THE CAUSES AND PREVENTION OF CROWD DISASTERS

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ABSTRACT

Crowds occur frequently, usually without serious problems. Occasionally venue inadequacies and deficient crowd management result in injuries and fatalities. Major crowd incidents are described. Extreme crowding results in individual loss of control, and both psychological and physiological problems. A simple model with the acronym "FIST" is proposed to provide a basic understanding of crowd disasters. The acronym elements are defined as the crowd Force (F); the Information (I) upon which the crowd acts; the physical Space (S) involved, both in terms of individual density and larger scale architectural features; and Time (T), the duration of the incident. The model is used to illustrate crowd characteristics and to develop guidelines for the prevention of crowd disasters. It is concluded that real time information and communication are key factors in preventing crowd disasters. The formal certification of crowd manager for venues of 500 persons or more is recommended.

CROWDING IS A COMMON EXPERIENCE

Crowds, or large concentrations of people, occur frequently in modern society. A major sporting or entertainment event can attract 70,000 avid fans. Large transportation terminals such as New York Grand Central Terminal and Pennsylvania Station accommodate 200,000 passengers each weekday. The former New York World Trade Center office and retail complex was reported to have up to 50,000 employees and 80,000 daily visitors. Two transit stations were within the complex, and three other transit stations were nearby. More than 1 million spectators view the annual Tournament of Roses parade along a 9km.(5.5 mi.) route in Pasadena, California. Usually these large gatherings of people occur without serious problems. Occasionally the combination of inadequate facilities and deficient crowd management results in injury and death.

EXAMPLES OF CROWD DISASTERS

The lethal potential of crowds is illustrated by descriptions of major crowd incidents. This sampling shows that crowd incidents occur in a wide variety of venues and different circumstances. Minor incidents resulting in crowd induced falls and other injuries occur much more frequently.

Air Raid Shelter

In 1943 during World War II, 173 persons died of compressive asphyxia and 92 injured in a London Underground air raid shelter after someone fell on a lower level entry stair. Excited by the sounds of bombing, people at the surface continued to press forward. This resulted in tangled mass of humanity on the stair that took rescuers 3 hours to unravel. [1]

Funeral Procession

Untold hundreds, and possibly thousands, were killed in Moscow, Russia during a massive procession of 3 million people viewing the body of Joseph Stalin after his death in 1953. Army tanks and trucks to control movement of the crowd blocked side streets along the route to Stalin's bier. Police and military, some on horseback, beat people with clubs to further control the crowd, even as people were fatally crushed against building walls, the parked tanks and trucks. Horses were lifted off their feet by crowd surges, and also crushed to death. [2]

Sporting Event Egress

Major crowd incidents occur in soccer stadia occur with deadly regularity. Those involving United Kingdom fans have been the most thoroughly documented. In 1971, 66 people were killed and many injured at the Ibrox Park Stadium in Glasgow, Scotland. [3] Fans began to leave the stadium in the last moments of a scoreless match. As the game ended, a goal was scored. The roar of the crowd caused some to attempt reentry, while the mass exited. The resulting conflict caused a pile of bodies "about 10 feet high".

In 1981, 24 Greek soccer fans were killed in the Athens stadium as a capacity crowd of 45,000 attempted to leave shortly before the end of the match. The fans in the front ranks found the exit gates were locked, but those in the rear continued to press forward. In 1982, 340 people were reported killed at a match in Moscow's Lenin Stadium.

Sporting Event Ingress

In 1989, 94 persons were asphyxiated and 174 injured at the Hillsborough Stadium in Sheffield, England. [4] A larger than expected group of fans striving to enter the Stadium caused police to open gates to relieve crowd pressures. Instead of relieving pressures, the resulting surge of fans into enclosed terraces created a critical overcrowding. In 1985, 10 were killed and 30 injured in a Mexico City incident similar to that at Hillsborough. A locked gate blocked hundreds of fans attempting to force their way into the stadium through two tunnels.

In 1991, nine persons were asphyxiated in a pileup at the bottom landing of a gymnasium stair at the City University of New York. [5] A celebrity basketball game was scheduled in the gymnasium, and an excess of people arrived for the well promoted event. Doors at the lower landing entry to the gymnasium opened only outward, in compliance with fire codes. People precariously queued on the stair were driven into the restricted landing and closed doors by crowd pressures from above. Police in the street outside the venue did not establish communications with inside security, and were unaware of the evolving disaster, even though the stair could be seen from the street.

Riot

In 1985 a riot by English and Italian fans in the stands at a European Cup final at Heysel Stadium in Brussels, Belgium precipitated a flight of spectators that resulted in 38 deaths by asphyxia and 437 injured.

Weather

In 1988 more than 100 persons died and 700 others were injured at Nepal's National Stadium in Katmandu. A sudden violent hailstorm caused 30,000 spectators to flee the open grandstand but found the exit gates were locked.

Religious Events

In 1990, 1426 people were killed in a crowd crush during the annual pilgrimage of 2 million at Mecca, Saudi Arabia. The crush occurred in a 500 m long tunnel joining Mecca and the Tent City of Mina. Temperatures at the time were 44 deg. C outside the air-conditioned tunnel. It is speculated that someone fell in the tunnel blocking movement.

In 1986, 46 pilgrims died in Hardwar, India on a crowded bridge across the Ganges River. At the 12-year cycle of the Khumb Mela festival as many as 4 million Hindus gather to bathe in the Ganges. During the 1980 world tour of the Pope, 13 people were killed in two African cities in crowd rushes.

Power Failure

In 1981 45 persons died 27 of them children, in the Quitab Minar tower, New New Delhi, India. The 800-year-old tower is a popular tourist attraction and museum. A blackout, combined with what some witnesses said were cries that the tower was falling, triggered a sudden exodus of 300 to 400 people.

Food Distribution

In Bangkok, Thailand 19 persons died as crowd of 3,000 assembled to obtain packages of free food. The crowd was attempting to press through a gate approximately 4m (13 ft.) wide into a meeting hall where the food was being distributed. A contingent of 20 police officers assigned to control the crowd was overwhelmed by the crush.

Entertainment Events

In 1979, 11 young rock music fans were asphyxiated in a crowd crush outside the Cincinnati, Ohio Coliseum. [6] After 10,000 persons had entered the venue, 8,000 were still waiting to enter the general admission event. Many were waiting for hours with inadequate lavatory facilities. A warm-up band started playing, and the fans outside thought the concert had begun. Only two doors were opened for entry.

In 1991, 3 rock music fans died of compressive asphyxia at a festival seating event in Salt Lake City, Utah. Fans standing in an open area in front of the concert stage pressed forward, causing some to fall, and others to be forced on top of them.

Escalators and Moving Walkways

Passenger conveyors have the characteristic of continuously delivering people without regard to outlet conditions. When restrictions at the outlet limit the discharge rate, a pileup will occur. [7] These incidents are of interest because they are not attributable to crowd behavior.

In 1964 one child was killed and 60 children injured at the outlet end of a Baltimore, Maryland Stadium escalator. The escalator was set up for egress the day before with a one-person wide gate at the top. The escalator was reversed for entry the next day, but the gate was not removed. A pileup resulted at the exit, with many severely lacerated by the moving

escalator steps. At the 1970 Japanese World Exposition, 42 people were injured at a moving walkway exit when a passenger fell and others were driven into the pileup.

THE VIEW FROM THE CROWD

It is difficult to describe the psychological and physiological pressures within crowds at maximum density. When crowd density equals the plan area of the human body, individual control is lost, as one becomes an involuntary part of the mass. At occupancies of about 7 persons per square meter the crowd becomes almost a fluid mass. Shock waves can be propagated through the mass sufficient to lift people off of their feet and propel them distances of 3 m (10 ft) or more. People may be literally lifted out of their shoes, and have clothing torn off. Intense crowd pressures, exacerbated by anxiety, make it difficult to breathe. The heat and thermal insulation of surrounding bodies cause some to be weakened and faint. Access to those who fall is impossible. Removal of those in distress can only be accomplished by lifting them up and passing them overhead to the exterior of the crowd.

Internal Communication

Psychologists have likened a crowd to a series of intermeshing behavioral cells. Each cell is comprised of a small group of surrounding people, with limited communication between them. Cell members do not have a broad view of what is occurring in the crowd. A dominant cell member may influence the collective behavior of the cell. Chains of cell to cell communication can occur, often with the spread of rumors and incorrect information, potentially inciting inappropriate behavior.

Most crowd incidents exhibit a lack of front to back communication. People in the rear of the crowd press forward while those in front experience severe distress. This is due in part to the flow process itself. The lighter densities in the rear allow freer movement while those in front are immobile and under great pressure. The collapsing of front ranks gives a false perception of forward movement. Security personnel often attempt local control of the crowd from the front, urging people not to push. However, this type of control is ineffective during a serious crowd incident in progress.

Motivation

The crowd incidents described above show different types of group motivation. In some cases there is an interruption of a simple traffic process such as exiting a stadium or a passenger conveyor, resulting in a critical crowd pressure point. Others fall into two general behavioral categories, either a flight response or a craze. [8] Flight occurs where people experience either a real or perceived threat. Frequently mislabeled a panic, closer investigation usually shows that flight was a reasonable group reaction under the perceived circumstances. These incidents often show mutual cooperation and assistance among individuals within the group, rather than destructive behavior.

A mass craze is a competitive rush to obtain some highly valued objective. The Bangkok food distribution crush is a clear example of a craze. Craze like group behavior has been created where participation in an event, or viewing of a public personage, is intensively promoted. General admission events and so-called "festival seating" concerts, cause craze like competition for favorable seats or standing positions close to entertainers.

THE FIST MODEL OF CROWD DISASTERS

The primary elements involved in crowd disasters have been determined from personal experiences, analysis of major crowd incidents, and basic traffic flow principles. The elements

provide a model for understanding the causes of crowd disasters, means of prevention, and possible mitigation of an ongoing crowd incident. The elements of the model form the acronym "FIST", which is a useful reminder that any crowd situation can quickly become threatening and potentially lethal. The acronym is defined as follows: FORCE (F) of the crowd, or crowd pressure; INFORMATION (I) upon which the crowd acts or reacts, real or perceived, true or false; SPACE (S) involved in the crowd incident, standing area, physical facilities - stairs, corridors, escalators; TIME (T) duration of incident, event scheduling, facility processing rates.

Force

Crowd forces can reach levels that almost impossible to resist or control. Virtually all crowd deaths are due to compressive asphyxia and not the "trampling" reported by the news media. Evidence of bent steel railings after several fatal crowd incidents show that forces of more than 4500 N (1,000 lbs.) occurred. Forces are due to pushing, and the domino effect of people leaning against each other.

Compressive asphyxia has occurred from people being stacked up vertically, one on top of the other, or horizontal pushing and leaning forces. In the Ibrox Park soccer stadium incident, police reported that the pile of bodies was 3 m (10 feet) high. At this height, people on the bottom would experience chest pressures of 3600-4000 N (800-900 lbs.), assuming half the weight of those above was concentrated in the upper body area.

Horizontal forces sufficient to cause compressive asphyxia would be more dynamic as people push off against each other to obtain breathing space. In the Cincinnati rock concert incident, a line of bodies was found approximately 9 m (30 ft) from a wall near the entrance. This indicates that crowd pressures probably came from both directions as rear ranks pressed forward and front ranks pushed off the wall.

Experiments to determine concentrated forces on guardrails due to leaning and pushing have shown that force of 30% to 75% of participant weight can occur. In a US National Bureau of Standards study of guardrails, three persons exerted a leaning force of 792 N (178 lbs.) and 609 N (137 lbs.) pushing. [9] In a similar Australian Building Technology Centre study, three persons in a combined leaning an pushing posture developed a force of 1370 N (306 lbs.). [10] This study showed that under a simulated "panic", 5 persons were capable of developing a force of 3430 N (766 lbs.).

Information

In the broad systems sense, information has many forms. It includes all means of communication, the sights and sounds affecting group perceptions, public address announcements, training and actions of personnel, signs, and even ticketing.

Space

The configuration, capacity, and traffic processing capabilities of assembly facilities determine degrees of crowding. Space includes standing and seating areas, projected occupancies, and the practical working capacities of corridors, ramps, stairs, doors, escalators, and elevators.

Time

A simple illustration of timing is the more gradual and lighter density arrival process before an event, compared to the rapid egress and heavy crowd densities after an event.

PREVENTION OF CROWD DISASTERS BY CROWD MANAGEMENT

Most major crowd disasters can be prevented by simple crowd management strategies. The primary crowd management objectives are the avoidance of critical crowd densities and the triggering of rapid group movement.

Terminology

Although the terms crowd management and crowd control are often used interchangeably, there are important differences. Crowd management is defined as the systematic planning for, and supervision of, the orderly movement and assembly of people. Crowd control is the restriction or limitation of group behavior. Crowd management involves the assessment of the people handling capabilities of a space prior to use. It includes evaluation of projected levels of occupancy, adequacy of means of ingress and egress, processing procedures such as ticket collection, and expected types of activities and group behavior.

Crowd control may be part of a crowd management plan, or occur as an unplanned reaction to a group problem. It can include extreme measures to enforce order, such as the use of force, arrest, or threat of personal injury. It may employ barriers that alter the space available for occupancy and patterns of group movement. Inappropriate or poorly managed control procedures have precipitated crowd incidents rather than preventing them. For example, police reacting to a group of unruly persons at a rock concert, herded spectators into areas where there were no means of egress.

INFORMATION

Crowd mangers must determine a wide range of information about a venue and the people occupying it before a group assembly occurs. Included is an assessment of the nature of the group, experience with similar groups, potential behavior patterns, projected occupancy, facility processing rates, staffing, and means of communication between staff and with the crowd.

Nature of Crowd

Crowds can attract participants who come to observe and to peacefully enjoy the event, predators in search of victims, and people with other psychological or social agenda. [11] Constant monitoring of crowd behavior is necessary for good crowd management. A proactive type of management is required, anticipating and resolving problems before they occur, rather than reacting when it could be too late.

Crowd Management Center

Real time information about the status of crowd conditions in large assembly spaces is critical. A centralized crowd management and communications center should be set up for this purpose. The ideal center would provide a maximum view of the venue, supplemented by video camera access to blind spaces, pressure points, and major movement pathways. Full communications coordination should be provided between all venue staff, local police, fire, and emergency medical services, and any on-site radio or television media. Radio frequencies, telephone numbers, and similar communications information and related procedures should be in a printed form distributed to all staff.

Staff Training

The training of crowd management personnel is of vital concern. Often casual labor is employed at large events. These employees may only receive vague instructions, usually about controlling certain crowd behaviors. Even permanent staff may have limited training in crowd management, recognition of potentially dangerous crowd problems, and the handling of accidents and other emergencies. Training should include instructions on the basics of normal and emergency crowd movement and assembly; initial handling of accident victims, altercations and other crowd incidents; communications procedures and use of communications equipment; avoidance of actions that would incite or trigger dangerous crowd behaviors; and conduct and demeanor during an emergency. All personnel should be provided with a quick reference pocket guide to reinforce training guidelines and communications procedures.

Emergency Response

Response to crowd incidents must be rapid, authoritative, and provide clear and unambiguous information about the emergency and required group actions. Dispersion by multiple routes away from the cause of a crowd incident is preferred over concentrated paths of movement. The summoning of emergency services must be initiated immediately, and not left until the scope of the incident is determined. Victims of compression asphyxia can be revived only if resuscitation begins quickly.

Responsibilities of Performers

Actions by performers such as late cancellation, walking off stage, encouraging fans to move closer, throwing souvenirs to the audience, or other actions have precipitated inappropriate or hazardous group reactions. Entertainers should be fully informed of their own responsibilities for maintaining order, and the problems associated with inciting potentially dangerous group behaviors. Performers must provide advance notice of cancellation, before patrons begin entering the venue. Communication with the crowd should not be delayed if cancellation occurs after entry. Announcements should clearly establish refund policies, exit routes, and need for orderly movement.

Ticketing

Tickets are an important crowd management information factor. Reserved section and seat tickets determine specific area occupancy, and routes of entry and egress. Tickets also provide a means of instructing patrons on rules of conduct expected within the venue. Major art exhibitions have managed crowding by arrival time ticketing, valid only during a specific time period.

The Duty to Warn

A legal view of crowd management responsibilities requires that crowd participants be informed of foreseeable dangers associated with crowd behaviors and/or assembly facilities. Litigation proceedings have shown that concert managers are aware that festival seating events cause some to faint from heat exhaustion, and furthermore, that these persons are virtually inaccessible within the crowd. This knowledge requires that crowd participants be warned of crowding hazards, and be instructed in aid procedures.

SPACE

Architects and engineers typically give minimal attention to the movement of people in initial building design, beyond compliance with local building codes. Code compliance does not guarantee that a building will function well during normal assembly use or emergency egress. Designing for crowd management requires that projected maximum occupancy levels of a space be correlated with the movement capabilities of all corridors, stairs, ramps, escalators, and other facilities. Designers have the responsibility of preparing the initial crowd management plan as part of the life safety evaluation of a new venue. [12] The plan should establish the assembly and people movement capabilities of all aspects of the venue, movement patterns, identify possible problem areas, and generally describe how the design will accommodate normal and emergency crowd movement. Traffic capacities of corridors, stairs, passenger conveyors, and waiting spaces, have been established by a number of sources. [13]

Movement Pathways

Access tree diagrams, or schematic line illustrations of pathway configuration, pedestrian volume and direction, are useful planning tools. The tree diagrams show the capacities of doors, corridors, stairs, escalators, landings, and identify pressure and conflict points. Pathway alignments should be simple and direct, and not circuitous or offset from the normal straight line of sight. Arrangements that result in unbalanced use of egress or ingress routes, dead ends, or similar confusing and irregular pathway choices, are not acceptable. Dispersed and equally balanced ingress and egress points are preferred over a single centralized location. The influence of external facilities on the volume and direction of movement must be considered. Concentration of parking or transit on one side of a venue will focus internal movement towards that side, resulting in unbalanced traffic demands. Architectural statements, aided by directional graphics, should be used to visually define and clarify what processing functions are taking place. Ticketing should be separated from admissions, and the flow between them sequential, uni-directional, and without crossing conflicts.

Pressure Points

Pressure points are locations where a change in pathway processing capacity, normal directions of movement, or a confluence of traffic streams, results in conflicts or accident exposure. Examples include directional changes where there are inadequately guarded openings to lower levels, at stair approaches, and landings at the discharge or outlet ends of escalators. Crowd pressures at such locations have resulted in people being pushed over guardrails, down stairs, or in structural failure of guardrails.

Back-up Standby Power

Alternative power sources for lighting and communications are required. The New Delhi tower museum crowd incident is an example of the confusion resulting from a combined lighting and communications failure. A public address system tied to only one source could be lost when most needed.

Emergency Medical Facilities

Emergency room space and equipment sufficient to handle routine accidents and larger crowd incidents is required. Lives have been unnecessarily lost in large crowd incidents by the lack of simple equipment such as stretchers and oxygen. Many venues accommodate the population equivalent of a medium sized city, requiring that the medical center be equipped to provide skilled response to cardiac, spinal injury cases and other emergencies. Means of

communication with local emergency medical services, their response times and ability to handle a mass crowd disaster should be established as part of the crowd management plan.

TIME

The rationale for time based crowd management strategies is the control of pedestrian demand rates so that traffic flow does not exceed the capacity of any element of the venue. The objective of temporal strategies is to keep pedestrian densities below critical levels. Restaurant reservations and the arrival time ticketing method used for museum exhibits are familiar examples of time based crowd management.

Metering

It may be necessary to meter, or throttle the arrival rate demand at facilities with limited processing capacity. Examples could include stairs, narrow corridors, escalators, ticket gates, pressure points, or other locations where excessive arrivals will cause hazardous overcrowding. Metering must be carefully applied because it will cause waiting lines and crowding on the approaches to the metered facility. The approach area should be large enough to accommodate expected demands and to establish formal queue lines. Communication is a critical aspect of metering control. Personnel involved in the metering operation should be in constant communication with each other and alert to any interruptions in flow.

Early Opening and Delayed Closing

Early opening of a venue to extend the ingress arrival process, and post event entertainment or other strategies to lengthen the egress process, reduces crowding within the venue and traffic pressures on external transit, road, and parking facilities.

CONCLUSIONS

The crowd incident model and its derivative guidelines show that many crowd disasters could have been avoided by simple advance planning and management techniques. Reliable real-time communication between those responsible for crowd management, and authoritative communication with the crowd, are also critical elements in defusing a potentially lethal crowd incident. These strategies are also the least costly means of preventing crowd disasters.

The Certified Crowd Manager

Crowd managers have an awesome responsibility for the safety of large numbers of people. Yet there is little formalized training in crowd management principles and techniques. Police training focuses on crowd control, and not generally on crowd management. It is recommended that every venue accommodating more than 500 persons be required by law to have a certified crowd manager on staff. In order to become certified the candidate would undergo formalized testing on the basics of crowd management and handling of emergencies.

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