not later cluttered by obstacles and trip hazards
- do consider dynamic response of structures to crowd action (walking, jumping, swaying to music etc)
- do design for behaviours in the event of terrorism and crime
- don’t change the design after doing modelling work without remodelling
- do take problems and solutions to the regulatory authorities
- do ensure that there is enough space between the venue and transport hubs
- do design for people with disabilities and impaired mobility by engaging with representative organisations. This requires careful examination of needs and solutions. It is easy to make assumptions that are impractical or wrong. Remember an estimated 15 per cent of the European population are in some way disabled. Only a very small fraction of these are wheelchair users.
Questions for clients

- Have you adequately considered how the environment will be operated?
- Have you articulated this in a documented operational concept or operational strategy document?
- Have you appointed a representative for your organisation who is responsible for liaising with the designers to ensure that operational requirements are integrated into design?
- Have all of appropriate standards been identified, including operational standards?
- Does the design team understand how to use and build upon the standards, taking account of the unique details of your project?
- Is the design going to be fully-integrated from an early stage with the operational strategy and systems you plan to operate?
- Has an appropriately qualified and experienced person been appointed to manage the integration process so that you can benefit from an holistic solution?
- Have all relevant transportation issues been considered?
- Has a what if risk analysis been undertaken and the issues arising fed back into the design?
- Is there a design assurance process that details how the design team demonstrates that it has adequately taken operational requirements into account during the design?
Case study 1

Cardiff Central – crowd management

This brief outline case study identifies some of the key crowd management issues faced by rail operators in safely managing crowd flow between the Millennium Stadium and Cardiff Central railway station. It reflects an approach based on traditional experience and practical application and not on advanced flow modelling. It is also an example of what could be termed a “forced operation” because it had to be accommodated in a non-purpose-built, limited space already occupied by other users, and with resources taken from a daily operation already working close to maximum capacity.

In 1998 the new Millennium Stadium in Cardiff was nearing completion. The significant planned increase in capacity and the proximity to Cardiff’s Central Railway Station (just four minutes walk) produced a clear and urgent need on the part of First Great Western – the then station operators – to review their approach to dealing with post-event crowds.

The previous process of a single approach route was not going to work on the greater numbers. And because of the increased ground capacity there would be greater numbers. So the policy was to close the area around the stadium to road traffic, the rail station and establishments in the same location.
The challenge coincided with Railtrack’s (as they then were) redevelopment of Cardiff Central Station and with Cardiff County Council’s upgrade of the central square area between the station and the Stadium. This gave a limited opportunity to amend some of the infrastructure.

Several key crowd management issues were identified, which were addressed as follows:

**The crowd flows would need to be matched to available, limited rail capacity**

This was the key issue and the one that would determine waiting times and, by extension, crowd behaviour. To ensure limited train capacity was fully used it would be necessary to present the crowds to the station entrance by geographical line of route. So whenever train capacity was available the correct queue could be drawn forward to satisfy it.

To help this it proved necessary to provide separate entrances or approach routes to the four major rail flows: Valleys, West, East and Newport. The extent of the commitment led to the building of a completely new platform and an extra station entrance. By clever use of the two subways, four distinct geographical flows could operate independently of one another.

**Proximity of the Stadium meant a very limited window for customer decisions**

In most similar situations, customers leaving the venue have time to spread out and take their travel decisions along an extended route to the returning station. At Cardiff the proximity of the station to the Stadium meant that the decision point was reached before most customers were ready for it.
To avoid customers missing their queue and having to turn back (a major problem with up to 20 000 involved) the queuing options were provided on a step basis to enable customers to select or reject each queue in turn, with a route should they need to return to the beginning.

**Large waiting numbers would need to be controlled**

With allocation to the correct queue being fundamental and with the need to reassure and inform large waiting numbers it was decided to use external stewarding resources with the British Transport Police maintaining law and order. Stewards were trained specifically for this work at this location and joint agency briefing and debriefing meetings allowed a process of continual improvement to take effect.

**Waiting queues needed an outlet at all times**

With multiple queues holding significant numbers over a period of three hours, it was critical that an outlet could be provided in the event of unauthorised crowd movement or surging. This was accommodated partly through the independence of the four main flows (allowing the platforms to be used for forced overflow) and by strategic queue breaks leading into designated sterile areas within the overall control area.

**Non-rail customer movements would have to be accommodated**

The area in which rail queuing was forced to take place was also the only thoroughfare for non-rail customers accessing car parks and park and ride facilities.
So it was necessary to provide a designated, controlled route through the rail queuing area for those wishing only to pass through.

**Several agencies would need to work together in a relatively confined area**

With a major queuing operation – holding 4000 people over a three hour period – a number of agencies found themselves brought together. A key approach to this was the creation of the Stadium Events Liaison Group to bring together those agencies influential in planning and controlling the movement of crowds outside the stadium. In this forum it was possible to co-ordinate the work of the police (South Wales and British Transport), bus operators, the local authority and local retailers by working closely with the stadium and directly with event organisers for pre-planning purposes.

**Information provision**

Each station platform was loaded with the appropriate numbers for the next service, so those in the queue would not catch the next train but perhaps the following one or two. Information provision had to be carefully managed to avoid over-expectation and subsequent frustration when those expectations did not materialise. Information was provided on a
queue by queue basis in the form of likely waiting time rather than identification of a specific rail service.

Over time the initial process was refined in the light of experience. In particular, the data carefully collected on a multi-agency basis after each event revealed clear predictive trends according to the nature of the event, the size of the crowd and the start time. For instance, rail’s share of the travelling market was highest for rugby internationals at around 32 per cent of crowd capacity, dropping to only 11–13 per cent for international football matches. This allowed for increasingly accurate matching of rail capacity to travelling numbers.

Crowd behaviour became similarly more predictable with the early feared major football matches proving less disrupted by drinking disorder than expected. International rugby matches extended the crowd management periods as rugby fans chose to stay in town travelling over an extended period. Crowd stress was often highest after concerts where the late finish and reduced time window of return led to greater concern from customers.
However, with constant adjustment and refinement – of queues, approach routes, information provision, signage and flow control – some 1.7m customers safely passed through the controlled queuing process during the first 160 events.

The key message from this case study is to ensure an integrated approach involving both operators and stakeholders is adopted. On the one side of the operation were five separate train operators providing the transport capacity for up to 30 per cent of the event attendees. On the other was the Millennium Stadium providing the event itself. In between lay a formal combination of operators and stakeholders from the police and local authority to public transport operators and retailers brought together into the Stadium Events Liaison Group, which has co-ordinated issues of safety, crowd management operation and quality of service for over nine successful years. AvonAnglia was responsible for producing the crowd management plan for Cardiff Central and for directly operating and resourcing the plan for the first seven years. AvonAnglia has provided similar crowd management services for other rail operators.

(courtesy Ian Body, Managing Partner, AvonAnglia Crowd Management)
Case study 2

Planning and designing the Olympic Park

Introduction
Up to 300,000 people will visit the Olympic Park each day and there will be up to 200,000 people in the Olympic Park at any one time – about the size of Newcastle-upon-Tyne. Clearly the Olympic Park has to be designed with crowd movement and safety in mind.

Operational Integration
The London 2012 Olympics will be delivered by two organisations – the Olympic Delivery Authority (ODA), which is responsible for delivering the new venues, infrastructure and transport, and the London Organising Committee of the Olympic Games (LOCOG), which is responsible for delivering and managing the Games.
The lead times for development of the venues, infrastructure, and transport are such that the ODA needed to begin planning and design several years before the Games, and before LOCOG is able to provide detailed plans.

The ODA has set up an operability group covering areas such as vehicle transport and crowd movement to develop specifications for the infrastructure in these disciplines, based on assumptions of how the Games could operate. The objective was to make the infrastructure fit for purpose. The Crowd Movement sub-group (the CMG) included representatives from ODA, LOCOG, the design team, and specialist consultants.
Crowd modelling

The CMG worked to develop forecasts for the number of people in the Olympic Park and their movement patterns throughout the duration of the Games. Importantly, at the time of writing, it was recognised that the forecasts contained uncertainties as before the Beijing 2008 Games, many aspects of the London 2012 Games had not yet been developed.

In any case, crowd behaviour may depend on the weather in England on the day! So the consequences of these uncertainties for the forecast and design, and its affect on crowd safety and visitor experience, have been analysed using sensitivity and scenario testing.

The CMG also developed the crowd movement standards needed to ensure safety and achieve a visitor experience that is comfortable but busy enough to ensure a vibrant feeling to the Games. These standards and targets were discussed and agreed with stakeholders such as local authorities and disability forums.
The CMG used spreadsheet modelling and computer simulation techniques in tandem to test and iterate the size and designs of the crowd circulation infrastructure, such as the many pedestrian bridges and central walkway of the Olympic Park.

Models were developed for different peak periods in the morning and in the evening, and during the busiest times of the day. This activity demonstrated that the original widths of bridges in the Olympic Park could be reduced while achieving crowd movement and safety targets, with savings of more than £100m.

The modelling is being continually reviewed as the venue designs and management plans, including contingency plans, for the Park develop. The modelling has given comfort that the plans for the Olympic Park will be safe and enjoyable for the visiting crowds, and have been achieved with the minimum of cost.
Reference material


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LUL Manual of standards <http://www.lulstandards.co.uk/>

National Association of Disabled Supporters (NADS) <www.nads.org.uk/>


Sports Council (1990) *Designing for safety in sports buildings*, Factfile 5

**Codes**

BSI: BS8300:2001 *Design of Buildings and their approaches to meet the needs of disabled people*
Where to get help and further advice

Local authorities
Local police forces
Local ambulance services (NHS, St John)
Local fire services
Transport providers
Home Office
Metropolitan Police specialists in crowd issues and emergency control
Football Licensing Authority (FLA)
National Association of Disabled Supporters (NADS)
Rail Safety and Standards Board (RSSB)
Emergency Planning College
National Counter Terrorism Security Office (NaCTSO)
Specialist consultants.
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